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Evaluation of recreation benefit by household production function approach

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Abstract

The travel cost method (TCM) is a revealed preference approach to evaluating the recreation benefit. The traditional application of the TCM is to measure the consumer surplus of recreation sites and activities by calculating the consumer surplus of the site as the area below the demand function and above the implicit price. However, TCM has a setup problem of choke price. The purpose of this paper is to propose the evaluating theory of recreation benefit of environmental quality improvements by household production function approach with revealed preference data. Our approach suggested is operational and allows to decide whether the behavior observed and the household production functions are consistent.

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1. Introduction

The economic evaluation methods of non-market goods (e.g. environmental quality) are roughly classifiable as *revealed preference* approaches and *stated preference* approaches. The former evaluate environmental quality indirectly through socioeconomic activity; the latter evaluate environmental quality by asking people about their awareness of it. The revealed preference approach is the more dependable method because in incorporates observable market data; especially, *travel cost method* (TCM hereinafter) is applied widely for evaluation of recreation benefit.

Hotelling's letter(1947) to the Director of the National Park Service proposing a method for measuring the benefit provided by recreation sites gave birth to TCM. The important fundamental theory of TCM is the Weak Complementarily Theory by Mäler(1971, 1974), which holds that if a private market can be found that is closely related to a non-market good that one seeks to evaluate, the amount of change of consumer surplus in a substitute market represents the evaluation value of the amount of change of a non-market good. In other words, presuming that the demand of substitute market x is zero, even if the level of a non-market good Q changes, it does not affect individual expenditure. The description presented above can be expressed as

$$e(p^c, Q^0, \overline{u}) = e(p^c, Q, \overline{u}) \tag{1}$$

where p signifies the price of x; p^c is the choke price; Q^0 is the original level of environmental quality; $\overline{u}$ is a given utility level; and $e(\cdot)$ is the *expenditure function*. Then, if x is not consumed and individual expenditure is an indiscrimination against Q, it is possible to define the relation between x and Q as weak complementarily.

Therefore, we must know the choke price level if we apply the Weak Complementarily Theory, but it is unobservable in a market. We can, however, execute a social experiment. Then, the ordinary method can be used to estimate the demand function by statistical extrapolation. Additionally, the TCM theory necessitates estimation of the Compensated Demand Function (or Hicksian Demand Function) and calculation of the difference of the Hicksian Compensating Value Measure because of the change of the environment level. Nevertheless, it is impossible to observe the Compensated Demand Function in the market. Accordingly, practical applications of TCM necessitate the estimation of the Marshallian Demand Function, which is observable in the market, along with measurement of the difference of Consumer Surplus because of the change of the environment level. Unfortunately, this presents a theoretical inconsistency. It is noteworthy that this problem does not arise if no Income Effect exists.

As described herein, we avoid several problems of TCM described above and suggest a new theory—applying household production approach—that can evaluate recreation benefit according to environmental improvement.

2. Review of previous studies and the object of this article

Several economic definitions of environmental quality have been advanced. First, environmental quality is regarded as a good whose properties resemble those of public goods. Second, it is regarded as natural capital or a part of the commons. Furthermore, at least one definition casts it as a location-specific good in a local space. Consequently, recreational benefit is regarded as a good or service that is produced through interaction between environmental quality and an individual. It can be considered that the recreational benefit this article treats is a sort of benefit that is generated by enjoying the environment as a location-specific good at a recreational site that is separate from one's domicile. Therefore, a recreational experience in this article is interpreted as a commodity that is produced by an individual who combines travel time, travel cost, and a recreational site as a service of location-specific goods. In this paper, we derive an equation evaluating recreational benefit through application of the household production function.

In the first of several relevant studies, Bradford and Hildebrandt(1977) proved the necessity of the Samuelsonian condition after establishment of the weak complementarily theorem presented by Mäler. Moreover, Hori(1975) showed that it was impossible to separate the relationship between a public good and a private good because the consumption of a public good has some technical relation to consumption of some private goods. To explain this idea concretely, he cited an example in which an individual can enjoy the same security police protection provided by hiring private guards, installing locks, and so on. In his paper, he suggested the household production function and proved the following: if it assumed that environmental quality is used only as an input in the production process and is not consumed directly, the environmental quality can be evaluated. This article follows his idea because we assume that an individual produces the recreational experience by consuming a market good of demand for a recreation site and a public good of the environmental quality, whose relation is inseparable. Later, Bartik(1988) introduced the household production function by defining personal environmental quality. Smith(1991), Bockstael and McConell(2002), and Freeman(2003) applied the same approach. Furthermore, Ebert(2007) showed that the approach is effective if a utility function is independent, at least directly, of the environmental quality.

This paper is presented as follows. Section 3 introduces the model that develops Ebert(2007) and incorporates a time constraint. Using this model, we regard recreational experience as a commodity that is produced by individuals who combine the time, cost and recreation site as location-specific goods. Using this concept, we formulate the model of recreational behavior and show the value of environmental quality. Section 4 presents an equation for evaluating the recreational benefit, and shows its approximation, when environmental quality of a recreation site is improved. Finally, Section 5 summarizes this presentation and concludes with some thoughts related to future research.

3. Model of recreational behavior when considering travel time

3.1 Formulation of individual behavior

As described this section, we improve the model of recreational behavior by Ebert(2007) by addition of travel time to that model. First, assume the consumer faces the following problem.

$$\begin{aligned} \max_{z,l,x} \quad & u\left(z,l,f\left(x,Q\right)\right) \\ \text{s.t.} \quad & z+px=y \\ & l+tx=T \end{aligned} \tag{2}$$

Therein, $u(\cdot)$ is a utility function of the consumer (or traveler); z is a numeraire commodity; x signifies demand for a recreation site; Q is its environmental quality; and $f(\cdot)$ is the household production function, which employs the input and Q to produce another commodity F—the recreational experiment. Furthermore, p represents the travel cost, and

y is income including wages that the consumer gains by fixed working hours. In addition, l is the leisure time, excluding travel time. Also, t is the travel time to a recreation site, and T is the available time a working hours. Subscripts indicate partial derivatives.

The first-order conditions of this problem reduce to the expressions shown below.

$$\frac{u_{f(x,Q)} f\left(x,Q\right)_x}{\lambda} = p + \frac{\mu}{\lambda} t \tag{3}$$

$$u_l = \mu \tag{4}$$

$$u_z = \lambda \tag{5}$$

In those equations, λ and μ are the Lagrange multipliers, respectively indicating the shadow prices of income and time. The fraction μ/λ represents the willingness to pay for time.

The consumer's maximum attainable utility $V\left(\cdot\right)$, as given by this indirect utility function, is equal to the Lagrangian of the consumer's maximization problem, or

$$\begin{aligned} &V\left(p,y,t,T,Q\right) \\ &\quad \equiv u\left(z\left(p,y,t,T,Q\right), l\left(p,y,t,T,Q\right), f\left(x\left(p,y,t,T,Q\right),Q\right)\right) \\ &\qquad + \lambda\left(p,y,t,T,Q\right)\left(y - z\left(p,y,t,T,Q\right) - px\left(p,y,t,T,Q\right)\right) \\ &\qquad + \mu\left(p,y,t,T,Q\right)\left(T - l\left(p,y,t,T,Q\right) - tx\left(p,y,t,T,Q\right)\right) \end{aligned} \tag{6}$$

By applying the envelope theorem to (6) and using (4) and (5), the following are derived.

$$\frac{\partial V}{\partial p} = V_p = -\lambda x \tag{7}$$

$$\frac{\partial V}{\partial y} = V_y = \lambda \tag{8}$$

$$\frac{\partial V}{\partial t} = V_t = -\mu x \tag{9}$$

$$\frac{\partial V}{\partial T} = V_T = \mu \tag{10}$$

$$\frac{\partial V}{\partial Q} = V_Q = u_{f(x,Q)} f\left(x,Q\right)_Q \tag{11}$$

3.2 Value of environmental quality using revealed preference data

Environmental quality is generally interpreted as a public good. For that reason, the value of environmental quality (hereinafter, VOE) is defined as the marginal rate of substitution for Q and y under the assumption of constant demand.

$$VOE \equiv -\left.\frac{dy}{dQ}\right|_{V=\text{Const.}} \tag{12}$$

By applying (3), the value of environmental quality can be expressed as follows.

$$VOE \equiv -\frac{dy}{dQ}\bigg|_{V=\text{Const.}} = \frac{V_Q}{V_y} = \frac{u_{f(x,Q)} f\left(x,Q\right)_Q}{\lambda} = \frac{u_{f(x,Q)} f\left(x,Q\right)_Q}{u_{f(x,Q)} f\left(x,Q\right)_x} \cdot \frac{u_{f(x,Q)} f\left(x,Q\right)_x}{\lambda}$$
$$= \frac{f\left(x,Q\right)_Q}{f\left(x,Q\right)_x} \cdot \left(p + \frac{\mu}{\lambda} t\right) \tag{13}$$

That is, if it is possible to express μ/λ using revealed preference data, the value of the environment can also be expressed using it, even if a time constraint is added.

As pointed out by Randall(1994), the important assignment of TCM was how to set the value of time (VOT). According to De Serpa(1971), De Donnea(1972), and Bates et al.(2001), VOT can be categorized as follows.

First, it is the value of time as a resource. It is precisely equal in economic terms to the concept of opportunity cost. In other words, it is defined as the benefit people could have received by taking an alternative action when scarce resources (time) are consumed by specific way. Second, it is the value of time as a commodity. In the case of valuing time as a commodity, travel time is affected by factors relating to satisfaction or dissatisfaction of traveling, such as comfort, fatigue, convenience, and appreciation of scenery among others: it can be interpreted as the service level for trips. Third, it is the value of changes in consumption patterns. Because this article specifically describes examination of environmental quality valuation, we employ the value of time as a resource.

In fact, VOT is defined as the marginal substitution rate for utility between travel cost p and travel time to a recreation site t under the assumption of constant demand. Therefore, VOT is defined as follows (e.g. Larson and Shaikh(2004) or Morisugi(2006)):

$$VOT \equiv -\frac{dp}{dt}\bigg|_{V=\text{Const.}} \tag{14}$$

Adopting (14) and applying Roy's identities to (7)–(10), VOT can be expressed as

$$VOT \equiv -\frac{dp}{dt}\bigg|_{V=\text{Const.}} = \frac{V_t}{V_p} = \frac{-V_T x}{-V_y x} = \frac{\mu}{\lambda} \tag{15}$$

Then, to express (15) in terms of recreational demand, the approach is to take the respective derivatives of $V_p = -V_y x$ and $V_t = -V_T x$, which are derived from (7)–(10) with respect to t and p to express the VOT in terms of x,

$$V_{pt} = \left(-V_y x\right)_t = V_{Ty} x^2 + V_T x x_y - V_y x_t \tag{16}$$
$$V_{tp} = \left(-V_T x\right)_p = V_{Ty} x^2 + V_y x x_T - V_T x_p \tag{17}$$

Noting that (16) and (17) are equal by Young's theorem, equating them yields

$$V_T\left(x_p + x x_y\right) = V_y\left(x_t + x x_T\right) \tag{18}$$

Therefore, it follows from (18) that VOT as a resource can be expressed in terms of recreational demand x as shown below.

$$VOT = \frac{V_t}{V_p}\bigg|_{V=\text{Const.}} = \frac{V_T}{V_y} = \frac{x_t + xx_T}{x_p + xx_y} \tag{19}$$

Analyzing (19), the value of time under the assumption of constant utility can be measured from observable changes in recreational demand x, where x_t is the change in demand with respect to change in travel time to a recreational site, x_p is the change in demand with respect to change in travel cost, x_T is the change in demand with respect to change in all available time, and x_y is the change in demand with respect to change in income. By applying (15) and (19) to (13), VOE—derived from the model of recreational behavior considering the case of travel time—can also be expressed using household production function and data that are observable in the market.

$$\begin{aligned} VOE &\equiv -\frac{dy}{dQ}\bigg|_{V=\text{Const.}} \\ &= \frac{f(x,Q)_Q}{f(x,Q)_x} \cdot \left(p + \frac{x_t + xx_T}{x_p + xx_y} \cdot t \right) \end{aligned} \tag{20}$$

In light of the fact that the accuracy of the benefit measured using TCM has been questionable because of the problem of the value of time, it will be possible to determine a more realistic value of environmental quality through application of our approach.

4. Derivation of an equation evaluating recreation benefit

Assume that environmental quality in a recreation site is improved from Q^0 to Q^1 ($Q^0 < Q^1$). In this situation, the level of utility changes from $V^0\left(p,y,t,T,Q^0\right)$ to $V^1\left(p,y,t,T,Q^1\right)$. However, it must be noted that $\left(p,y,t,T\right)$ does not change because we specifically examine only the change of the level of environmental quality. This paper applies Equivalent Variation and Compensating Variation (denoted hereinafter as EV and CV), which proves Path Independence to evaluate recreational benefit.

By applying the expenditure function to use EV, it can be expressed as (21) and (22).

$$EV \equiv e\left(p,t,T,Q^0,V^1\right) - e\left(p,t,T,Q^0,V^0\right) \tag{21}$$

$$\begin{aligned} EV &\equiv \int_{V^0}^{V^1} e_V dV = \int_{Q^0}^{Q^1} e_V V_Q dQ \\ &= \int_{Q^0}^{Q^1} e_V V_y \left(V_Q / V_y\right) dQ = \int_{Q^0}^{Q^1} e_V V_y \left(VOE\right) dQ \end{aligned} \tag{22}$$

The second approximation (23) is obtainable by application of Taylor Expansion to (22).

$$EV \approx \frac{1}{2}\left(e_V^0 V_y VOE^0 + e_V^1 V_y VOE^1\right)\left(Q^1 - Q^0\right) \quad \left(e_V^i \equiv \frac{\partial e}{\partial V}\bigg|_{V=V_i} \quad \left(i = 0,1\right) \right) \tag{23}$$

By applying $e\left(p,t,T,Q^0,V^0\right)\equiv y$, $e_V^0 V_y = 1$ is derived and eqs. (24)–(26) can be derived by first approximation of $e_V^1 V_y$ near $e_V^0 V_y$.

$$e_V^1 V_y \approx e_V^0 V_y + e_V^0 V_{yQ}\left(Q^1 - Q^0\right) \tag{24}$$
$$e_V^0 V_{yQ} = e_V^0 V_{Qy} = e_V^0\left(V_{yy} VOE^0 + V_y VOE_y^0\right) = VOE_y^0 \tag{25}$$
$$e_V^1 V_y \approx 1 + VOE_y^0\left(Q^1 - Q^0\right) \tag{26}$$

By substituting (26) for (23), one obtains an approximation of EV((27)). Therefore, even if the recreational benefit gained by improving environmental quality is defined as EV, it is possible to evaluate its benefit solely by application of revealed preference data that are observable in the market.

$$EV \approx \frac{1}{2}\left(VOE^0 + \left(1 + VOE_y^0\left(Q^1 - Q^0\right)\right)VOE^1\right)\cdot\left(Q^1 - Q^0\right) \tag{27}$$

In fact, CV can also be derived using the same logic as that used for EV. It is readily apparent that the recreational benefit that is gained by improving environmental quality is defined as CV, it is possible to evaluate its benefit by sole application of revealed preference data that are observable in the market:

$$CV \approx \frac{1}{2}\left(VOE^1 + \left(1 + VOE_y^1\left(Q^1 - Q^0\right)\right)VOE^0\right)\cdot\left(Q^1 - Q^0\right) \tag{28}$$

5. Conclusions

This paper described investigation of the evaluation theory of recreation benefit using revealed preference data and applying the household production function approach. The salient conclusions are explained below.

First, we suggest a model of recreational behavior in the case of consideration of travel time by developing Ebert's model. If the form of the household production function is knowable, then the environmental quality of a site is definable merely using revealed preference data.

Secondly, we derive the value of time from revealed preference data that are observable in the market. Because a profound problem of TCM is the value of time, stronger and more accurate values might be obtained through application of our approach.

Finally, approximations of EV and CV derived in this paper are expressed merely by revealed preference data that are observable in market. Consequently, our approach can evaluate recreation benefit with less error than traditional TCM, which is based on Weak Complementarily Theory.

Our approach not only has merits: it has assignments. They are whether the hypothesis of existence of household production function is valid or not and whether estimation of it is possible or not. The former assignment reflects the possible existence $u\left(z,l,f\left(x,Q\right),x\right)$ or $u\left(z,l,f\left(x,Q\right),Q\right)$. Ebert(2007) also points out this problem, so this matter is under consideration. Because this is also related to the latter problem, those problems described above are important.

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Appendix

A household production function for fishing or hunting, for which the dependent variable is clear, can be estimated. However, recreational activities for which the dependent variables are not clear (e.g. green tourism or eco-tourism) are difficult to define in terms of production. Nevertheless, our model can be a tool for general use by redefining the production criterion (dependent variable) as *satisfaction*. In such cases, although the dependent variables are stated preference (SP) data, no necessity exists to define the utility function perfectly. It is therefore possible to estimate a form of household production function by regarding it as a kind of a part-worth function if we carry out a questionnaire survey to assess travelers' *satisfaction*. Consequently, we can conceive of a household production function as a function that has the property of a part-worth function.