THE NATIONAL ECONOMIC EVALUATION OF POLICES TO REGULATE EXTERNAL DISECONOMIES CAUSED BY AUTOMOBILES

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Abstract

Issues of external diseconomies caused by automobiles have been a worldwide great concern. The policies to regulate external diseconomies are expected to reduce automobile-related externalities. It is well known, however, that these policies generate the market economic disbenefit through the increase of automobile user's cost. Hence the paper proposes a socioeconomic model for evaluating regulation policies of automobile-related externalities, whose framework is based on the computable general equilibrium (CGE) model where interactions among automobile related industrial sectors, and the externalities are modeled. In the case study, some regulatory policies are evaluated with the CGE model calibrated to Japanese economy.

INTRODUCTION

Issues of external diseconomies caused by automobiles, such as noise, Green House Gas (GHG) emissions, local air pollution, accident and road congestion, have been a world-wide great concern. A lot of policy options to reduce the automobile transport activities have been proposed and actually applied. These policies are expected to decrease the volume of automobiles, and as a result, the reduction automobile-related externalities. It is well known, however, that these policies raise commodity prices through the increase of automobile user's cost. If the policy makes commodity prices away from the first best economy or results in huge deadweight loss (welfare loss), it may not be socially acceptable even if we take into account the benefit of automobile-related externalities reduction. In order to judge the feasibility of such policies, therefore, it is necessary to compare environmental improvement benefits, which consist of automobile-related externality reduction with market disbenefits representing the loss of welfare due to the commodity price increase.
This paper proposes a socioeconomic model for evaluating regulatory policies of automobile-related externalities in framework of cost benefit analysis. The framework of the model is the computable general equilibrium (CGE) model where interactions among automobile related industrial sectors, and the externalities including noise, GHG emission, air pollution and accident are modeled. The remaining industrial sectors which reflect/affect the price change due to the policies. This structure of the model enables us to analyze the impact of the policies not only from the theoretical point but also from the practical one. In the case study, four regulatory policies, the motor vehicle fuel taxation, the motor vehicle tonnage taxation, the public transportation improvement policy and the diffusion policy of clean energy vehicle, are evaluated with the CGE model calibrated to Japanese economy. We compare the effectiveness among them.

BRIEF OVERVIEW OF ENVIRONMENTAL POLICY ANALYSIS WITH CGE MODEL

CGE modeling approaches have been developed, for the purpose of evaluating economic effects arising from taxation or international trade policy, which are surveyed by Shoven and Whalley (1984). Recently, the CGE models for evaluating general equilibrium effects of environmental policy, have been developed by Jorgenson and Wilcoxen (1990), Bergman (1991), Ballard and Medema (1993), Mayeres and Proost (1995) and Verhoef(1996). In particular, Bergman (1991) discussed impacts on factor prices and resource allocation of reductions of SO_x, NO_x and CO_2 emissions with the CGE model, into which the markets for emission permits and technologies for emission control are introduced. Mayeres and Proost (1995) studied optimal taxation and marginal tax reforms in the context of transport externalities, but this paper was not described on transport behavior in detail. In Japan, Miyata (1995) discusses the waste-economic system with a CGE model, into which industrial waste self-treatment activities are introduced.
In this paper, we try to construct a CGE model especially focusing on the automobile-related sectors. The model implies not only commodity production/consumption modeled in a standard CGE but also transport behavior such as mode choice, car ownership and so on.

THE CGE MODEL

Assumptions

We first have the following major assumptions.
(a) An economy consists of industries, in which transportation sectors are included, labeled

by $j \in J$, a representative household and a central government, as illustrated in Figure 1.

(b) Each industry provides commodities/services by inputting factors that consist of labor, automobile capital and other capital supplied by the household, and intermediate goods. The automobile capital is utilized only for transportation activities.

(c) The household gains income by supplying factors, and consumes commodities/services provided by industries under the budget constraint.

(d) All of passenger transportation services inputted to production of commodity/service are supplied by the sector of passenger transportation. But private automobile trips consumed by the household are supplied by her own.

(e) Markets are considered on each commodity, labor, automobile capital and other capital. They are assumed to be perfectly competitive.

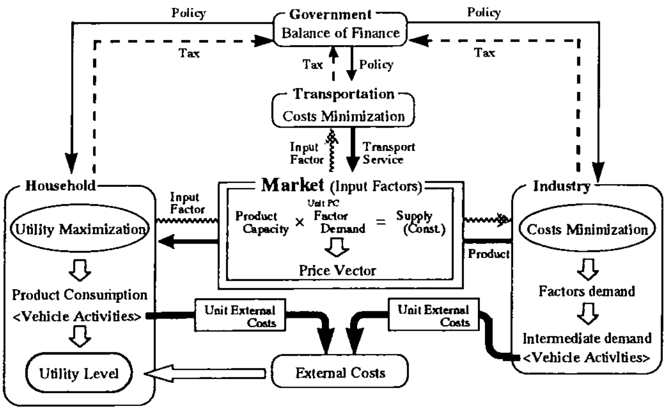

Figure 1 – Framework of the CGE model

Industries' behavior

Industries produce commodities/ services, by inputting factors and intermediate goods. Its behavior model is built by the nested structure (in figure 2), that is, at first, industries determine on quantities of the composite input factor and each intermediate goods, at second, they decide on input quantities of each factor. The industry that inputs automobile capital is only transportation sector. So, at below level, transportation sector decides on the share of automobile capital for type of fuel.

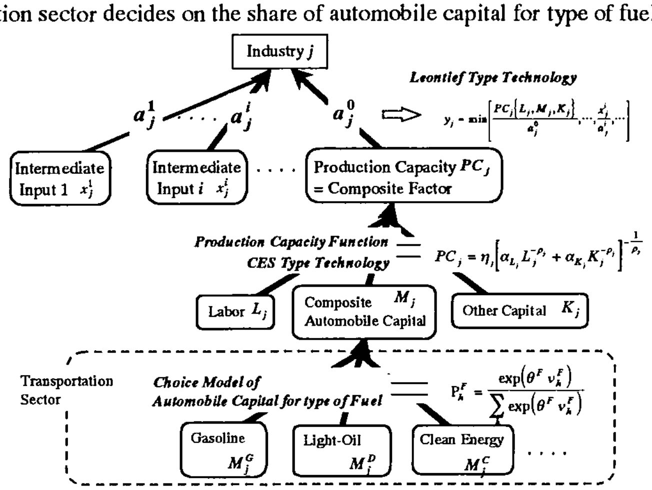

Figure 2 – Nested structure of industries' behavior

First step: behavior of producing commodities/ services

At first step, industries determine on quantities of the composite input factor and intermediate goods. This behavior model is formulated as minimization of production costs under Leontief type technology constraint.

$$C_j = \min_{PC_j, x_j^i} \; c_j\left(p_{L_j}{}^+, p_{M_j}{}^+, p_{K_j}{}^+\right) PC_j + \sum_i p_i x_j^i \tag{1.a}$$

$$\text{s.t.} \quad y_j = \min\left(\frac{PC_j\{L_j, M_j, K_j\}}{a_j^0}, \ldots \frac{x_j^i}{a_j^i}, \ldots \right) \tag{1.b}$$

Where, PC_j : production capacity (composite input factor), x_j^i : intermediate input from industry i to industry j, y_j : output volume, L_j, M_j, K_j : labor, automobile capital and other capital input volume, respectively, c_j : unit cost of composite input factor, $p_{L_j}, p_{M_j}, p_{K_j}$: labor wage automobile capital rent and other capital rent, respectively, +: superscript for factor price including tax, p_i : the price of commodity i, a_j^0 : production capacity rate [production capacity for product the unit output], $a_j^i\ (i \neq 0)$: input coefficient in Leontief Matrix and C_j : product cost.

Solving the programming in (1), we obtain production capacity PC_j and intermediate input goods x_j^i, respectively.

$$PC_j = a_j^0 y_j, \quad x_j^i = a_j^i y_j \tag{2}$$

Substitution of the (2) into the (1) gives the product cost C_j in industry j

$$C_j = \left[a_j^0 c_j\left(p_{L_j}{}^+, p_{M_j}{}^+, p_{K_j}{}^+\right) + \sum_i a_j^i p_i \right] y_j \tag{3}$$

Second step: behavior of inputting factors

At second step, industries decide on quantities of the each input factor. This behavior is formulated as minimization of the cost for input factors.

$$c_j = \min_{L_j, M_j, K_j} \; p_{L_j}{}^+ L_j + p_{M_j}{}^+ M_j + p_{K_j}{}^+ K_j \tag{4.a}$$

$$\text{s.t.} \quad PC_j = \eta_j \left[\alpha_{L_j} L_j^{-\rho_j} + \alpha_{M_j} M_j^{-\rho_j} + \alpha_{K_j} K_j^{-\rho_j} \right]^{-\frac{1}{\rho_j}} = 1 \tag{4.b}$$

Where, $\eta_j, \alpha_{L_j}, \alpha_{M_j}, \alpha_{K_j}$: parameters and ρ_j : $= (1 - \sigma_j)/\sigma_j$ (σ_j : elasticity of substitution among input factors).

The Solution of cost minimization programming the input factor in (4) yields to the each input factor demand function $D_{L_j}, D_{M_j}, D_{K_j}$ under condition for unit PC_j.

Labor demand: $$D_{L_j} = \frac{1}{\eta_j} \left[\alpha_{L_j} + \alpha_{M_j} \left(\frac{\alpha_{j_k} \cdot p_{M_j}{}^+}{\alpha_{M_j} \cdot p_{L_j}{}^+} \right)^{\frac{\rho_j}{1+\rho_j}} + \alpha_{K_j} \left(\frac{\alpha_{L_j} \cdot p_{K_j}{}^+}{\alpha_{K_j} \cdot p_{L_j}{}^+} \right)^{\frac{\rho_j}{1+\rho_j}} \right]^{\frac{1}{\rho_j}} \tag{5.a}$$

Automobile capital demand: $$D_{M_j} = \frac{1}{\eta_j} \left[\alpha_{L_j} \left(\frac{\alpha_{M_j} \cdot p_{L_j}{}^+}{\alpha_{L_j} \cdot p_{M_j}{}^+} \right)^{\frac{\rho_j}{1+\rho_j}} + \alpha_{M_j} + \alpha_{K_j} \left(\frac{\alpha_{M_j} \cdot p_{L_j}{}^+}{\alpha_{K_j} \cdot p_{L_j}{}^+} \right)^{\frac{\rho_j}{1+\rho_j}} \right]^{\frac{1}{\rho_j}} \tag{5.b}$$

Other capital demand: $$D_{K_j} = \frac{1}{\eta_j}\left[\alpha_{L_j}\left(\frac{\alpha_{K_j}\cdot p_{L_j}{}^{+}}{\alpha_{L_j}\cdot p_{K_j}{}^{+}}\right)^{\frac{\rho_j}{1+\rho_j}} + \alpha_{M_j}\left(\frac{\alpha_{K_j}\cdot p_{L_j}{}^{+}}{\alpha_{M_j}\cdot p_{L_j}{}^{+}}\right)^{\frac{\rho_j}{1+\rho_j}} + \alpha_{K_j}\right]^{\frac{1}{\rho_j}} \tag{5.c}$$

Substituting (5) into the (4), we obtain the unit cost of composite input factor c_j.

Third step: behavior of choosing the automobile capital for type of fuel (for transportation sector)

At third step, transportation sectors decide on the share of automobile capital for type of fuel. This behavior is formulated as well as Miyagi(1986) :

$$S^F = \max_{P_h^F}\left[\sum_h P_h^F\left\{-p_M^h\right\} - \frac{1}{\theta^F}\sum_h P_h^F \ln P_h^F\right] \tag{6.a}$$

$$\text{s.t.} \quad \sum_h P_h^F = 1 \tag{6.b}$$

Where, h: label for fuel type of automobile capital, P_h^F : the share of choosing automobile capital of fuel h, p_M^h: automobile capital rent of fuel h, θ^F: logit parameter and S^F : inclusive expected utility.

The programming in (6) yields to the share function expressed by the logit model.

$$P_h^F = \frac{\exp\theta^F\left\{-p_M^h\right\}}{\sum_h \exp\theta^F\left\{-p_M^h\right\}} \tag{7}$$

We can have the inclusive expected utility as

$$S^F = \frac{1}{\theta^F}\ln\sum_h \exp\theta^F\left\{-p_M^h\right\} \tag{8}$$

The above programming also yields to the automobile capital price p_M,

$$p_M = \sum_h p_M^h \exp\theta^F\left\{-p_M^h - S^F\right\} \tag{9}$$

Price vector of products

The price $[p_j]$ of produced commodity of industry j is led through the condition of the profit maximization in industry j. The profit maximization behavior is formulated below, because the product cost of industry j, $[C_j]$ is obtained in (3), and the unit cost of composite input factor c_j is yielded from the programming (4).

$$\Pi_j = \max_{y_j} \; p_j y_j - C_j \tag{10.a}$$

$$\text{s.t.} \quad C_j = \left[a_j^0\left\{p_{L_j}{}^{+}D_{L_j} + p_{M_j}{}^{+}D_{M_j} + p_{K_j}{}^{+}D_{K_j}\right\}\left(1+\omega_{O_j}\right) + \sum_i a_j^i p_i\right] y_j \tag{10.b}$$

Where, ω_{O_j} : tax rate of net indirect tax imposed on commodity of industry j.

The first order condition of the programming (10) gives the price p_j,

$$p_j = a_j^0\left\{p_{L_j}{}^{+}D_{L_j} + p_{M_j}{}^{+}D_{M_j} + p_{K_j}{}^{+}D_{K_j}\right\}\left(1+\omega_{O_j}\right) + \sum_i a_j^i p_i \tag{11}$$

Substituting (11) into the (10), it can be seen that the profit for each industry is zero.
By transforming the right side of equation (11), we obtain a price vector of products,

$$\begin{bmatrix} p_1 \\ \vdots \\ p_j \\ \vdots \\ p_J \end{bmatrix}' = \begin{bmatrix} a_1^0\{p_{L_1}{}^{+}D_{L_1} + p_{M_1}{}^{+}D_{M_1} + p_{K_1}{}^{+}D_{K_1}\}(1+\omega_{O_1}) \\ \vdots \\ a_j^0\{p_{L_j}{}^{+}D_{L_j} + p_{M_j}{}^{+}D_{M_j} + p_{K_j}{}^{+}D_{K_j}\}(1+\omega_{O_j}) \\ \vdots \\ a_J^0\{p_{L_J}{}^{+}D_{L_J} + p_{M_J}{}^{+}D_{M_J} + p_{K_J}{}^{+}D_{K_J}\}(1+\omega_{O_J}) \end{bmatrix}' [\mathbf{I}-\mathbf{A}]^{-1} \quad (12)$$

Where, $\mathbf{I}$: unit matrix, $\mathbf{A}$: input coefficient matrix and ': transposed matrix.

Household behavior

Outline of household's behavior

We suppose that the household maximizes its utility under the myopic expectation. Hence the consuming behavior of the household should be illustrated in a nested structure, as shown in figure 3. Note that, in figure 3, we formulated this model by focusing its consumption of passenger trip service, in order to evaluate the regulation of external diseconomies caused by automobile.

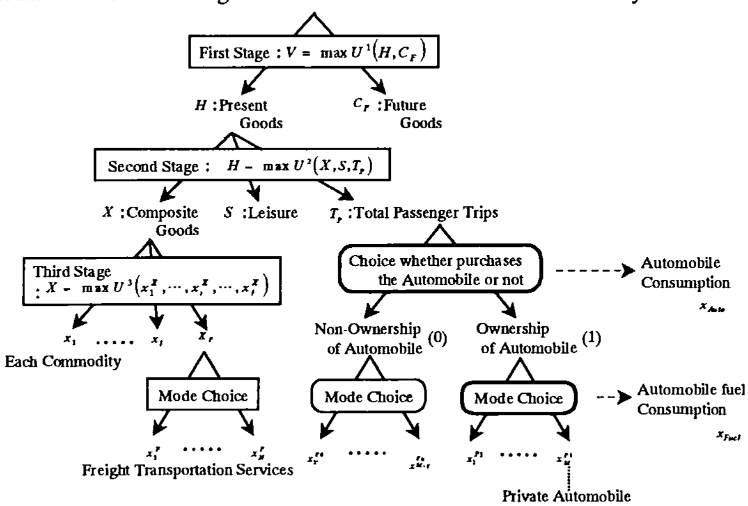

Figure 3 – Outline of household's consuming behavior

At first stage, the household determines consumption levels of present goods and future goods, and, at second stage, determines consumption levels of composite goods, leisure time and total passenger trips, and, at third stage, determines consumption levels of each commodity and total freight transportation services. The choice model whether the household purchases the automobile or not is formulated at later stages. The mode choice model is formulated the stage next to it.

Formulation of consumption behavior

In this section, the consumption behaviors of the household illustrated in figure 3 are formulated, stage by stage.

At the first stage, the household determines consumption levels of present goods and future goods. Suppose that the household behaves so as to maximize its utility that is specified as CES (constant elasticity of substitution) type, under its budget constraint [I_D: full income]. The environmental utility is introduced into this model as being proportionate to environmental quality r. Its behavior is formulated by

$$V = \max_{H,C_F} \left[U^1 = \left\{ \beta_H^{\frac{1}{\sigma_1}} H^{v_1} + (1-\beta_H)^{\frac{1}{\sigma_1}} C_F^{v_1} \right\}^{\frac{1}{v_1}} + \mu \cdot r \right] \tag{13.a}$$

$$\text{s.t. } p_H H + p_F C_F = p_L \Omega + \sum_h p_M^h \overline{M^h} + p_K \overline{K} (\equiv I_D) \tag{13.b}$$

Where, H , C_F : consumption level of present goods and future goods, respectively, p_H, p_F : price of present consumption and future consumption, respectively, Ω : endowment of time, $\overline{M^h}, \overline{K}$: endowment of capital, β_H , μ : parameters and $v_1 = (\sigma_1 - 1)/\sigma_1$ (σ_1 : elasticity of substitution).

And endowment of time Ω is defined as

$$\Omega = L_S + S + \sum_m t_m x_m^P \tag{14}$$

Where, L_S : labor supply, S : leisure time, t_m : time required for using mode m and x_m^P : consumption level of passenger trips of mode m .

The solution of the programming in (13) gives demands for H and C_F , respectively.

$$H = \frac{\beta_H I_D}{p_H^{\sigma_1} A_1}, \quad C_F = \frac{(1-\beta_H) I_D}{p_F^{\sigma_1} A_1} \tag{15}$$

Where, $A_1 = \beta_H p_H^{(1-\sigma_1)} + (1-\beta_H) p_F^{(1-\sigma_1)}$.

Substituting (15) into the (13), we obtain the indirect utility V ,

$$V(p_H, p_F, I_D, r) = I_D (A_1)^{\frac{1}{\sigma_1 - 1}} + \mu \cdot r \tag{16}$$

The relation of C_F with savings: S_I is described as below. If we consider household's return of saving as the budget to purchase future goods under the condition that the price of future goods is same level as the present goods, equation (17) is to be constructed.

$$p_c \varphi_c \cdot S = p_X C_F \tag{17}$$

Where, c : a label of capital, p_c : the rent of capital c , φ_c : ratio of capital flow and capital stock.

In (17), we suppose that the budget for future goods is expressed as the savings multiplied by capital return $p_c \varphi_c$. Hence equation (17) leads to the relation of S_I with as C_F :

$$p_{SI} S_I = \left(\frac{p_{SI}}{p_c \varphi_c} p_X \right) C_F \equiv p_F C_F \tag{18}$$

Substituting the optimum C_F into (18), we obtain S_I

$$S_I = \frac{(1-\beta_H) I_D}{p_{SI} p_F^{\sigma_1 - 1} A_1} \tag{19}$$

At the second stage, the household determines consumption levels of composite goods, leisure time and total passenger trips. Suppose that the household behaves so as to maximize its sub-utility that is specified as CES type, under its budget constraint [$I_D - p_{SI} S_I (\equiv I_D^2)$: net income at second stage]. The behavior is formulated as

$$\max_{X,S,T_P} \left[U^2 = \left\{ \gamma_X^{\frac{1}{\sigma_2}} X^{v_2} + \gamma_S^{\frac{1}{\sigma_2}} S^{v_2} + \gamma_P^{\frac{1}{\sigma_2}} T_P^{v_2} \right\}^{\frac{1}{v_2}} \right] \tag{20.a}$$

$$\text{s.t. } p_X X + p_L S + p_P T_P = I_D^2 \tag{20.b}$$

Where, X , S , T_P : consumption level of composite commodity, leisure time and total passenger trip, respectively, p_X, p_P: the price of composite goods, and total passenger trips, respectively, p_L : labor wage (the price of leisure time), γ_X , γ_S , γ_P : share parameters and $v_2 = (\sigma_2 - 1)/\sigma_2$ (σ_2 : elasticity of substitution).

Note that the price of leisure equals to labor wage as an opportunity cost.

The solution of the programming in (20) yields to demands for X , S and T_P , respectively.

$$X = \frac{\gamma_X I_D^2}{p_X^{\sigma_2} \Delta_2}, \quad S = \frac{\gamma_S I_D^2}{p_L^{\sigma_2} \Delta_2}, \quad T_P = \frac{\gamma_P I_D^2}{p_P^{\sigma_2} \Delta_2} \tag{21}$$

Where, $\Delta_2 = \gamma_X p_X^{(1-\sigma_2)} + \gamma_S p_L^{(1-\sigma_2)} + \gamma_P p_P^{(1-\sigma_2)}$.

We also obtain the marginal utility of present consumption as the lagrangian multiplier accompanied with the solution, or the shadow price of present goods.

$$p_H = [\Delta_2]^{\frac{1}{1-\sigma_2}} \tag{22}$$

At the third stage, the household determines the consumption level of each commodity and total freight transport service. Suppose that the household behaves to maximize the sub-utility that is specified as Cobb-Douglas type, under its budget constraint [$I_D^2 - p_L S - p_P T_P (\equiv I_D^3)$: net income at third stage]. The behavior is formulated as,

$$\max_{x_j, X_F} \left[U_3 = \prod_j x_j^{\lambda_j} \cdot T_F^{\lambda_F} \right] \tag{23.a}$$

$$\text{s.t.} \quad \sum_j p_{x_j} x_j + p_F X_F = I_D^3 \tag{23.b}$$

Where, x_j : consumption level of each commodity j, X_F : total freight transport services, p_j , p_F : the price of commodity j and total freight transport service, respectively and λ_j, λ_F : parameters.

The programming in (23) yields to x_j and X_F , in the same manner.

$$x_j = \frac{\lambda_j}{p_{x_j}} I_D^3, \quad X_F = \frac{\lambda_F}{p_F} I_D^3 \tag{24}$$

And we obtain the marginal utility of the price of composite commodity, as well as second stage.

$$p_X = \prod_j \left(\frac{p_{x_j}}{\lambda_j} \right)^{\lambda_j} \cdot \left(\frac{p_F}{\lambda_F} \right)^{\lambda_F} \tag{25}$$

Next, the modal choice in freight transport services is considered. Suppose that the household behaves by maximizing its utility $U^F(x_1, \cdots, x_n, \cdots)$, which is specified as CES type, under its budget constraint [$I_D^3 - \sum_j p_j x_j \; (\equiv I_D^F)$: net income at the stage of mode choice on freight transport services] as well as First and Second Stage. Its behavior is formulated as

$$\max_{x_n^F} \; U^F = \left[\sum_n (\chi_n)^{\frac{1}{\sigma_F}} x_n^{F\, v_F} \right]^{\frac{1}{v_F}} \tag{26.a}$$

$$\text{s.t.} \quad \sum_n p_n^F x_n^F = I_D^F \tag{26.b}$$

Where, n : mode of freight transportation, x_n^F : freight transportation service level of mode n and

p_n^F : the price for freight transportation service of mode n.

Solving the programming in (26), we obtain the demand function for the freight transportation service of mode n.

$$x_n^F = \frac{\chi_n I_D^F}{\left(p_n^F\right)^{\sigma_\Phi} \Delta_F} \tag{27}$$

Where, $\Delta_F = \sum_n \chi_n \left(p_n^F\right)^{1-\sigma_\Phi}$

We have the price of total freight transport service in the same manner as often used in the paper.

$$p_n^F = \left[\Delta_F\right]^{\frac{1}{1-\sigma_\Phi}} \tag{28}$$

Formulation of the mode choice behavior on transportation services

We try to introduce the mode choice model for the total passenger trips $\left[T_P\right]$.

The mode choice behavior in passenger transportation is formulated as the nested logit model consisting of two steps, illustrated in figure 3. But, in this section, these conditional decisions are formulated in the reverse direction (from the step of mode choice behavior to that of automobile purchasing behavior), in order to efficiently formulated the condition at each step.

First, the household determines the mode share on passenger trips. Here, we consider the case of automobile owner [1]. Its behavior is formulated as well as choice model of automobile capital of each type of fuel, formulated at section of industries' behavior.

$$S^{M1} = \max_{P_m^{M1}} \left[\sum_m P_m^{M1} u_m^{M1} - \frac{1}{\theta^{M1}} \sum_m P_m^{M1} \ln P_m^{M1} \right] \tag{29.a}$$

$$\text{s.t.} \quad \sum_m P_m^{M1} = 1 \tag{29.b}$$

Where, m: mode of passenger transportation (private automobile: $Auto$), P_m^{M1}: probability of choosing the mode m, u_m^M : utility of choosing the mode m and θ^M : logit parameter.

From the Assumption, private automobile trips consumed by household are produced by her own. Additionally, we assume that automobile, its fuel and time element are consumed for trips. Hence utility of choosing the private automobile is formulated as

$$u_{Auto}^{M1} = -\left(\tau p_{Fuel} + t_{Auto} p_L\right) \tag{30}$$

Where, τ : automobile fuel consumption for unit private automobile trip, p_{Fuel}: price of automobile fuel and t_{Auto} : time required by using private automobile.

And utility of choosing other modes are specified as

$$u_m^{M1} = -\left(p_m + t_m p_L\right) \tag{31}$$

Where, p_m: price of passenger trip of mode m and t_m : time required for using mode m.

The programming in (29) yields to the probability functions again expressed by the logit model,

$$P_m^{M1} = \frac{\exp\left(\theta^{M1} u_m^{M1}\right)}{\sum_m \exp\left(\theta^{M1} u_m^{M1}\right)} \tag{32}$$

We can have the inclusive expected utility as

$$S^{M1} = \frac{1}{\theta^{M1}} \ln \sum_m \exp\left(\theta^{M1} u_m^{M1}\right) \tag{33}$$

The above programming also yields to the price of passenger trip of mode m faced by automobile owner.

$$p_P^1 = \sum_m p_m \cdot \exp\left(\theta^{M1} u_m^{M1} - S^{M1}\right) \qquad (34)$$

In the case of non-automobile owner [0], its behavior is formulated in the same way. The programming corresponding to (29) gives modal share P_m^{M0}, inclusive expected utility S^{M0} and price of passenger trip of mode m faced by non-automobile owner p_P^0.

Next, the household who does not own the automobile decides whether she purchases the automobile or not. That behavior is formulated as well as the previous step.

$$S^A = \max_{P_o^A} \left[\sum_o P_o^A u_o^A - \frac{1}{\theta^A} \sum_o P_o^A \ln P_o^A \right] \qquad (35.a)$$

$$\text{s.t.} \quad \sum_o P_o^A = 1 \qquad (35.b)$$

Where, o: (=1) to purchase the automobile, (=0) other wise, P_o^A: probability of the purchasing the automobile or not, u_o^A: utility of purchasing the automobile or not purchasing, θ^A: logit parameter and S^A: inclusive expected utility.
The utility of purchasing the automobile and not purchasing are formulated as, respectively,

$$u_1^A = S^{M1} - \frac{x_{Auto} p_{Auto}}{x_{Auto}^P}, \quad u_0^A = S^{M0} \qquad (36)$$

Where, x_{Auto}: consumption of private automobile, p_{Auto}: price of private automobile and x_{Auto}^P: passenger trips of private automobile.
The programming in (35) yields to the probability function expressed by the logit model.

$$P_o^A = \frac{\exp\left(\theta^A u_o^A\right)}{\sum_o \exp\left(\theta^A u_o^A\right)} \qquad o = 0 \ or \ 1 \qquad (37)$$

It also leads to the inclusive expected utility.

$$S^A = \frac{1}{\theta^A} \ln \sum_o \exp\left(\theta^A u_o^A\right) \qquad (38)$$

The above programming also gives the representative price of passenger transportation service.

$$p_P = \sum_o p_P^o \cdot \exp\left(\theta^A u_o^A - S^A\right) \qquad (39)$$

From the probability of purchasing the automobile in (37), we obtain consumption of private automobile

$$x_{Auto} = \left[\overline{x_{Auto}} - (1-\delta) x_{Auto}^{t-1}\right] \cdot P_1^A \qquad (40)$$

Where, $\overline{x_{Auto}}$: total consumption level of private automobile under assumption that all of household are own the automobile, x_{Auto}^{t-1}: consumption level of private automobile at $t-1$ period and δ: depreciation rate of automobile.
And the consumption level of private automobile in (37) leads to the ownership probability function of automobile P_1^H

$$P_1^H = \frac{x_{Auto} + (1-\delta) x_{Auto}^{t-1}}{\overline{x_{Auto}}} \qquad (41)$$

Equilibrium conditions

In this model, equilibrium conditions are formalized as

Commodity j: $y_j = \sum_i x_i^j(q) + F_j(q) + \overline{E_j} - \overline{m_j}\left[\sum_i x_i^j(q) + F_j(q)\right] \qquad (42)$

Labor: $L_S(q) = \sum_j a_j^0 y_j D_{L_j}$ (43.a)

Automobile capital of fuel type h: $\overline{M^h} = \sum_j a_j^0 y_j P_h^F D_{M_j}$ (43.b)

Other capital: $\overline{K} = \sum_j a_j^0 y_j D_{K_j}$ (43.c)

Fiscal balance: $T^+ = T$ (44)

Where, q : price vector, F_j : domestic final demand of commodity j, $\overline{E_j}$: export volume of commodity j, $\overline{m_j}$: import coefficient of commodity j, T^+ : announced total tax revenue and T : total tax revenue.

Domestic final demand F_j includes consumption demand of household and government, and investment demand. As for the consumption demand of household, we are able to obtain it as the demand functions of commodity/service as already solved in section of household behavior model. The consumption of government is given as constant. The investment demand is given by the solution of savings of household. And, In (42), the import volume is introduced as being proportionate to the domestic total demand. Solving (42), we can get y_j

$$\mathbf{y} = \left[\mathbf{I} - \left(\mathbf{I} - \overline{\mathbf{M}}\right)\mathbf{A}\right]^{-1}\left[\left(\mathbf{I} - \overline{\mathbf{M}}\right)\mathbf{F} + \mathbf{E}\right] \tag{45}$$

Where, $\mathbf{y}$: domestic output vector, $\mathbf{F}$: domestic final demand vector, $\mathbf{E}$: export volume vector and $\overline{\mathbf{M}}$: import coefficient matrix.

The LHS (43) indicates the total demand for the input factor, because $a_j^0 y_j$ is the production capacity, and D_{c_j} is the factor demand for a unit production capacity, already solved in (5).

On the other hand, the supplies of input factors are considered as follow. The labor supply is obtained through the difference between the endowment of time and the time consumed for leisure and total passenger transport. The supplies of automobile capital and other capital are constant.

BENEFITS DEFINITION OF POLICIES

In this paper, the benefit of policies is defined by the equivalent variation (EV). EV can be formulated as follow, because the function form of indirect utility has been obtained in equation (16).

$$EV = \underbrace{\frac{I_D{}^B\left(\Delta_1{}^B\right)^{\frac{1}{\sigma-1}} - I_D{}^A\left(\Delta_1{}^A\right)^{\frac{1}{\sigma-1}}}{\left(\Delta_1{}^A\right)^{\frac{1}{\sigma-1}}}}_{[1]} + \underbrace{\frac{\mu\cdot\left(r^B - r^A\right)}{\left(\Delta_1{}^A\right)^{\frac{1}{\sigma-1}}}}_{[2]} \tag{46}$$

Where, A, B : expressing with policy and without policy, respectively.

The term [1] in equation (46) expresses the market disbenefit, and the term [2] expresses the environmental improvement benefit.

In this paper, the environmental improvement benefit is measured by the difference in the external costs, including noise, GHG emission, air pollution and accident, between with-policy and without-policy cases. As for the external costs, this study follows the result of Morisugi et al (1995), that is estimated multiplying the unit damage costs by the predicted value of road transport activities.

SIMULATION OF THE IMPACTS OF REGULATORY POLICIES

Parameter setting

Parameters included in production functions of industry and utility functions of household should be identified by calibration method, following Shoven and Whalley(1992). In this paper, the benchmark year is 1990, and these parameters are determined under the condition that they must reproduce this benchmark equilibrium data set.

Simulation of regulatory policies

The motor vehicle fuel taxation

At first,, we simulate the impacts of the motor vehicle fuel taxation, as one of regulations of external diseconomies. In this fuel taxation, the fuel tax rate for gasoline and light oil is raised on the principle that their after taxed prices should be equal. When the fuel tax was gradually raised, the road transport activities decreased through the modal split mechanism. Consequently, we obtained results that environmental improvement benefits increased with a constant rate, while the market economic disbenefits decreased successively. Hence we obtained the SNB curve which has the peak shown in Figure 4. This peak indicates the optimal fuel price level and it is determined at the level 98 (Yen/ℓ), where the gasoline tax rate should be lower (6.3%), while the light oil tax rate should be higher (14.7%).

The point, which the author especially emphasizes, is that the SNB has been positive. The fuel taxation is worth carrying out in the context of Japanese economy.

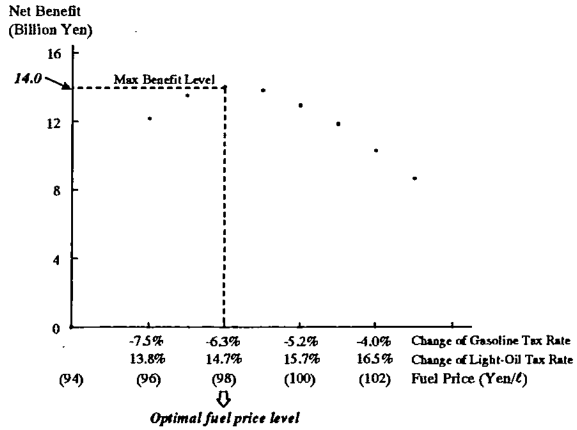

Figure 4 – Social net benefit in fuel taxation

Other regulatory policies

Next, the impacts of other regulatory policies are simulated, the motor vehicle tonnage taxation, the public transportation improvement policy and the clean energy vehicle diffusion policy. The scenario of each regulatory policy is set as follow.

Case1) *The motor vehicle fuel taxation*: In this case, the SNB is maximized, simulated at the previous section.

Case2) *The motor vehicle tonnage taxation*: The case that the tonnage tax rate is 10.3%, in which the environmental improvement benefit is equivalent to that of Case1.

Case3) *The public transportation improvement policy*: In this case, a generalized price of the public transportation is lower 5% than 1990.

Case4) *The diffusion policy of the clean energy vehicle*: In this case, we substitute the clean energy vehicles for 2% of the gasoline and diesel vehicles.

The comparison of each item of benefit in these cases is shown in figure 5.

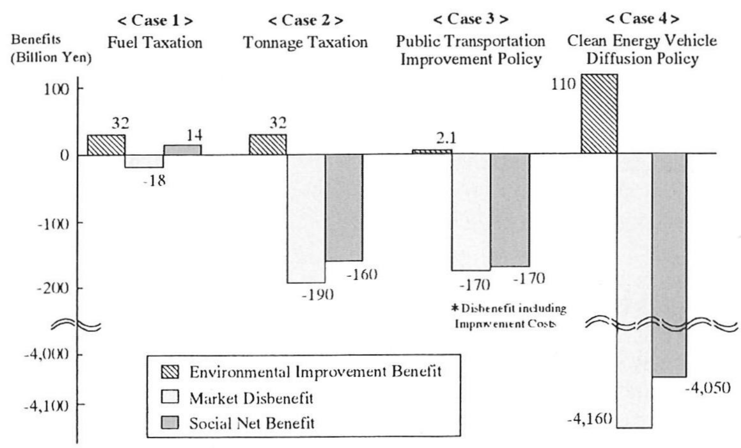

Figure 5 – Comparison of each item of benefit in four regulatory policies

In Case1 and 2 in figure 5, the market disbenefits are the value from which tax revenues from taxation are taken away. In Case3, the market disbenefit is the value from which the improvement costs of public transportation is excluded.

These simulation results are briefly summarized in what follows.

Case1) The fuel taxation can be considered as worth carrying out, because the SNB has been positive.

Case2) It may be said that the tonnage taxation is less effective than the fuel taxation. This result might be caused by the difference of price elasticity of demand between two taxation. The tonnage taxation has the structure that the average ownership cost for a unit automobile trip gets lower by making more and more trips, even if the total cost of a automobile ownership is higher. The structure shows that the price elasticity of automobile demand is less than that of automobile fuel demand. Hence it is anticipated that the tonnage taxation needs to be set at much higher level than that of the fuel taxation.

Case3) It is thought that this policy is little effective, because the shift from the private automobile to public transportation is not much elastic. Since total transport demands are endogenous in this model, an existence of the induced demand might be another reason for this result.

Case4) The efficiency of this policy is worst among the four policies in the case study. This is because the price of clean energy vehicle is quite higher than the price of gasoline or diesel vehicle at present. This policy generates the huge market disbenefit.

Needless to say, those results meaningful only in the simulation we have done. If we change the setting of parameters in the model or political scenarios, it is possible to get another result. However, through the simulations, we could say that the policies do not always bring the positive SNB, but might result in the negative SNB in the case of too much market economic disbenefits.

CONCLUSION

This paper has built a CGE model in order to evaluate the policies for reduction of external diseconomies caused by automobiles. We have measured not only environmental improvement benefits but also market economic disbenefits generated by policy implementation. Then we have tried simulations of four regulation policies, the motor vehicle fuel taxation, the motor vehicle tonnage taxation, the public transportation improvement policy and the clean energy vehicle diffusion policy. Although the implementations obtained from these simulation results have been already indicated for each policy at previous section, we could say only that the fuel taxation is most effective among four policies.

Finally, we remark that there remain some tasks.

(a) The model built in this paper is a static model. However when we have a scope for time horizon, policies may impact on the economy in different way from the simulations in this paper. The dynamic computable equilibrium model must be developed for this point.

(b) The mechanism of impacts of tax policies on a market economy is more complex in the real world, and there are cases, which can not be judged only through results the specified computable model gives. We attempt to analyze the impacts in the analysis within the more theoretical background and general model.

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REFERENCES

Ballard, C.L. and Medema, S.G. (1993): The marginal efficiency effects of taxes and subsidies in the presence of externalities, **Journal of Public Economics 52**, 199-216.

Bergman, L. (1991): General equilibrium effects of environmental policy: a CGE-modeling approach, **Environmental and Resource Economics 1**, 43-61.

Jorgenson, D.W. and Wilcoxen, P.J. (1990): Intertemporal general equilibrium modeling of U.S. environmental regulation, **Journal of Policy Modeling 12-4**, 715-744.

Mayeres, I and Proost, S. (1995): Optimal tax rules for congestion type of externalities, **Paper presented at the 7th WCTR**, Sydney, Australia.

Miyagi, T. (1986): On the formulation of a stochastic user equilibrium model consistent with the random utility theory: a conjugate dual approach, **Selected Proceeding of WCTR'86**, 1619-1635.

Miyata, Y. (1995): A general equilibrium analysis of the waste-economic system -a CGE modeling approach-, **Infrastructure Planning Review 12**, pp.259-270.

Morisugi, H., Koike, A. and Muto, S. (1995): Japan transport sector case study on social cost of automobiles, **Report of OECD**.

Shoven, J.B. and Whalley, J. (1984): Applied general equilibrium models of taxation and international trade: an introduction and survey, **Journal of Economic Literature 22**, 1007-51.

Shoven, J.B. and Whalley, J. (1992): **Applying general equilibrium**, Cambridge University Press, Cambridge.

Varian, H.R. (1993): **Intermediate microeconomics**, Norton & Company.

Verhoef, E.T. (1996): Economic efficiency in second-best regulation of road transport externalities, **Paper presented at the 36th ERSA**, ETH Zurich, Switzerland.