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Conference Paper Measurement of use value and non-use value of environmental quality consistent with general equilibrium approach

54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Sakamoto, Naoki; Nakajima, Kazunori (2014) : Measurement of use value and non-use value of environmental quality consistent with general equilibrium approach, 54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at: https://hdl.handle.net/10419/124455

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Measurement of use value and non-use value of environmental quality consistent with general equilibrium approach¹

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Abstract

This paper proposes the consistent method with general equilibrium models to measure use value and non-use value of large-scale change in environmental quality. First, we develop a general equilibrium model that parameters of the utility function with environmental quality as a dependent variable can be estimated on the basis of the travel cost method and the contingent variation method. Second, we examine to identify the general equilibrium impact of environmental quality by a comparative static analysis. Third, considering change in prices and income, we decompose the benefits from change in environmental quality into use value and non-use value.

JEL Classifications: C68, Q51, Q54

Keywords: Computable general equilibrium models; Use value; Non-use value

¹ This work was supported in part by the Global Environmental Research Fund S-8 by the Ministry of theEnvironment, Japan. We gratefully acknowledge the generosity of these funds.

1. Introduction

It is desirable to adopt a general equilibrium model when measuring impacts on some nationwide change in environmental quality such as sandy beach erosion, tidal flat erosion and mortality risk reduction by the global warming. Generally environmental quality, and affects factor income as well as other goods prices unconcerned recreation demands. Such change in prices and income would feed back to the recreation demands concerning the environmental quality, and would vary use value of environmental quality. On the other hand, non-use value of environmental quality measuring by monetary term also changes since marginal cost of utility varies along with change in goods prices and income induced by environmental quality reduction. Although partial equilibrium approach dominates in measuring impacts on small change in an environmental quality, it is necessary to utilize a general equilibrium model in the case of nationwide change in environmental quality so as to consider the effect of prices and income.

The purpose of this paper is to propose a method to measure use value and non-use value of large-scale change in environmental quality on the basis of general equilibrium approach. In computable general equilibrium analysis, parameters in utility function and production function are determined by the calibration using a social accounting matrix. Social accounting matrix, however, doesn't contain data of environmental quality explicitly. Thus, in order to estimate general equilibrium impacts of nationwide change in environmental quality, we must introduce data of corresponding environmental quality to a computable general equilibrium model by some methods.

By the way, Miyata (1995) derived the utility function from the waste discharge demand function and applied it to the computable general equilibrium model. The utility function was recovered by solving the integrability problem with respect to the waste discharge demand function which was pre-formulated by the parameter statistically estimated in the previous study. On the other hand, Nakajima and Sakamoto (2013) adopted Miyata's (1995) approach to the derivation of the utility function from the recreation demand function estimated on the basis of the zonal travel cost method. The derived utility function has the environmental quality as an independent variable, so that it is possible to analyze the general equilibrium impact of the environmental quality reduction by a computable general equilibrium model.

This analytical approach, however, cannot estimate only use value of environmental quality. Therefore, in order to measure non-use value considering general equilibrium impacts, we attempt to introduce the parameters estimated by contingent valuation method to computable general equilibrium model.

Furthermore, we examine to identify general equilibrium impacts of environmental quality by a comparative static analysis. Nakajima and Sakamoto (2013) proved that the sandy beach erosion as the environmental quality reduction by global warming would decrease recreational benefits from beaches, but the factor income and all prices would increase in Japanese economy. In this paper, by using a simpler general equilibrium model than Nakajima and Sakamoto (2013) in the meaning of abstracting intermediate goods, we will examine whether this simulation results are supported by theoretical analysis or not.

This paper is organized as follows. Section 2 formulates the consumer behavior consistent with the commonly used the travel cost method and the contingent valuation method. Section 3 introduces the consumer behavior in the previous section to a simple general equilibrium model. Section 4 clarifies that the general equilibrium impacts of change in environmental quality by a comparative static analysis. Section 5 defines the benefit from environmental quality considering general equilibrium impacts. Section 6 notes that the estimation strategy of utility function which applied to a computable general equilibrium model. Section 7 provides concluding remarks.

2. Basic Model

Our basic model is addressed to an economy with a recreation site. The population size in this economy is unity. Each individual derives utility from private goods, visits to the recreation site, and the environmental quality in the recreation site. We assume that each individual has homogeneous preferences, which are defined by a quasi-linear utility function

$$u(x_1, x_2, q) \triangleq x_1 + u_2(x_2, q) + u_3(q), \qquad (1)$$

where x_1 is the consumption of private goods, x_2 is the number of visits to the recreation site, and q is the level of the environmental quality in the recreation site.

The second term of (1), $u_2(x_2,q)$, relates to the use value of the environmental quality. We assume that x_2 is the weakly complementary good for q, so that $\partial u_2(0,q) / \partial q = 0$ is satisfied. For details, see Phaneuf and Smith (2006). Furthermore, the third term of (1), $u_3(q)$, is the utility derived from the environmental quality without visiting the recreation site, and would concern the non-use value of the environmental quality. We assume that $u'_3(q) > 0$. Thus $u(x_1, x_2, q)$ doesn't satisfy weak complementarity, though $u_2(x_2, q)$ satisfies it. This property is also confirmed by $\partial u(x_1, 0, q) / \partial q = u'_3(q)$. We assume that $u_2(x_2, q)$ and $u_3(q)$ are estimated by the travel cost method and the contingent valuation method respectively.

Each individual maximizes (1) subject to the budget constraint,

$$p_1 x_1 + p_2 x_2 = y , (2)$$

where y is the factor income from labor and capital, and p_i is the price of the *i* th goods. Denoting by λ the Lagrange multipliers associated with (2), or marginal utility of income, the first-order conditions are

$$1 - \lambda p_1 = 0, \qquad (3)$$

$$\frac{\partial u_2(x_2,q)}{\partial x_2} - \lambda p_2 = 0.$$
(4)

Putting (3) and (4) together, we obtain

$$\frac{\partial u_2(x_2,q)}{\partial x_2} = \frac{p_2}{p_1}.$$
(5)

The demand function for goods 2, namely, the recreation demand function is induced by (5) without using budget constraint (2) since the utility function is assumed to be quasi-linear. Thus the recreation demand has no income effect, so that the recreation demand function is expressed as $x_2(p_1, p_2, q)$.

By the way, we assumed that the recreation demand function was estimated by using some travel cost method. Let us specify the recreation demand function as

$$x_{2} = \exp\left[\beta_{1} + \beta_{2}(\frac{p_{2}}{p_{1}} + \omega t)\right]q^{\beta_{3}},$$
 (6)

where β_1 , β_2 , β_3 and ω are the parameters estimated by some econometric method and must satisfy that $\beta_2 < 0$, $\beta_3 > 0$ and $\omega > 0$. ω denotes the value of time and *t* expresses the round-trip time to the recreation site. Although ω is an essentially endogenous variable, we assume that it denotes exogenous marginal disutility for increase in the round-trip time to the recreation site for simplicity. β_2 is necessary to be negative value for the property of demand function. β_3 also denotes the elasticity of recreation demand with regard to change in environmental quality and would be positive value. The specification of recreation demand function expressed by (6) would coincide with the expected number of visits in estimating the recreation demand function by the Poisson regression, which is usually used in the individual travel cost method. Moreover, taking the logarithm of both sides in (6), we have

$$\ln x_2 = \beta_1 + \beta_2 (\frac{p_2}{p_1} + \omega t) + \beta_3 \ln q , \qquad (7)$$

which would seem to be commonly used model in the zonal travel cost method.

Generally there is a utility function from which a system of demand functions can be derived. It is known as integrability problem to induce a utility function from a system of demand functions. If each individual has (6) as a recreation demand function, then the subutility function associated with use value must be specified as

$$u_{2}(x_{2},q) \triangleq \beta_{2}^{-1}x_{2}\left\{\ln x_{2} - (\beta_{1} + \beta_{2}\omega t + \beta_{3}\ln q) - 1\right\}$$
(8)

by solving the integrability problem. Obviously(8) satisfies $\partial u_2(0,q) / \partial q = 0$.

From substitution of (6) and (8) into (1), we derive the indirect utility function as follows:

$$T(v(p_1, p_2, q, y), q) \triangleq v(p_1, p_2, q, y) + u_3(q),$$
(9)

where

$$v(p_1, p_2, q, y) \triangleq \frac{y + CS(p_1, p_2, q)}{p_1}.$$
 (10)

In (10), $CS(p_1, p_2, q)$ denotes the consumer's surplus which is obtained by integrating(6) with respect to p_2 . The definite integral for inducing $CS(p_1, p_2, q)$ is as follows:

$$CS(p_{1}, p_{2}, q) \triangleq \int_{p_{2}}^{\infty} \exp[\beta_{1} + \beta_{2}(\frac{l}{p_{1}} + \omega t)]q^{\beta_{3}} dl$$

$$= -\beta_{2}^{-1} p_{1} \exp\left[\beta_{1} + \beta_{2}(\frac{p_{2}}{p_{1}} + \omega t)\right]q^{\beta_{3}}.$$
(11)

3. Factor markets and general equilibrium

In order to measure benefit/damage by change in environmental quality comprehensively considering price determinations under consumption goods and production factor markets, we introduce the individual's behavior in the previous section to a simple general equilibrium model. It is assumed that the economy has four markets for two consumption goods and two production factors. The markets for factors are that of labor and capital. On the other hand, the markets for goods are that of private goods and visits to the recreation site (transportation). Individual's initial endowments of labor and capital are denoted by \overline{L} and \overline{K} , respectively, which are supplied to the firms produced consumption goods. The firm produced the *i* th goods has a production function $f^i(L_i, K_i)$, where L_i is labor inputs and K_i is capital ones. It is also assumed that the production function exhibits constant returns to scale.

Each firm maximizes its profit as follows:

$$\max_{L_i,K_i} p_i f^i(L_i,K_i) - wL_i - rK_i, \qquad (12)$$

where w is the wage rate and r is the interest rate. The first order conditions for (12) are

$$p_i f_L^i(L_i, K_i) = w, (13)$$

$$p_i f_K^i(L_i, K_i) = r$$
. (14)

Furthermore, the market equilibrium conditions are

$$\overline{L} = L_1 + L_2, \tag{15}$$

$$\overline{K} = K_1 + K_2, \tag{16}$$

$$f^{1}(L_{1}, K_{1}) = \frac{y}{p_{1}} - \frac{p_{2}}{p_{1}} \exp\left[\beta_{1} + \beta_{2}(\frac{p_{2}}{p_{1}} + \omega t)\right] q^{\beta_{3}}, \qquad (17)$$

$$f^{2}(L_{2}, K_{2}) = \exp\left[\beta_{1} + \beta_{2}(\frac{p_{2}}{p_{1}} + \omega t)\right]q^{\beta_{3}}.$$
 (18)

It is possible to determine eight variables, p_1 , p_2 , w, r, L_1 , L_2 , K_1 , and K_2 , as market equilibrium solutions since market equilibrium conditions consist of the same number of equations, which are represented by (13) to (18). One of the market equilibrium conditions, however, is redundant due to Walras' law. This redundancy is certified by budget constraint, (2), where each individual's income can be written as

$$y \equiv w\overline{L} + r\overline{K}, \qquad (19)$$

since firms have no profit on the basis of the assumption that the production functions have the property of constant returns to scale and individuals only gain factor income from labor and capital. In addition, we suppose the measurement of benefits by change in environmental quality utilizing computable general equilibrium analysis, so that it is assumed that labor is numeraire, that is,

$$w = 1, \qquad (20)$$

which is the assumption commonly used in computable general equilibrium analysis.

4. Comparative statics with respect to environmental quality

Nakajima and Sakamoto (2013) attempted to apply the utility function derived from the zonal travel cost method to a simple computable general equilibrium model and simulated what impact the environmental quality reduction have on Japanese economy. As a consequence, it was proved that the sandy beach erosion as the environmental quality reduction by global warming would decrease recreational benefits from beaches, but the factor income and all prices would increase in Japanese economy. In this section, by using a simpler general equilibrium model than Nakajima and Sakamoto (2013) in the meaning of abstracting intermediate goods, we will examine whether this simulation results is supported by theoretical analysis or not.

First of all, eliminating p_1 , p_2 , w, r, L_2 , and K_2 in (13), (14), (15), (17), (19) and (20), we have

$$\frac{f_K^1(L_1, K_1)}{f_L^1(L_1, K_1)} = \frac{f_K^2(L - L_1, K - K_1)}{f_L^2(L - L_1, K - K_1)},$$
(21)

$$f^{2}(L-L_{1},K-K_{1}) = \exp\left[\beta_{1} + \beta_{2}\left(\frac{f_{L}^{1}(L_{1},K_{1})}{f_{L}^{2}(L-L_{1},K-K_{1})} + \omega t\right)\right]q^{\beta_{3}}.$$
 (22)

Taking the logarithm of both sides in (21) and (22), these equations are transformed as follows.

$$\ln f_K^1(L_1, K_1) - \ln f_L^1(L_1, K_1) - \ln f_K^2(L - L_1, K - K_1) + \ln f_L^2(L - L_1, K - K_1) = 0, \quad (23)$$

$$\ln f^{2}(L-L_{1},K-K_{1}) - \beta_{1} - \beta_{2}\left(\frac{f_{L}^{1}(L_{1},K_{1})}{f_{L}^{2}(L-L_{1},K-K_{1})} + \omega t\right) - \beta_{3}\ln q = 0.$$
(24)

(23) and (24) determines L_1 and K_1 , which depend on q. The comparative statics of L_1 and K_1 with respect to q is shown by the total differential of (23) and (24), that is,

$$\begin{bmatrix} \left(\frac{f_{LK}^{1}}{f_{K}^{1}} + \frac{f_{LK}^{2}}{f_{K}^{2}}\right) - \left(\frac{f_{LL}^{1}}{f_{L}^{1}} + \frac{f_{LL}^{2}}{f_{L}^{2}}\right) & - \left(\frac{f_{KL}^{1}}{f_{L}^{1}} + \frac{f_{KL}^{2}}{f_{L}^{2}}\right) + \left(\frac{f_{KK}^{1}}{f_{K}^{1}} + \frac{f_{KK}^{2}}{f_{K}^{2}}\right) \\ - \frac{f_{L}^{2}}{f^{2}} - \beta_{2} \frac{f_{K}^{1}}{f_{K}^{2}} \left(\frac{f_{LL}^{1}}{f_{L}^{1}} + \frac{f_{LL}^{2}}{f_{L}^{2}}\right) & - \frac{f_{K}^{2}}{f^{2}} - \beta_{2} \frac{f_{K}^{1}}{f_{K}^{2}} \left(\frac{f_{KL}^{1}}{f_{L}^{1}} + \frac{f_{KL}^{2}}{f_{L}^{2}}\right) \end{bmatrix} \begin{bmatrix} \frac{dL_{1}}{dq} \\ \frac{dK_{1}}{dq} \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{\beta_{3}}{q} \end{bmatrix}, \quad (25)$$

which implies that

$$\frac{dL_1}{dq} = \frac{1}{\Delta} \frac{\beta_3}{q} \left\{ \left(\frac{f_{KL}^1}{f_L^1} + \frac{f_{KL}^2}{f_L^2} \right) - \left(\frac{f_{KK}^1}{f_K^1} + \frac{f_{KK}^2}{f_K^2} \right) \right\} < 0,$$
(26)

$$\frac{dK_1}{dq} = \frac{1}{\Delta} \frac{\beta_3}{q} \left\{ \left(\frac{f_{LK}^1}{f_K^1} + \frac{f_{LK}^2}{f_K^2} \right) - \left(\frac{f_{LL}^1}{f_L^1} + \frac{f_{LL}^2}{f_L^2} \right) \right\} < 0,$$
(27)

where Δ is the determinant of the matrix in L.H.S. of (25). It is confirmed that the sign of Δ is negative by using the assumption that production function is constant return to scale. Furthermore, using (15) and (16), it is found that the comparative statics of L_2 and K_2 with respect to q are positive:

$$\frac{dL_2}{dq} = -\frac{dL_1}{dq} > 0, \qquad (28)$$

$$\frac{dK_2}{dq} = -\frac{dK_1}{dq} > 0.$$
 (29)

As for the comparative statics of prices and income, we can obtain the following equations by using (13), (14) and (19).

$$\frac{dp_i}{dq} = -\frac{L_i f_{LL}^i}{(f_L^i)^2 q} \left(\frac{dL_i}{dq} \frac{q}{L_i} - \frac{dK_i}{dq} \frac{q}{K_i} \right), \text{ for } i = 1, 2, \qquad (30)$$

$$\frac{dr}{dq} = -\frac{L_i f_K^i f_{LL}^i + K_i f_L^i f_{KK}^i}{(f_L^i)^2 q} \left(\frac{dL_i}{dq} \frac{q}{L_i} - \frac{dK_i}{dq} \frac{q}{K_i} \right), \text{ for } i = 1, 2.$$
(31)

$$\frac{dy}{dq} = \overline{K}\frac{dr}{dq}.$$
(32)

Thus, it would be concluded that the elasticity of factor demands (labor and capital) with respect to environmental quality determines the signs of comparative statics of prices and income:

$$\operatorname{sgn}\left(\frac{dp_1}{dq}\right) = \operatorname{sgn}\left(\frac{dp_2}{dq}\right) = \operatorname{sgn}\left(\frac{dr}{dq}\right) = \operatorname{sgn}\left(\frac{dy}{dq}\right) = \operatorname{sgn}\left(\frac{dL_1}{dq}\frac{q}{L_1} - \frac{dK_1}{dq}\frac{q}{K_1}\right), \quad (33)$$

$$\operatorname{sgn}\left(\frac{dL_1}{dq}\frac{q}{L_1} - \frac{dK_1}{dq}\frac{q}{K_1}\right) = \operatorname{sgn}\left(\frac{dL_2}{dq}\frac{q}{L_2} - \frac{dK_2}{dq}\frac{q}{K_2}\right).$$
(34)

Surprisingly all endogenous variables of prices and income will alter in the same direction by change in environmental quality. This result coincides with the simulation results in Nakajima and Sakamoto (2013).

5. Definition of benefits

In previous section, we had theoretical results that change in environmental quality leads to change in prices and income even in the framework of a simple general equilibrium model where individuals have a quasi-linear utility function. Such an effect that environmental quality has on prices and income should be considered especially in estimating benefits or costs of nationwide change in environmental quality such as sandy beach erosion, tidal flat erosion and mortality risk reduction by global warming. Large change in environmental quality would have an effect on prices and income.

In this section, we attempt to define the benefit of change in environmental quality including change in prices and income and decompose the benefit into use value and non-use value. If we ignore changing of prices and income, then it is natural to define the total benefit by concept of compensating variation, C.

$$T(v(p_1^0, p_2^0, q^0, y^0), q^0) = T(v(p_1^0, p_2^0, q^1, y^0 - C), q^1),$$
(35)

where superscript 0 denotes the value of the corresponding variable before changing the environmental quality and superscript 1 denotes after. Hanemann (1993) suggests the following decomposition:

$$C = C_U + C_N \,, \tag{36}$$

where C_U and C_N denote use value and non-use value respectively. These are also defined as follows.

$$T(v(p_1^0, p_2^0, q^0, y^0), q^0) = T(v(p_1^0, p_2^0, q^1, y^0 - C_U), q^0),$$
(37)

$$T(v(p_1^0, p_2^0, q^0, y^0), q^0) = T(v(p_1^0, p_2^0, q^0, y^0 - C_N), q^1),$$
(38)

(35), (37) and (38) can be written as

$$C = \left[CS(p_1^0, p_2^0, q^1) - CS(p_1^0, p_2^0, q^0) \right] + p_1^0 \left[u_3(q^1) - u_3(q^0) \right],$$
(39)

$$C_{U} = CS(p_{1}^{0}, p_{2}^{0}, q^{1}) - CS(p_{1}^{0}, p_{2}^{0}, q^{0}), \qquad (40)$$

$$C_{U} = p_{1}^{0}[u_{3}(q^{1}) - u_{3}(q^{0})], \qquad (41)$$

respectively. Obviously (36) is satisfied from (39), (40) and (41).

Let us introduce change in prices and income to the above framework. We define the use value containing general equilibrium impacts as \tilde{C}_U in the following equation:

$$T(v(p_{1}^{0}, p_{2}^{0}, q^{0}, y^{0}), q^{0}) = T(v(p_{1}^{1}, p_{2}^{1}, q^{1}, y^{1} - \tilde{C}_{U}), q^{0})$$

$$\Leftrightarrow \quad \tilde{C}_{U} = p_{1}^{1} \left[\frac{CS(p_{1}^{0}, p_{2}^{0}, q^{1})}{p_{1}^{0}} - \frac{CS(p_{1}^{0}, p_{2}^{0}, q^{0})}{p_{1}^{0}} \right]$$

$$+ p_{1}^{1} \left[\frac{CS(p_{1}^{1}, p_{2}^{1}, q^{1})}{p_{1}^{1}} - \frac{CS(p_{1}^{0}, p_{2}^{0}, q^{1})}{p_{1}^{0}} \right]$$

$$+ p_{1}^{1} \left[\frac{y^{1}}{p_{1}^{1}} - \frac{y^{0}}{p_{1}^{0}} \right].$$
(42)

Total value should be also defined as

$$T(v(p_1^0, p_2^0, q^0, y^0), q^0) = T(v(p_1^1, p_2^1, q^1, y^1 - \tilde{C}), q^1)$$

$$\Leftrightarrow \quad \tilde{C} = \tilde{C}_U + p_1^1 \Big[u_3(q^1) - u_3(q^0) \Big].$$
(43)

Based on Carson and Hanemann (2006), we define non-use value as the difference

$$\tilde{C}_{N} \triangleq \tilde{C} - \tilde{C}_{U} = p_{1}^{1} \Big[u_{3}(q^{1}) - u_{3}(q^{0}) \Big].$$
(44)

It is obvious that $C \neq \tilde{C}, C_U \neq \tilde{C}_U$ and $C_N \neq \tilde{C}_N$, so that we can conclude that general equilibrium impacts make the benefit from the environmental quality change. The use value (\tilde{C}_U) contains the variation of the consumer's surplus and the real income by changing prices and factor income as well as the variation of consumer's surplus by changing the environmental quality. The non-use value (\tilde{C}_N) also changes by the marginal cost of utility ex post.

6. Strategy for estimation of utility function

As for the estimation of utility function, we propose to use the travel cost method and the contingent variation method. First, estimate the following equation by the zonal travel cost method or the individual travel cost method:

$$x_2 = \exp\left[\gamma_1 + \gamma_2 p_2 + \gamma_3 t\right] q^{\gamma_4} .$$
(45)

This estimation determines some parameters of the utility function as follows:

$$\hat{\beta}_1 = \hat{\gamma}_1, \quad \hat{\beta}_2 = \hat{\gamma}_2, \quad \hat{\beta}_3 = \hat{\gamma}_4, \quad \hat{\omega} = \frac{\hat{\gamma}_3}{\hat{\gamma}_2}.$$
 (46)

Second, we generate inputted data into the social accounting matrix as follows:

$$x_{2}^{0} = \exp\left[\hat{\beta}_{1} + \hat{\beta}_{2}(p_{2}^{0} + \hat{\omega}t^{0})\right]q^{\hat{\beta}_{3}}, \qquad (47)$$

where we assume $p_1^0 = 1$ such as computable general equilibrium analysis. We also assign the travel costand time from the representative point in the analyzing area to the

recreation site as the data of p_2^0 and t^0 respectively.

Third, we correspond aggregate travel costs, $p_2^0 x_2^0$, to the sectors in social accounting matrix such as transportation sector. Finally, we estimate $u_3(q)$. Let us specify as $u_3(q) = \delta q$. For the hypothetical situation that q = 0, we define WTP for preventing it as follows:

$$y - WTP - \hat{\beta}_2^{-1} \exp\left[\hat{\beta}_1 + \hat{\beta}_2(p_2 + \hat{\omega}t)\right] (q^0)^{\hat{\beta}_3} + \delta q^0 = y$$

$$\Leftrightarrow WTP = -\hat{\beta}_2^{-1} x_2 + \delta q^0.$$
(48)

It is possible to estimate δ by the contingent valuation method.

7. Concluding remarks

This paper proposed the consistent method with general equilibrium models to measure use value and non-use value of large-scale change in environmental quality. Based on the comparative static analysis, change in environmental quality has influence on prices and income in general equilibrium model. Furthermore, we defined the use value and non-use value under the general equilibrium situation. As a consequence, it was found that these values are different by whether considering general equilibrium impacts or not. Although the methods that we proposed are necessary to estimate the utility function, we noted the strategy to estimate it by using the travel cost method and the contingent valuation method.

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