Towards the lifestyle of sustainable consumption society: a simulation analysis using the demand function in the AIDS and the environmental input-output table

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1 The Aim of Our Study

According to our previous study (Shinozaki, Nakano and Washizu, 2005), CO_2 emission per capita induced by consumption activity steadily increased, however, now it seems to have reached the peak. In 1985 it was 3.8 t-CO_2, but in 1990, 4.4 t-CO_2, 5.0 t-CO_2 in1995, and in 2000, 4.9 t-CO_2. Furthermore, most of CO_2 emission is induced by the three consumption items based on the "Family Income and Expenditure Survey", such as “fuel, light, water supply”, “transportation and communication”, and “food” that covers almost 70% of all.

Then, to investigate the factor cause of the changes in the CO_2 emission per capita Japanese, a factor decomposition analysis of them is carried out. That is, the historical change of CO_2 emission amount Japanese per capita is decomposed into the effect of the consumption structure, the income effect (caused by the change of the total consumption expenditure) and the technical effect (the effect from the CO_2 emission amount per consumption expenditure (CO_2 emission score) change). Then, we observed which factor had the most influence on the total change.

Among these three factors, the income effect was the largest. That is, the increase of consumer’s income resulted in a higher environmental load. Therefore, if we try to lighten the environmental load, we will have to be prepared to "endure". That is, bearing the inconvenience of the utility level.

As for the effect of consumption structure, the more the expenditure component ratio increase in the household activities, the more CO_2 became to be induced from the service consumption. Furthermore, when we look at the technical effect, the CO_2 emission scores caused by expenditures on services, such as recreation activities, have been increasing year after year. This increase of service’s emission score leads to the up burden of environmental load caused by the household consumption. While the CO_2 emission factors from most of the industrial products decrease, the tendency of increase in the service goods factor is a unique phenomenon.

The UNEP research paper (2002) has given us the concept of “sustainable consumption”. Now, towards the “sustainable consumption” society we must seek a more environment-friendly life style which enables the environmental problems to be consistent with the up level of our life standard.

Under the awareness of such issues, we gave an evaluation on the environmental change caused by the change in household consumption structure. In this study we focused on two types of changes in household consumption structure, which are the high use of services and change in the transportation means.

For the case of the high use of services, the change will be expressed as an expenditure increase in eating out, using cooked food and recreation activities. These behaviors occur when the household subjectively regard the market value cheaper than actual, and will be called a "subjective discount activity". When the consumers estimate these services price lower than that of the actual market, the demand for the services increase following the demand scheduled. This is the same phenomena as when the actual price goes down. We regard the more one “wants” to consume, the higher “subjective discount ratio” in mind one has. The environmental effect is evaluated based on the change in demand schedule with the environmental household account analysis.

For the case of changing transportation means, we all know that changing them from using our private cars to public transportation will give a big environmental effect. Road pricing system, for example, is an efficient measure to deal with the problem. Through the system the cost of using private cars become higher, and consumers should use public transportation instead of their private cars.

Recently mobility management has come to our notice as another efficient measure to decrease our private car demands. According to Fujii, S. and Taniguchi, A. (2006), “The mobility management for travel behavior modification through communicative measures are called “soft measures” or “psychological and behavioral strategies”; they include the provision of specific information on public transport, travel campaigns, and travel education.” That is, mobility management is a kind of consumer education through persuading communication by which people become aware that public transportation is a more convenient means. Through the management, consumers stop using their private cars wastefully and prefer using trains and buses. In the framework of our study these consumers’ behavior are explained as follows. The convenience of using trains and buses make people consider the price of such transportation means rather cheap, and change their behavior pattern. Here the changes, such as expenditure decrease in using private cars or increase in using trains and buses will be expressed as a behavior that occurs when the household faces the change of a relative price. For the case of introducing of the road pricing system, the actual price of using one's private car goes up. Then, consumers using cars decrease following the demand scheduled. For the case of the mobility management, however, consumer's using trains and buses increase, and this occurs when they subjectively regard the market value cheaper than actual, which is "subjective discount activity".

In this study we compare the environmental effect of the above two measures, such as road pricing system and mobility management, by applying the demand function system to the environmental household account analysis using the input-output table. To carry this out, it is necessary to divide the transportation fee into cars and other transportations and calculate the demand function system.

In section 2, the observation is based on the Environmental Household Account following 2000 Environmental Input-Output table (Nakano, 2005) and the CO_2 emission score table. The method used in this section is basically the same as Shinozaki, Nakano and Washizu (2005). However, this time the environmental input-output table is renewed, and the observation came up with some new findings.

In section 3 we will analyze the effect caused by the two changes in household consumption structure.

For the case of high use of services, the utility per environmental load will increase (the environmental efficiency of the consumption behavior increases) and especially in the change in the demand of recreational services, the difference is clear. Those are because the high use of services improves consumers' utility a lot and decreases the environmental load. For the case of changing transportation means, road pricing system increases the environmental efficiency more than mobility management. It seems that another traffic strategy is necessary to make the mobility management become environmentally effective.

2 CO_2 Emission per Japanese and Emission Score

2.1 The Model

The method for the estimation of the CO_2 emission score induced by Japanese per capita is based on the open model of Input-Output analysis. The emission score is calculated as the CO_2 emission induced by the 10 thousand yen (in purchaser's price) of household consumption.

Let c_i be induced CO_2 emission from Japanese consumption of i-th goods or services, it follows that

$$c_i = \left(\mathbf{c^p} \left(\mathbf{I} - \left(\mathbf{I} - \hat{\mathbf{M}} \right) \mathbf{A} \right)^{-1} + \mathbf{c^f} \right) \mathbf{f_{(i)}} \quad (1)$$

where $\mathbf{c^p}$ is the vector of CO_2 emission factor for production (Nakano, S. (2005)),

$\left(\mathbf{I}-\left(\mathbf{I}-\hat{\mathbf{M}}\right)\mathbf{A}\right)^{-1}$ is Leontief inverse matrix, $\mathbf{c^f}$ is the vector of CO_2 emission factor for consumption (Nakano, S. (2005)), $\mathbf{f_{(i)}}$ is the vector which shows household consumption of *i*-th goods or services.

The first term of equation (1) shows induced CO_2 emission per capita in the production and the distribution process of *i*-th goods or services, and the second term demonstrates CO_2 emission in the process of consumption.

The vector $\mathbf{f_{(i)}}$ represents the consumption (f_i) of the *i*-th product in producer's price, and the trade margin ($margin_i$) and the domestic freight ($freight_i$) accompanied by the consumption of *i*-th good. The other factors of the vector are zero.

$$\mathbf{f_{(i)}} = \begin{pmatrix} 0 \\ \vdots \\ f_i \\ \vdots \\ 0 \\ margin_i \\ freight_i \\ 0 \end{pmatrix}$$

Here

$$\widehat{f}_i = f_i + margin_i + freight_i \qquad (2)$$

The scalar $\widehat{f}_i$ is the Japanese consumption expenditure of *i*-th goods or services in purchaser's price. Dividing c_i by Japanese population yields CO_2 emission per capita induced by *i*-th goods or services. Also dividing c_i by consumption expenditure of *i*-th goods or services in purchaser's price, we obtain the CO_2 emission score of *i*-th goods or services.

2.2 The Result

The result is classified into 10 items based on the "Family Income and Expenditure Survey". Table 1 shows the per capita CO_2 emission caused directly and indirectly through the consuming activities. Giving a close look at the total amount of CO_2 emission per capita, it was 4,941kg-CO_2 in 2000. The emission per capita stays about the same as that of 1995. With regard to the component ratio, it did not change much among years. Most of CO_2 emission is induced by energy intensive activities, such as fuel, light and water charges (1,420 kg-CO_2), and transportation and communication (1,280 kg-CO_2), that covers almost 50% of all.

<Table 1>

Focusing on the recreation and private transportation activities in connection with the simulation we made in section 3, CO_2 emission of "amusement and recreation activities" and "hotel and other lodging places" are the largest of all activities in this item. “Gasoline”, “motor vehicles” and “diesel oil” are considerable amounts of CO_2 emissions per capita in the private transportation.

The Ministry of Internal Affairs and Communications carried out a questionnaire research on the time use of a day and published “A Survey of Time Use and Leisure Activities”. In this survey, “amusement and recreation facilities” are classified in “hobbies and recreation activities”. The time spent on “hobbies and recreation activities” was, on average, only 3 minutes in 1976, but increased to 42 minutes in 2001. According to “A Survey of Time Use and Leisure Activities”, the number of travellers increased to 85.90 million in 2001, while in 1986 it was 77.24 million. Also according to “National Time Use Survey” by Nippon Hoso Kyokai, Japan Broadcasting Cooperation, the time spent for excursions and strolling was 15 minutes in 1985, but increased to 18 minutes in 1995. The one for sightseeing was 2 minutes in 1990, while it reached 4 minutes in 1995.

Table 2 shows the average CO_2 emission score of each item. The total average is 23.4kg-CO_2 in 1995 and in 2000, 23.9kg-CO_2. Looking at the scores in 2000, the CO_2 emission scores of “fuel, light and water charges” and “private transportation” are especially high. Decomposing the fuel, light and water charges, “kerosene” (286.5kg-CO_2), “electricity” (847.6kg-CO_2) and “gas supply” (229.7kg-CO_2) have high scores. When we look at goods and services that have high scores in the private transportation, the scores of “gasoline”, “motor vehicles” and “diesel oil” are 749.1kg-CO_2, 107.0kg-CO_2 and 60.3kg-CO_2, respectively.

<Table 2>

3 Environmental Affect Evaluation along with the Life Style Changes

3.1 The “Willingness to Pay” that changes Consumption Activities

The environmental friendly types of consumption activities induce the cost increase such as opportunity cost. Then, to what extent are the consumers ready to bear the cost in changing their behavior pattern? In this study, we estimate the amount of “willingness to pay” from the differences between the necessary total expenditure; when consumers subjectively discount the price of a certain item, and the total expense calculated through the actual price system, given a certain level of utility. That is, the minimum total expenditure changes in before and after the discount price.

Becoming more environmental friendly means change of consumers’ preference. Thus, the parameters of the utility function change and it becomes difficult to compare the utility change in before and after the discount price. In contrast, this study treats environmental friendly behavior as a subjective discount behavior and makes it easier to measure the change in the utility level.

3.1.1 Simulation 1 –transportation-

Using the public transportation saves more time compared with using the private car (private transportation) because we could avoid traffic jams. This is expressed in Figure 1 using the indifference curve. Through subjectively discounting the price of public transportation, the equilibrium point changes from E_0 to E_1. But the actual price has not changed, thus in order to meet the utility level at U_1, the expenditure evaluated in using the private transportation must increase from OA to OA'. This expenditure difference is the equivalent variation caused by the change in public transportation price, and can be understood as the amount of "willingness to pay"; the amount that consumers are ready to pay more, to save time.

If the rate of time preference is high, the idea; "discounting the price of public transportation subjectively", might be acceptable. However, if not, it is not necessarily true. Thus, we assumed the introduction of traffic policy such as road pricing to provide incentives to a modal shift. This is expressed in Figure 2 using the indifference curve, as in the case of the change in public transportation price. If the price of private transportation increases, the equilibrium point will change from E_0 to E_1. To meet the utility level at U_1 under the price before changing, the expenditure evaluated in using the public transportation decrease from OA to OA'. This expenditure difference is the equivalent variation caused by the change in private transportation price.

<Figure 1>

<Figure 2>

3.1.2 Simulation 2 –eating out and recreation-

Let's think about the dinning style. The individual needs diversify and the preference to the leisure time becomes relatively high. But women cannot use their leisure time since they mainly share the household activities. Thus if the dinning style changes from eating at home to eating out, it is possible to cut down their cooking time. Saving time makes housewives consider the price of eating out services rather cheap, and change their behavior pattern.

The recreation activity can be understood in the same way. The save of working time and the diversification of demand has caused the change of recreation services into necessary services from luxurious services. But the supply for recreation services has not increased a lot, and the market of recreation is a sellers market. The buyer's competition is intense. Therefore people tend to hurry to purchase, which induces the feeling that the price of recreation services is cheap.

In this study, we carried out an analysis on calculating the expenditure change when eating out, public transportation, and recreation discount ratio changes from 5%, 10%, 15%, up to 20%, and observed how the consumer's behavior are affected by the price change.

3.2 The Consumer Demand System and the Data

In this study, we specified the consumer demand system into the Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980a, 1980b) and estimated the model.[1] The items are the following twelve; eating at home, eating out, fuel and light, furniture, clothes, medical care, public transportation, private transportation, communication, education, recreation, and others.[2] The expenditure function $c(u, p)$ based on the PIGLOG class of preferences is as follows.

$$\log c(u, p) = \log(a(p)) + u \log(b(p)) \qquad (3)$$

u and p denote utility level and price, respectively. $a(p)$ is the subsistent

[1] Nakano, Shinozaki and Washizu (2006) specified the demand system into the linear expenditure system (LES). In this study, we adopted the AIDS model which relaxes the constraint of the LES.

[2] The expenditure for housing is treated as an exogenous variable in this study.

expenditure and $b(p)$ is the expanding expenditure as the utility level becomes high.

$$\log a(p) = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma'_{ij} \log p_i \log p_j \qquad (4)$$

$$\log b(p) = \beta_0 \prod_i p_i^{\beta_i} \qquad (5)$$

When (4) and (5) are substituted into (3),

$$\log c(u, p) = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma'_{ij} \log p_i \log p_j + u\beta_0 \prod_i p_i^{\beta_i} \qquad (6)$$

Derived from Shephard's lemma, the budget share of the i-th item becomes

$$\frac{\partial \log c(u, p)}{\partial \log p_i} = w_i = \alpha_i + \sum_i \gamma'_{ij} \log p_j + \beta_i u \beta_0 \prod_i p_i^{\beta_i} \qquad (7)$$

Then, solve the utility maximization problem, total expenditure E equals to $c(u, p)$.

$$w_i = \alpha_i + \sum_i \gamma_{ij} \log p_j + \beta_i \log\left(\frac{E}{P}\right) \qquad (8)$$

where $\log P = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma'_{ij} \log p_i \log p_j$ and $\gamma_{ij} = \frac{1}{2}(\gamma'_{ij} + \gamma'_{ji})$.

When the cost function is linear homogeneous and strictly increasing in prices, the demand function satisfies the following conditions.

$$\sum_i^n \alpha_i = 1 (\text{adding up}), \sum_i^n \gamma'_{ij} = 0, \sum_i^n \beta_i = 0 (\text{linear homogeneity}), \gamma'_{ij} = \gamma'_{ji} (\text{symmetry})$$

Though the AIDS model is nonlinear, we simplified estimation using the linear approximation of the AIDS model; the LA-AIDS model. The LA-AIDS model approximates the income deflator P by the Stone's price index;

$$\log P = w_i \sum_i \log p_i \qquad (9)$$

The income (total expenditure) elasticity for demand based on the LA-AIDS model

(Green and Alston 1990, 1991, Buse 1994) is written as

$$e_{iy} = 1 + \frac{\beta_i}{w_i}\left(1 - \sum_j w_j \log p_j \left(e_{jy} - 1\right)\right). \quad (10)$$

The price elasticity for demand is expressed as

$$e_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left(w_j + \sum_k w_k \log p_k \left(e_{kj} + \delta_{kj}\right)\right). \quad (11)$$

δ_{ij} is the Kronecker delta and has the following property.

$$\begin{cases} \delta_{ij} = 1, \text{ if i = j} \\ \delta_{ij} = 0, \text{ otherwise} \end{cases}$$

The data for the item consumption is from the "Family Income and Expenditure Survey", and for the item price index is from "Consumer Price Index (CPI)" and "National Survey of Prices", both published by the Ministry of Internal Affairs and Communications.

3.3 The Result

We estimated the formula (8) by the GMM method in the period of 2000 to 2005 in 49 cities. The estimated result is given in Table 3 and 4. The subscript numbers are No.1, eating at home, No2 eating out, No.3 fuel ,light and water charges, No.4 furniture, No.5 clothing, No.6 medical care, No.7 public transportation, No.8 private transportation, No.9 communication, No.10 education, No.11 recreation, No.12 others. Table 5 and 6 show the own price elasticity and the cross price elasticity in year 2000 respectively, when the price of eating out, public transportation, private transportation and recreation change. According to Table 5, the highest item of own price elasticity is public transportation (5.462), and the lowest is eating out (0.312). Looking at Table 6, most of the cross price elasticity is positive and therefore eating out and other items, and private transportation and other items can be substituted, respectively. In contrast, half of the cross price elasticity in public transportation and recreation are negative. The private transportation and half of other items, and the recreation and half of other items are complementary, respectively.

<Table 3>

< Table 4>

< Table 5>

< Table 6>

3.4 The Consumer's Behavior following the Price Change and the Change in the CO_2 Emission induced

When an item's price is discounted subjectively, the consumption behavior changes, and the CO_2 emission induced by each item also changes. By multiplying this item consumption with the CO_2 emission factor calculated from “2000 Input-Output Table for Environmental Analysis” (Nakano, 2005), as in the former section, we can understand the change in CO_2 emission according to the price change.

Table 7-10 are the changes of the equivalent variation (EV) and the CO_2 emission calculated under the price change in dining out service, recreation activities, public and private transportation, using the price elasticity from Table 5 and 6 and the emission factor. In the base case the average CO_2 emission per household is 12.554t-CO_2.

<Table 7>

<Table 8>

<Table 9>

<Table 10>

When a subjective discount occurs in the dining out service and public transportation, both the equivalent variation and CO_2 emission increase along with the discount ratio. On the other hand, when the recreation service price is discounted, the EV increases, while the CO_2 emission decreases. If the private transportation price goes up, the EV decreases and also does the CO_2 emission.

In order to consider whether the behavior is efficient from the point of CO_2 emission, we have made an eco-efficiency index (EEI) of consumption behavior. To show the utility level, the total consumption is used for the numerator, and for the denominator, the CO_2 emission induced directly and indirectly through the goods and services consumed under this expenditure. For a sensitivity analysis, we add the equivalent variation that indicates the change of the utility level, to the total consumption. This index becomes higher when the consumer's behavior is more eco-efficient in induced CO_2.

$$EEI = \frac{\text{Total consumption expenditure}}{\begin{bmatrix} \text{CO}_2\ \text{Emissions}\ \textit{directly}\ \&\ \textit{indirectly} \\ \text{induced by consumption} \end{bmatrix}} \qquad (12)$$

The base case was 303.1 JPY/kg-CO_2. When recreation service price is subjectively discounted, as the discount ratio increases, the index becomes high, and the behavior becomes eco-efficient (Table 11). However, the dinning out service price is subjectively discounted, as the discount ratio increases, the index becomes low, and the behavior does not become eco-efficient.

Next, let us look at the result of transportation simulation. If the price of private transportation is driven up, the index becomes high. On the other hand, assuming that the price of public transportation is subjectively discounted, the index becomes low and the behavior does not become eco-efficient.

<Table 11>

4 Concluding Remarks

In this study, we specified the consumers' life style change as a subjective discount behavior and divided the consumers life style change into three types; increase in eating out, recreation, and public transportation demand. As a result, the increase in eating out and using cooked food, and public transportation demand will increase the total amount of environmental load. In addition, the utility per environmental load will decrease (the environmental efficiency of the consumption behavior decreases). On the other hand, the increase in recreation demand will decrease the total amount of environmental load. Thus, the utility per environmental load will increase.

The decrease of the CO_2 emissions by increasing the price of the private transport and decreasing the private transport demand is more than. the decrease in the utility level.

We are planning to expand out research in the following way.

1) Give a close look of the way the housewives use their increasing free time, due to the cut down of housework eating out and using cooked food. It might be necessary to

divide eating out, into the dinning for the purpose of recreation and others.

2) There are some recreation that cause a big environmental load and some not. The environmental load cause by the increase in recreation demand differs depending on what kind of recreation is carried out in the free time. Therefore, the recreation item must be divided and the effect analyzed in detail.

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Table 1: CO_2 Emissions Per Capita

	1995		2000	
	CO_2 emission	Component ratio	CO_2 emission	Component ratio
Eating at home	682.40	13.7%	505.59	10.2%
Eating out	262.47	5.3%	347.37	7.0%
Housing	89.33	1.8%	101.28	2.0%
Fuel,Light and Water	1520.34	30.5%	1420.19	28.7%
Furniture	286.19	5.7%	196.18	4.0%
Clothes	220.83	4.4%	85.19	1.7%
Medical Care	90.22	1.8%	165.56	3.4%
Public Transportation	180.55	3.6%	256.38	5.2%
Private Transportation	896.11	18.0%	982.52	19.9%
Communication	24.26	0.5%	40.64	0.8%
Education	46.26	0.9%	48.57	1.0%
Recreation	435.92	8.7%	473.03	9.6%
Other	251.81	5.0%	319.01	6.5%
Total	4986.69	100.0%	4941.49	100.0%

Table 2: CO_2 Emission Score (kg-CO_2/current 10,000JPY)

	1995	2000
Eating at home	19.0	17.0
Eating out	17.5	17.2
Housing	2.2	2.3
Fuel, Light and Water	235.4	222.9
Furniture	23.9	24.2
Clothes	16.1	10.7
Medical Care	15.9	15.8
Public Transportation	29.1	33.1
Private Transportation	56.3	77.2
Communication	6.9	7.5
Education	9.4	10.9
Recreation	17.3	17.1
Other	10.5	15.1

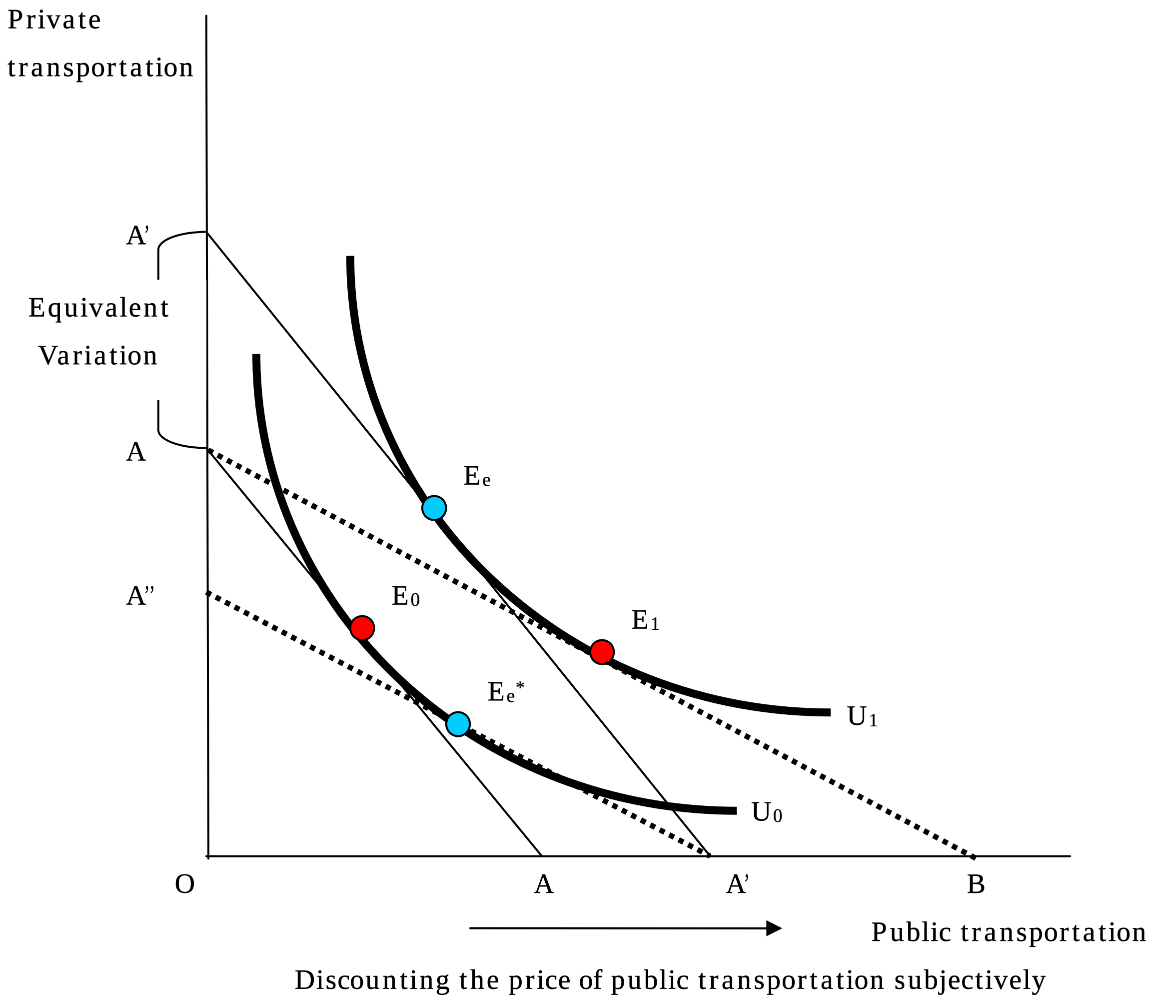

Figure 1: Concept of "Willingness to Pay"

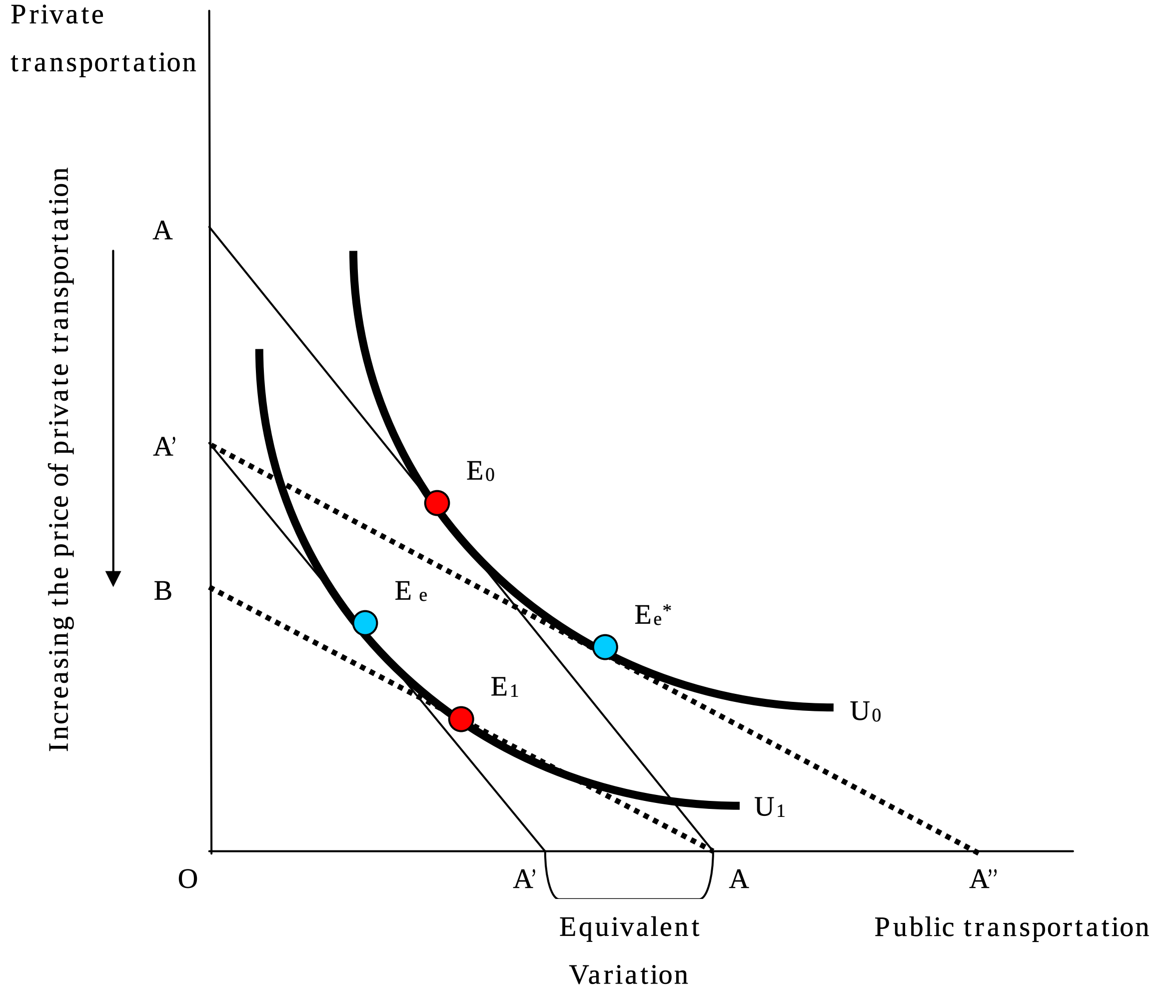

Figure 2: Concept of "Willingness to Pay (2)

Table 3: Estimation of Consumer's Demand Function (1)

Parameter	Estimate	t-statistics		Parameter	Estimate	t-statistics	
α_{1}	1.168	11.122	***	$\gamma_{1,1}$	-0.405	-6.782	***
α_{2}	0.943	14.374	***	$\gamma_{1,2}$	0.087	2.829	***
α_{3}	0.328	9.552	***	$\gamma_{1,3}$	0.005	0.353	
α_{4}	0.000	-0.007		$\gamma_{1,4}$	0.044	2.885	***
α_{5}	0.002	0.044		$\gamma_{1,5}$	-0.108	-7.673	***
α_{6}	-0.196	-3.032	***	$\gamma_{1,6}$	0.238	6.760	***
α_{7}	0.344	7.624	***	$\gamma_{1,7}$	-0.081	-5.908	***
α_{8}	-0.185	-2.236	**	$\gamma_{1,8}$	0.087	5.210	***
α_{9}	0.475	15.754	***	$\gamma_{1,9}$	-0.053	-3.315	***
α_{10}	-0.176	-3.838	***	$\gamma_{1,10}$	-0.073	-3.493	***
α_{11}	-0.158	-2.575	**	$\gamma_{1,11}$	0.274	9.286	***
α_{12}	-1.545			$\gamma_{1,12}$	-0.015		
β_{1}	-0.065	-9.369	***	$\gamma_{2,2}$	0.049	2.791	***
β_{2}	-0.057	-12.961	***	$\gamma_{2,3}$	-0.075	-10.964	***
β_{3}	-0.018	-7.659	***	$\gamma_{2,4}$	-0.061	-6.314	***
β_{4}	0.002	0.834		$\gamma_{2,5}$	0.023	2.940	***
β_{5}	0.004	1.458		$\gamma_{2,6}$	-0.136	-8.174	***
β_{6}	0.014	3.256	***	$\gamma_{2,7}$	0.082	9.661	***
β_{7}	-0.021	-6.901	***	$\gamma_{2,8}$	0.012	1.419	
β_{8}	0.018	3.167	***	$\gamma_{2,9}$	0.034	4.421	***
β_{9}	-0.030	-14.705	***	$\gamma_{2,10}$	0.080	7.619	***
β_{10}	0.014	4.514	***	$\gamma_{2,11}$	0.020	1.378	
β_{11}	0.018	4.407	***	$\gamma_{2,12}$	-0.113		
β_{12}	0.120			$\gamma_{3,3}$	0.026	4.637	***

Note） *** （**, *） denotes significance of the hypothesis at 1% （5%, 10%） significance level.

Table 4: Estimation of Consumer's Demand Function (2)

Parameter	Estimate	t-statistics		Parameter	Estimate	t-statistics		Parameter	Estimate	t-statistics	
$\gamma_{3,4}$	0.016	3.405	***	$\gamma_{5,11}$	0.052	5.425	***	$\gamma_{10,10}$	-0.045	-3.664	***
$\gamma_{3,5}$	0.006	1.223		$\gamma_{5,12}$	-0.026			$\gamma_{10,11}$	-0.027	-1.814	*
$\gamma_{3,6}$	-0.025	-1.700	*	$\gamma_{6,6}$	-0.063	-1.451		$\gamma_{10,12}$	0.107		
$\gamma_{3,7}$	-0.002	-0.295		$\gamma_{6,7}$	0.058	4.785	***	$\gamma_{11,11}$	-0.082	-3.415	***
$\gamma_{3,8}$	-0.017	-2.669	***	$\gamma_{6,8}$	0.055	3.379	***	$\gamma_{11,12}$	-0.064		
$\gamma_{3,9}$	0.041	6.601	***	$\gamma_{6,9}$	-0.053	-3.263	***	$\gamma_{12,12}$	-0.185		
$\gamma_{3,10}$	-0.009	-1.503		$\gamma_{6,10}$	-0.141	-6.465	***				
$\gamma_{3,11}$	-0.088	-9.172	***	$\gamma_{6,11}$	-0.132	-5.541	***				
$\gamma_{3,12}$	0.123			$\gamma_{6,12}$	0.159						
$\gamma_{4,4}$	-0.026	-3.395	***	$\gamma_{7,7}$	-0.108	-10.053	***				
$\gamma_{4,5}$	0.027	7.319	***	$\gamma_{7,8}$	0.063	10.894	***				
$\gamma_{4,6}$	-0.018	-1.690	*	$\gamma_{7,9}$	0.009	1.411					
$\gamma_{4,7}$	-0.032	-5.583	***	$\gamma_{7,10}$	-0.008	-1.107					
$\gamma_{4,8}$	-0.027	-4.517	***	$\gamma_{7,11}$	0.090	9.547	***				
$\gamma_{4,9}$	0.056	10.131	***	$\gamma_{7,12}$	-0.034						
$\gamma_{4,10}$	-0.022	-3.209	***	$\gamma_{8,8}$	-0.219	-17.719	***				
$\gamma_{4,11}$	-0.035	-3.593	***	$\gamma_{8,9}$	-0.048	-6.705	***				
$\gamma_{4,12}$	0.078			$\gamma_{8,10}$	0.067	7.463	***				
$\gamma_{5,5}$	-0.059	-10.210	***	$\gamma_{8,11}$	0.046	4.059	***				
$\gamma_{5,6}$	0.056	5.445	***	$\gamma_{8,12}$	-0.066						
$\gamma_{5,7}$	-0.037	-7.372	***	$\gamma_{9,9}$	-0.069	-5.470	***				
$\gamma_{5,8}$	0.045	8.967	***	$\gamma_{9,10}$	0.075	8.209	***				
$\gamma_{5,9}$	0.024	5.335	***	$\gamma_{9,11}$	-0.054	-4.558	***				
$\gamma_{5,10}$	-0.004	-0.610		$\gamma_{9,12}$	0.036						

Note） *** （**, *） denotes significance of the hypothesis at 1% （5%, 10%） significance level.

Table 5: Own Price Elasticity of Demand in 2000

Eating at home	-2.998
Eating out	-0.312
Fuel,Light and Water	-0.618
Furniture	-1.660
Clothes	-2.014
Medical Care	-2.651
Public Transportation	-5.462
Private Transportation	-4.302
Communication	-3.120
Education	-1.985
Recreation	-1.743
Other	-1.908

Table 6: Cross Price Elasticity of Demand in 2000

	Eating out	Public Transportation	Private Transportation	Recreation
Eating at home	1.276	-3.200	1.259	2.376
Eating out		3.462	0.163	0.160
Fuel,Light and Water	-0.927	-0.007	-0.275	-0.788
Furniture	-0.764	-1.291	-0.423	-0.312
Clothes	0.339	-1.485	0.666	0.449
Medical Care	-1.742	2.435	0.822	-1.162
Public Transportation	1.078		0.942	0.783
Private Transportation	0.208	2.683		0.397
Communication	0.467	0.417	-0.726	-0.479
Education	1.071	-0.303	0.998	-0.241
Recreation	0.338	3.821	0.666	
Other	-1.295	-1.194	-1.054	-0.599

Table 7: Changes of EV and CO_2 （Price of Public Transportation）

Discounting rate	EV (JPY)	ΔCO_2 (kg-CO_2)
5%	12,423	149
10%	27,743	299
15%	46,450	448
20%	69,149	598

Note） “EV” denotes equivalent variation.

Table 8: Changes of EV and CO_2 （Price of Private Transportation）.

Increasing rate	EV (JPY)	ΔCO_2 (kg-CO_2)
5%	-9,307	-408
10%	-17,717	-816
15%	-25,331	-1,223
20%	-32,238	-1,631

Note） “EV” denotes equivalent variation.

Table 9: Changes of EV and CO_2 （Price of Eating Out）

Discounting rate	EV (JPY)	Δ CO_2 (kg-CO_2)
5%	25,927	249
10%	52,470	499
15%	79,630	748
20%	107,403	998

Note） “EV” denotes equivalent variation.

Table 10: Changes of EV and CO_2 （Price of Recreation）.

Discounting rate	EV (JPY)	ΔCO_2 (kg-CO_2)
5%	18,373	-102
10%	38,623	-205
15%	61,031	-307
20%	85,938	-409

Note） “EV” denotes equivalent variation.

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（JPY/ kg-CO_2）

	Simulation 1		Simulation 2	
Changing rate	Public Transportation	Private Transportation	Eating Out	Recreation
0%	303.1			
5%	300.6	312.6	299.3	307.1
10%	298.3	322.7	295.6	311.3
15%	296.3	333.6	292.1	315.7
20%	294.6	345.5	288.8	320.4