IMPACT ANALYSIS OF ENVIRONMENTAL TAX AND TECHNOLOGICAL IMPROVEMENT ON INTERCITY TRANSPORTATION IN JAPAN —BASED ON MONOPOLISTIC COMPETITION THEORY—

Aoto MIMURO: Research Fellow of the Japan Society for the Promotion of Science, JAPAN, Email for correspondence: amimu@urban.env.nagoya-u.ac.jp

Takaaki OKUDA: Executive chief researcher, Chubu Institute for Social and Economic Research, JAPAN

ABSTRACT

Shifting to a sustainable intercity transportation system, while maintaining balance between increased environmental costs and accelerating deregulation to improve economic efficiency, is a very important policy issue. The present study simulates the impact balance between environmental tax imposed on crude oil imports, which is a cost-up factor and fuel consumption improvement which is a cost-cut factor in Japan's intercity transportation sector in the tough deregulation market.

Keywords: intercity transportation, environmental tax, fuel efficient improvement,

1. INTRODUCTION

1.1 Background and objective

In the first half of 21st century, improving the economic efficiency in transport sector has been very important issue such as to be more comfortable and cheaper. However, improving the environmental efficiency such as reduction of CO_2-emission from transport sector has become more important issue since around 1990 in Japan.. Despite the current imbalance between economic and environmental efficiency (Fig-1),

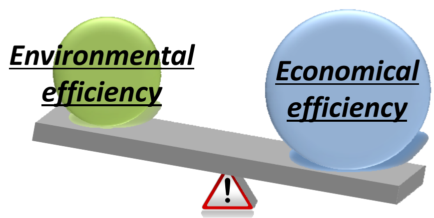

Figure 1 – Imbalance between environmental and economic efficiency

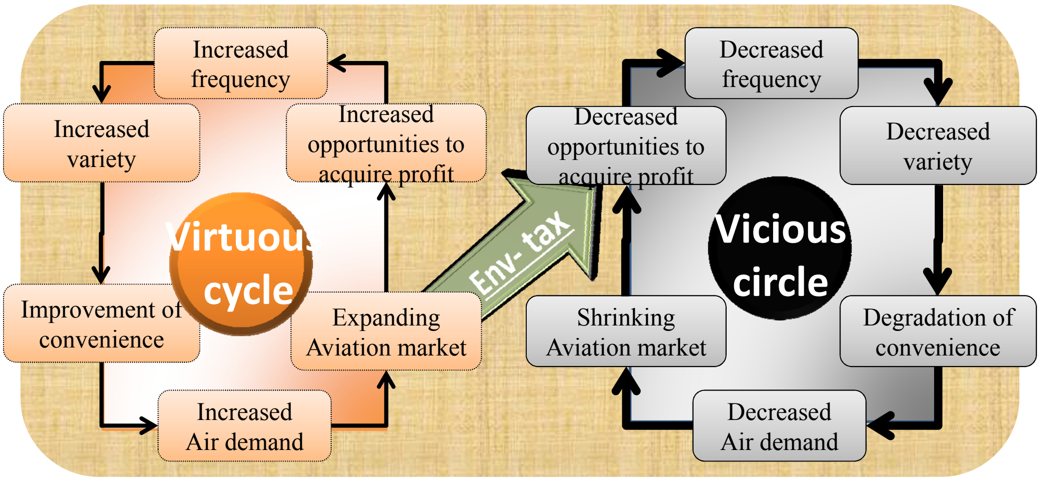

Figure 2 – Relationship of benefits and costs of the aviation industry

sustainability in intercity transport has become an increasingly important issue. In this study, "intercity transport" includes three transport modes such as aviation, High-speed rail and highway.

In this sector, many countries have introduced deregulation policies to improve economic efficiency. Especially in aviation market, deregulation accelerates competition between airlines, and level of service has been improved. Furthermore, improving the service level increases aviation demand because of the increase of flight frequency. However, in rural areas, deregulation has accelerated a decreasing demand and frequency because low aviation demand means low profits for airline. These situations cause a vicious circle, and studies are addressing the challenge of identifying methods to simulate these situations (Fig-2).

For the future, measures to reduce the environmental impact must be introduced to further reduce CO_2-emissions, and environmental tax is being considered as one such measure. However, environmental tax, which is a cost-up factor for airline operators, may cause operators to increase passenger fares to maintain their profitability. Introducing environmental taxes in the increasingly tough competitive market in the near future will decrease frequency even more rapidly.

To analyze the impact of the introduction of environmental tax under deregulation, we must develop a new model to express the mechanism of airlines' changing behavior in response to taxation and passengers' behavior in response to fares and frequencies. Furthermore, interaction between airlines and passengers are important in explaining the impact of taxation.

As an additional consideration, technological improvements such as lower fuel-consumption technologies have been developed for intercity transportation. In the aviation market, improved fuel consumption has become increasingly important in reducing CO_2-emissions. However, no quantitative analysis has yet studied both the impacts of environmental tax as a cost-up factor and technological improvements as cost-cut factors. The present study applies the monopolistic competition theory, originating in the field of economics, to express the above-described mechanism.

This study develops a new analytic model based on the monopolistic competition theory to describe the vicious circle triggered by introducing taxation into the aviation market and to quantitatively evaluate the impact of both environmental tax and technological improvement.

Here, the term "intercity transportation" specifically means long-distance trips using vehicles such as aircraft or high-speed rail for passenger transportation (Fig-3).

1.2 Structure of this paper

This paper consists of seven sections. The first section is the introduction, including the study's background and purpose. The second section reviews previous studies' evaluation approach and economic and environmental efficiency after reviewing European countries' environmental taxation systems. This section explains the study's perspective. The third section explains the monopolistic competition theory, developed in the field of economics since the 1980s, and describes the relationship between the aviation market mechanism and its theory before developing the simulation model. The fourth section explains the structures of the new simulation model, which improves the evaluation of the impact of environmental tax on the intercity transportation sector. The fifth section presents the model's calibration before starting the simulation. The sixth section discusses the results of the impact-analysis simulation. The final section concludes this study and suggests issues to be dealt with in future research.

2. LITERATURE REVIEW

2.1 Changes in the evaluation system from the perspective of economic efficiency evaluation

Many studies examine the inter-city transport market from the perspective of economic efficiency Okumura (2004, 2005) and Kaneko et al. (2006) attempted to organize the transition of research and challenges. Fig-3 is the flow of changing research topics in the aviation research, and shows the points of this study.

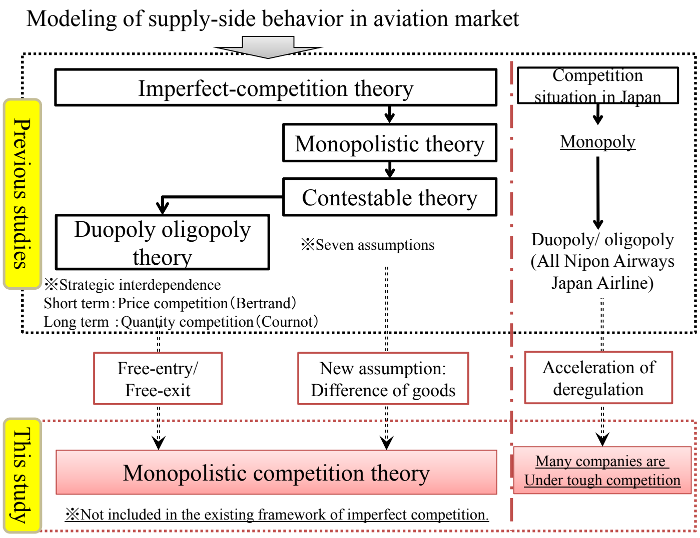

Figure 3 – Development of modeling approaches since 1960s

In the 1960s, growing problems of the natural monopolistic situation due to huge fixed-costs and decreasing aviation demand in each air Origin-Destination pairs were examined by studies. This mechanism is explained with the theory of monopolistic which is one of the theories of imperfect competition However, increasing aviation demands due to economic growth have revealed the inefficiency of monopolistic situations, and so studies started investigating methods for improving the aviation market system's efficiency. The new theory the contestable-market theory considering free-entry and exit mechanisms, has been used as a measurement for improving the market condition. This theory conveys that deregulation should be accelerated when all its seven hypotheses are satisfied. After arduous discussions in the USA, deregulation policies based on this theory were implemented, but they caused duopolistic and oligopolistic conditions because the real market could not satisfy all seven hypotheses simultaneously. In recent studies, the Cournot and Stacklelberg competition model has been improved.

2.2 Changes in the evaluation system from the perspective of environmental-efficiency evaluation

In the EU, many environmental policies have been implemented. Karen et al. (2007) simulated the impact of environmental taxation on aviation fuel and domestic and international traffic demands. Anger (2010) also simulated the impact of EU-ETS on the aviation market using the dynamic energy-environment-economy model. However, issues exist while considering environmental taxation's impact on the tough competition market because these models retain the supply-side behavior after taxation. Moreover, it is important to improve the supply-side model because market conditions will soon become exceedingly competitive.

2.3 Discussion points of modelling for future policy evaluation

The current trend of developing simulation models has focused on each aspect such as intercity transportation and economic efficiency or intercity transportation and environmental efficiency. In conditions where the market becomes more competitive, the modeling approach should include both economic and environmental efficiencies.
In particular, this study assumes the following two conditions: 1) market condition: more competitive and 2) environmental policies condition: introducing environmental tax. This study develops a new simulation model based on the monopolistic competition theory, as studied in the field of economics, to evaluate both these impacts. This model also simulates the impact of technological improvement to evaluate the balance between increasing tax rates and technological improvement rates. This study's modeling improvements enable us to determine the optimal balance between economic and environmental efficiencies in the aviation market.

3. THEORY OF MONOPOLISTIC COMPETITION

3.1 History, features and four prerequisites

The history of the monopolistic competition theory has accelerated after Krugman (1977) published "Increasing Returns, Monopolistic Competition, and International Trade" in the field of economics, especially in trade theory. Until the 1970s, analytic model has established assumptions such as perfect market competition and constant returns to scale, but Krugman found that these assumptions lead to imprecise simulation results because they neglect the differences between companies. To improve model structures, Krugman and Helpman introduce two assumptions, imperfect-competitive market and economies of scale, in the so-called new trade theory.

	Perfect competition	Monop-olistic	Contestable Market	Oligopoly duopoly	Monopolistic competition
①Number of companies	Many	one	Many	Few	Many
② Free entry and exit	Yes	Yes	Yes	No	Yes
③economies of scale	No	Yes	Yes	Yes・No	Yes
④Product differentiation	No	No	No	No	Yes
＋α : strategic-decision making	No	No	No	Yes	No

Figure 4 – Differences among theories of economics

Fig-4 shows differences among theories, classified into four categories: 1) Number of companies, 2) Free-entry and -exit, 3) Economies of scale (internal), and 4) Product differentiation. Each assumption is explained as follows:

Assumption 1) Number of companies

One of the benefits of assuming that there are many companies is the simplification of the model structure because it breaks the strategic interdependence assumption, which is set in the theory of oligopolistic and duopolistic competition. This assumption leads to a new assumption that one company produces only one product.

Assumption 2) Free-entry and free-exit

Free-entry and free-exit means that all companies are in the tough competitive market, and majority of the companies are always attempting a new entry to acquire profit. Companies are required to continually create differentiation production to avoid exiting the market, while considering prices. This assumption enables us to express the phenomenon that competition continues until the excess profits reach zero in the long term.

Assumption 3) Economies of scale (internal)

This assumption requires using a function that considers the fixed costs at the individual company level. Under the equilibrium condition in the long term, price and marginal cost will be equally affected by Assumption 2.

Assumption 4) Product differentiation

Each company will face a downward-sloping demand curve that is separate and distinct from the behavior of others. Companies will differentiate to reap the benefits, resulting in a higher income and pricing as high as possible. However, this process will result in a downward-sloping demand curve as the mid-size car market as a whole lost its demand and was not accepted by the consumer, thereby affecting extremely high priced companies. Here we found various companies that have experienced this phenomenon.

3.2 Relationship between the monopolistic competition theory and aviation market

This section explains the relationship between the theory of monopolistic competition and the market conditions in aviation sector (Fig-5).

Assumption 1) Many companies in aviation market

The assumption that one company produces only one product is interpreted as one airline operates only one flight between regions, thereby enabling us to consider that there are many companies in the aviation market. However, in real aviation market, there are low frequent network between locals. This situation is not fit for the assumption set by the theory. To overcome this difference, this study improves the model structure developed by Dixit–Stiglitz (1977) to simulate the case of lower-frequency in aviation market.

Assumption 2) Free-entry and free-exit

Entry into the aviation market means increasing frequencies between regions, and exit means decreasing frequencies.

Assumption 3) Economies of scale (internal)

Considering Assumption 1, one airline operates only one flight, the fixed cost comprises the aircraft and maintenance cost of operating a one-way flight. This assumption enables us to consider the issue of how to reduce the fixed cost, which is the key factor in increasing airlines' profit margin.

Assumption 4) Product differentiation

Producing a service different from other airlines to obtain more passengers incurs necessary additional cost. Airlines set slightly higher prices to recover cost but not excessively higher because if airlines set a very high price, they reduce their market share. In this study, the optimal balance between recovering cost and obtaining revenue is adjusted by mark-up factors.

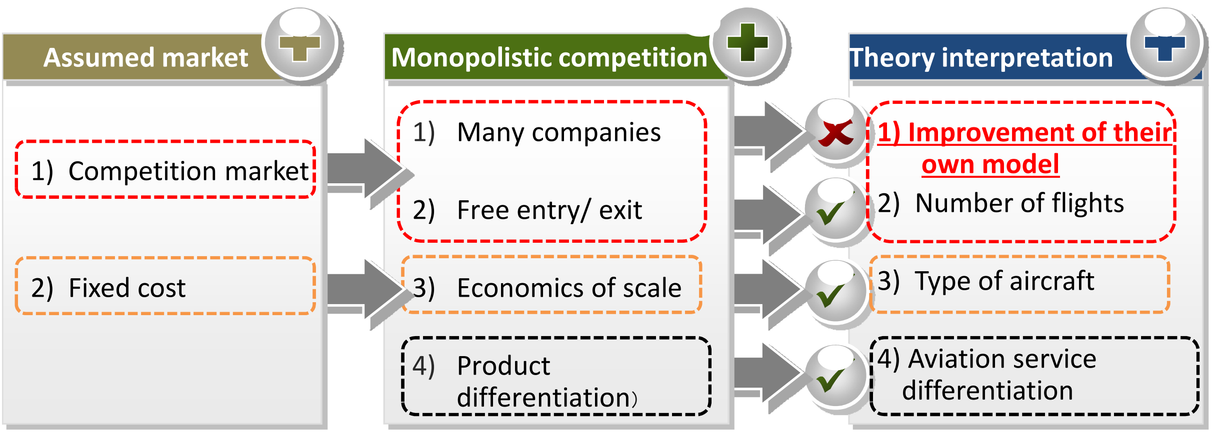

Figure 5 – Relationship between the monopolistic competition theory and the future aviation market

4. SIMULATION MODEL

4.1 Model structure

This section explains the model structure based on the monopolistic competition theory. It consists of three sub-models as mentioned below.

1) Demand-side model
2) Supply-side model
3) Equilibrium conditional formula

First, in Section 4.3, we describe the demand-side model's essential structure based on the general theory of consumer behavior, before improving the model component corresponding to the monopolistic competition theory. Section 4.4 is the supply-side model. Finally, Section 4.5 establishes the convergence condition.

4.2 Features of the analysis model

This section explains the terms frequently used in this model. The major terms are as follows, i: the region of origin, j: destination region, k: transportation mode including high-speed rail and aircraft. Two additional factors are σ elasticity of substitution between transportation modes and n: frequency of aviation from regions i to j.

4.3 Demand-side model

4.3.1 Constant Elasticity of Substitution-type utility function

Fig-6 depicts the entire structure of the utility function based on constant elasticity of substitution (CES). Utilities in a region i (u_i) consists of two components, consumptions for transportation (x_{ij}^{k}) or other goods (x_i). The consumptions for transportation consist of two transportation mode, high-speed rail and aviation. The CES-type utility function — other consuming function and traffic function— are mentioned below.

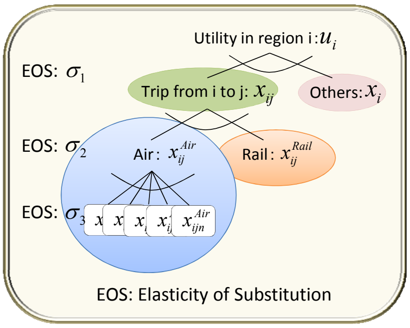

Figure 6 – CES utility functions

$$u_i = \left\{ \sum_j a_{ij}^{\frac{1}{\sigma_1}} x_{ij}^{\frac{\sigma_1 - 1}{\sigma_1}} + a_i^{\frac{1}{\sigma_1}} x_i^{\frac{\sigma_1 - 1}{\sigma_1}} \right\}^{\frac{\sigma_1}{\sigma_1 - 1}} \tag{4.1a}$$

$$x_{ij} = \left\{ a_{ij}^{Air\,\frac{1}{\sigma_2}} x_{ij}^{Air\,\frac{\sigma_2 - 1}{\sigma_2}} + a_{ij}^{Rail\,\frac{1}{\sigma_2}} x_{ij}^{Rail\,\frac{\sigma_2 - 1}{\sigma_2}} \right\}^{\frac{\sigma_2}{\sigma_2 - 1}} \tag{4.1b}$$

Here, α_{ij}, α_i, α_{ij}^{Rail} and α_{ij}^{Air} are the parameters of CES-type functions. x_{ij}: entire traffic demand in intercity transportation sector only, including high-speed rail and aviation users, x_i: numerical unit, x_{ij}^{Air}: traffic demand by air, x_{ij}^{Rail}: traffic demand by high-speed rail. σ_1: the elasticity of substitution between traffic demand and other consumptions. σ_2: the elasticity of substitution between high-speed rail and aviation, and σ_3: the elasticity of substitution among aircrafts.

Transportation users are select transportation mode to maximize their utility under budget constraints. For example, increase in σ_2 means that transportation user are sensitive to price change for choice of transportation mode. The term σ_2 is set by calibration using current data, as Section 5 explains in greater detail.

4.3.2 Generalized cost

The cost structure is simple, composed by fare and time value. The equation is as follows:

$$c_{ij}^{k} = p_{ij}^{k}(1+T_{ij}^{k}) \tag{4.2}$$

Here, c_{ij}^{k}: generalized cost, p_{ij}^{k}: fare, T_{ij}^{k}: rate of time-value for price.
Adding fare and time value is an important approach to express the generalized cost, but this model uses an Iceberg-type structure to correlate to the monopolistic competition theory. Using the Iceberg-type structure

$$c_{ij} = \left\{ \alpha_{ij}^{Air} c_{ij}^{Air^{1-\sigma_2}} + \alpha_{ij}^{Rail}\left(c_{ij}^{Rail}\right)^{1-\sigma_2} \right\}^{\frac{1}{1-\sigma_2}} \tag{4.5a}$$

enables us to calculate more easily because it uses only multiplication and not addition. Considering time value is very important for research on intercity transportation because time is an important factor in transportation-mode selection for a long-distance trip.

4.3.3 Budget constraint

Budget constraint is an important factor for consumers in choosing a transportation mode. The equation of budget constraint is as follows.

$$\sum_{k}\sum_{j} c_{ij}^{k} x_{ij}^{k} + c_i x_i \le I_i \tag{4.3}$$

Here, I_i: total income in region i.
The first term on the left side of the equation is the total consumption amount for transportation in region i. The second term is the total for other goods; c_i is the standard price of this calculation; and any transportation generalized cost (c_{ij}^{k}) is relative against c_i. The final term on the right side of the equation is the total income in region i, calculated by using average income data per year and person, divided by region i population.

4.3.4 Utility maximization

Maximum utility is calculated by the Lagrange-multiplier method using the CES-type utility function under budget constraints (Fig-7). The demand functions are as follows:

$$x_{ij} = \alpha_{ij}\left(\frac{c_{ij}}{c_i}\right)^{-\sigma_1}\frac{I_i}{c_i^{'}} \tag{4.4a}$$

$$x_{ij}^{Air} = \alpha_{ij}^{Air}\left(\frac{c_{ij}^{Air}}{c_{ij}}\right)^{-\sigma_2} x_{ij} \tag{4.4b}$$

$$x_{ij}^{Rail} = \alpha_{ij}^{Rail}\left(\frac{c_{ij}^{Rail}}{c_{ij}}\right)^{-\sigma_2} x_{ij} \tag{4.4c}$$

Here, generalized cost functions and the utility function are also calculated as follows:

$$c_i^{'} = \left\{ \sum_{j=1} \alpha_{ij} c_{ij}^{1-\sigma_1} + \alpha_i c_i^{1-\sigma_1} \right\}^{\frac{1}{1-\sigma_1}} \tag{4.5b}$$

$$u_i = \frac{I_i}{c_i^{'}} \tag{4.5c}$$

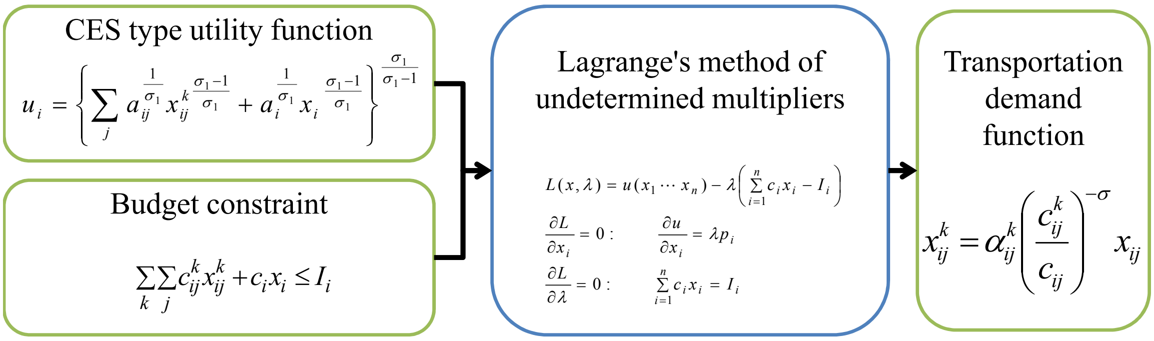

Figure 7 – Calculation flow by Lagrange's method

4.3.5 Modified demand functions based on the monopolistic competition theory

Demand functions calculated in equation (4.4b) is modified to ensure consistency with the monopolistic competition theory. The theory used in this study is based on research by Dixit and Stiglitz in 1977. The new demand and budget-constraint functions are as follows.

$$x_{ij}^{Air} = \left\{ \sum_{m=1}^{n} x_{ij}(m)^{\rho_3} \right\}^{\frac{1}{\rho_3}} \tag{4.6}$$

$$\sum_{m=1}^{n} x_{ij}(m) c_{ij}(m) = Y \tag{4.7}$$

Here, x_{ij} (m) is transportation demands in each aircraft , n is the number of variety, ρ_3 is elasticity of substitution, c_{ij} (m) is generalized cost in each aircraft, Y is total cost for aviation, with x_{ij} (m) calculated using Lagrange equation.

$$\Phi = \left\{ \sum_{m=1}^{n} x_{ij}(m)^{\rho_3} \right\}^{\frac{1}{\rho_3}} - \lambda \left\{ \sum_{m=1}^{n} x_{ij}(m) c_{ij}(m) - Y \right\} \tag{4.8}$$

$$\frac{\partial \Phi}{\partial x_{ij}(m)} = \frac{1}{\rho_3} \left(\sum_{m=1}^{n} x_{ij}(m)^{\rho_3} \right)^{\frac{1}{\rho_3}-1} \rho_3 x_{ij}(m)^{\rho_3 - 1} - \lambda c_{ij}(m) \tag{4.9}$$

$$x_{ij}(m) = \frac{x_{ij}^{Air}}{\lambda^{\sigma_3} c_{ij}(m)^{\sigma_3}} \tag{4.10}$$

The Lagrange multiplier is given as follows:

$$\lambda = \frac{1}{c_{ij}^{Air}} = \left(\sum_{m=1}^{n} c_{ij}(m)^{1-\sigma_3} \right)^{-\frac{1}{1-\sigma_3}} \tag{4.11}$$

Here, c_{ij}^{Air} is aviation generalized cost, and budget for aviation Y is as follows.

$$Y = x_{ij}^{Air} c_{ij}^{Air} \tag{4.12}$$

To calculate the x_{ij} (m), inserting equation (4.12) into (4.10).

$$x_{ij}(m) = \frac{Y}{c_{ij}(m)^{\sigma_3} c_{ij}^{Air\,1-\sigma_3}} \tag{4.13}$$

To calculate the $x(m)$, by substituting equation(4.12) into (4.13). We obtain the following equation:

$$x_{ij}(m) = \left\{\frac{c_{ij}(m)}{c_{ij}^{Air}}\right\}^{-\sigma_3} x_{ij}^{Air} \tag{4.14}$$

In this equation, for a given value of elasticity alternative, the calculated function is a downward-sloping demand curve.
In equation (4.11), $c_{ij}(m)$ is equal to c_{ijn}^{Air} under equilibrium.

$$c_{ij}^{Air} = n^{\frac{1}{1-\sigma_3}} c_{ijn}^{Air} \tag{4.15a}$$

$$c_{ijn}^{Air} = p_{ijn}^{Air}(1+T_{ij}^{k}) \tag{4.15b}$$

σ_3 is greater than 1.0 in this model in equation (4.15a), with decreasing frequency n, aviation's generalized-cost (c_{ij}^{Air}), increases.

4.4 Supply-side model

4.4.1 Profit functions

Supply-side models explain the behavior of aviation companies in the tough competition market. This model also applies the monopolistic competition theory, and the profit function is expressed as follows:

$$\pi_n = p_{ijn}^{Air} q_{ijn}^{Air} - \left(w_a^{Air} a_{MC}^{Air} + w_b^{Air} b_{MC}^{Air}\right) q_{ijn}^{Air} - w_F^{Air} F_{ij}^{Air} \tag{4.16a}$$

$$q_{ijn}^{Air} = x_{ij}(m) \tag{4.16b}$$

Here each character is defined as follows:

q_{ijn}^{Air} : Aviation demand in each aircraft
a_{MC}^{Air} : Unit for variable cost per unit seat
b_{MC}^{Air} :Unit for fuel cost per seat
F_{ij}^{Air} :Unit for fixed cost
w_a^{Air} : Variable cost
w_b^{Air} : Fuel price
w_F^{Air} : Fixed cost

Equation (4.16a) is formulated for each aviation company. In equation (4.16), the first term on the right side is revenue, the second is variable cost, and the last is fixed cost. Variable costs are divided into fuel cost and others. In this study, technological improvement is expressed by the change of b_{MC}^{Air} which means changing fuel efficiency is technological improvement. This model does not consider the difference of productivity between aviation companies because the Dixit–Stiglitz model which is based on the theory of monopolistic competition does not consider the productivity to make simple formula.

4.4.2 Profit maximization problem

The profit-maximization problem is applied to the first-order condition of profit maximization with respect to equation (4.16) and to the partial derivative of both sides with respect to the amount of production, $q(i)=q_{ijn}^{Air}$; thus, we obtain the following equation.

$$\frac{\partial \pi}{\partial q(i)} = p(i)\left(1+\frac{q(i)}{p(i)}\frac{\partial p(i)}{\partial q(i)}\right) - w_a^{Air} a_{MC}^{Air} - w_b^{Air} b_{MC}^{Air} = 0 \tag{4.17}$$

The mark-up μ is set as follows.

$$\mu = -\frac{q(i)}{p(i)}\frac{\partial p(i)}{\partial q(i)} \tag{4.18}$$

By inserting equation (4.18) into (4.17), the fare per each flight(p_{ijn}^{Air}) is calculated as follows.

$$p_{ijn}^{Air} = \frac{1}{1-\mu}\left[w_a^{Air} a_{MC}^{Air} + w_b^{Air} b_{MC}^{Air}\right] \tag{4.19}$$

According to the theory of perfect competition among market conditions, fares and marginal costs are equal because μ is fixed to zero, which means that fares are unaffected by the mark-up μ thereby decreasing frequency of aviation. However, in the monopolistic competition theory, fares equal to marginal costs increased by the mark-up μ. For example, when the frequencies of aviation decrease, the mark-up μ and fares (p_{ijn}^{Air}) increase, which in turn increases traffic demands.
The mark-up μ is formulated as a function of the aviation frequency as follows:

$$\mu = \frac{1}{\sigma_3} + \left(\frac{1}{n_{ij}^{Air}}\right)\left\{\frac{1}{\sigma_2} - \frac{1}{\sigma_3} + \left[\frac{1}{\sigma_1} - \frac{1}{\sigma_2}\right] S_{ij}^{Air}\right\} \tag{4.20}$$

The mark-up μ is calculated by the Dixit–Stiglitz model: $\mu=1/\sigma_3$. However, in the aviation market, the interaction between fares and mark-up with low frequency OD is important in evaluating the impact of environmental tax, a cost-up factor. In this model, the mark-up μ is based on Takeda (2007) to express the above-mentioned conditions. However, if the numbers of frequencies n are set to infinite μ is constant with respect to the reciprocal of the elasticity of substitution. For more information, refer to Takeda (2007).

4.4.3 Methods of environmental taxation

In this simulation, environmental tax is introduced as an upstream taxation mechanism, which means that it affects all transportation modes including aviation and high-speed rail through increased fuel costs. Fig-8 depicts the environmental-tax impact flow. Taxation is introduced between import and purification, and purification-business companies are the tax payers. The rates of environmental tax are set in terms of units of tons carbon.

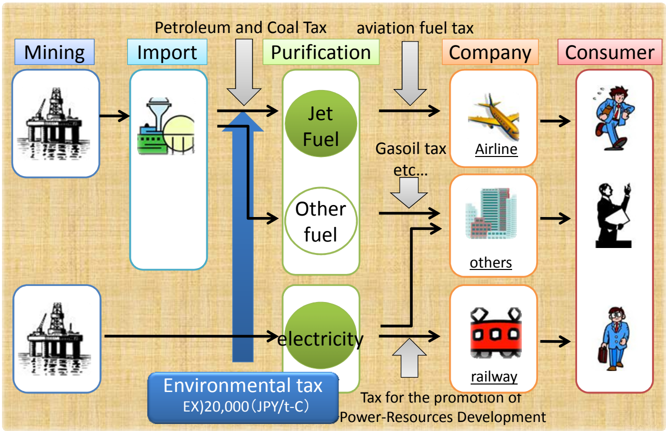

Figure 8 – Taxation mechanism

4.4.4 Refinement of simulation model by taxation and technological improvement

This model needs to improve the partial equations to express the taxation impact on fuel price. In addition, the model must express technological improvements by decreasing fuel consumption, which in turn reduces operating costs. To include this impact, equation (4.16) is improved as follows considering taxation impact and technological improvement.

$$w_b^{Air} b_{MC}^{Air} = z(1+\beta_{ij}^{Air}) w_b^{Air} b_{MC}^{Air} \tag{4.21}$$

The term β_{ij}^{Air} is the rate of increase in the fuel price against the current fuel price during the simulation period, and z is improvement rates of fuel consumption against the current rate. Equation (4.22) replaces equation (4.16) as follows:

$$\pi_n = p_{ij}^{Air} q_{ijn}^{Air} - \left\{ w_a^{Air} a_{MC}^{Air} + z(1+\beta_{ij}^{Air}) w_b^{Air} b_{MC}^{Air} \right\} q_{ijn}^{Air} - w_F^{Air} F_{ij}^{Air} = 0 \tag{4.22}$$

Equation (4.19) is also replaced because equation (4.22) has improved.

$$p_{ijn}^{Air} = \frac{1}{1-\mu} \left[w_a^{Air} a_{MC}^{Air} + z(1+\beta_{ij}^{Air}) w_b^{Air} b_{MC}^{Air} \right] \tag{4.23}$$

However, this research does not apply the monopolistic competition theory to the railway market. The introduction of environmental tax as upstream taxation affects electric costs, which is a mechanism expressed by improving the equation of generalized cost as follows:

$$c_{ij}^{Rail} = \left\{ \left(1+\beta_{ij}^{Rail}\right) r p_{ij}^{Rail} + (1-r) p_{ij}^{Rail} \right\} \left(1+T_{ij}^{Rail}\right) \tag{4.24}$$

Here, r: rates of electric cost in fares, and β_{ij}^{Rail}: increasing rates of the electric cost against the current rate.

4.5 Equilibrium conditions/ Numbers of operating frequency

The equilibrium condition is represented by equation (4.25) which means that calculations will stop when the profit of each airline becomes zero. According to the monopolistic competition theory, companies continue to place new entries into the aviation market until monopolistic profit becomes zero. The variables are the numbers of frequencies. In this study, increasing operating costs from taxation reduces aviation companies' profits, and subsequently, a few companies exit the market until the deficit equals zero. The numbers of operating frequencies for aviation companies are calculated by the following two equations.

$$\pi_n = p_{ij}^{Air} q_{ijn}^{Air} - \{w_a^{Air} a_{MC}^{Air} + (1+\beta_{ij}^{Air}) w_b^{Air} b_{MC}^{Air}\} q_{ijn}^{Air} - w_F^{Air} F_{ij}^{Air} = 0 \quad (4.25)$$

$$\mu = \frac{1}{\sigma_3} + \left(\frac{1}{n_{ij}^{Air}}\right)\left\{\frac{1}{\sigma_2} - \frac{1}{\sigma_3} + \left[\frac{1}{\sigma_1} - \frac{1}{\sigma_2}\right] S_{ij}^{Air}\right\} \quad (4.26)$$

Using equation (4.25) and (4.26), the numbers of frequencies are determined as follows:

$$n_{ijn}^{Air} = \frac{\sigma_3 \left[\{a_{MC}^{Air} + (1+\beta)_{ij}^{Air} b_{MC}^{Air}\} q_{ijn}^{Air} + F_{ij}^{Air}\right]}{F_{ij}^{Air}(\sigma_3 - 1) - \{a_{MC}^{Air} + (1+\beta_{ij}^{Air}) b_{MC}^{Air}\} q_{ijn}^{Air}} \left\{\frac{1}{\sigma_2} - \frac{1}{\sigma_3} + \left[\frac{1}{\sigma_1} - \frac{1}{\sigma_2}\right] S_{ij}^{Air}\right\} \quad (4.27)$$

4.6 Calculation flow

Fig-9 depicts the calculation flow starting with the introduction of environmental tax and ending with the zero profit condition on equation (4.25). First, environmental tax increases fuel costs for aviation (β_{ij}^{Air}), and electric costs for railways (β_{ij}^{Rail}). The term β_{ij}^{Air} increases fares for aviation (p_{ijn}^{Air}). The synthetic transportation price (c_{ij}) increases by increasing both generalized costs of aviation (c_{ij}^{Air}) and railway (c_{ij}^{Rail}). Then, utility decreases because incomes are fixed, but total costs c_i increase. After passengers' mode choice under budget constraints, aviation demand decreases more than the railway demand because the unit of CO_2-emission per person in the aviation market is greater than that for railways. Decreasing the aviation demand makes the profit non-zero; the aviation frequency, n, is adjusted until the profit becomes zero. Repeated computation ends when profit equals zero, and certain outputs such as frequencies n, mark-up rates μ, traffic volume x_{ij} and utility u_i are obtained.

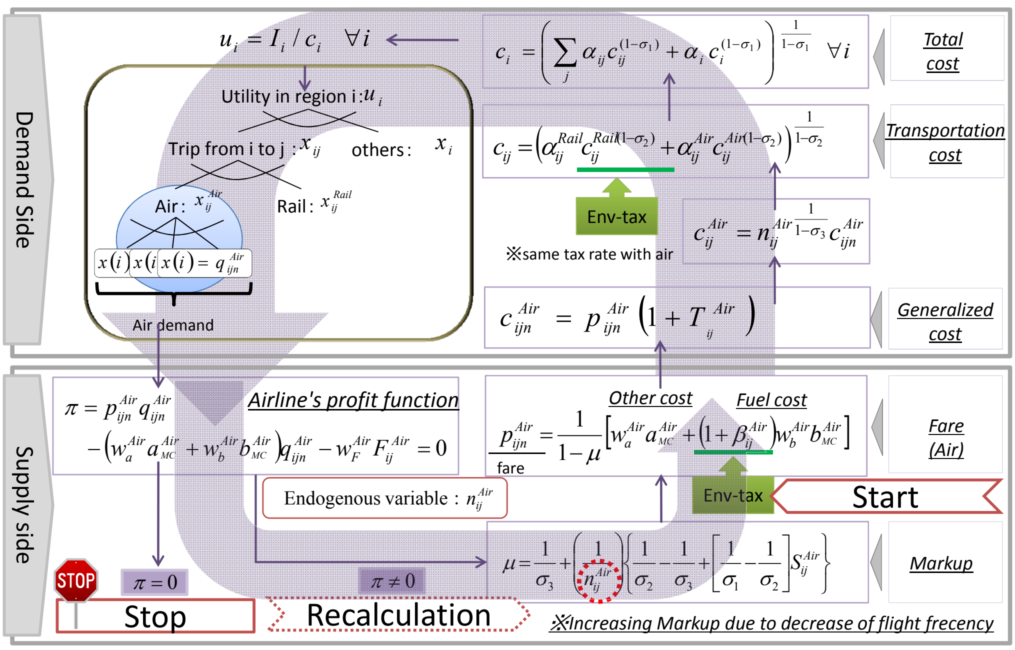

Figure 9 – Calculation flow

5. CALIBLATION

5.1 Data set

This study uses many data from 2005 in Japan. Data of traffic volume in 2005 originates from the "Inter-Regional travel survey," organized by Japan's Ministry of Land, Infrastructure and Transport (MLIT). Data on transportation networks and fares for rail and air are obtained from the National Integrated Transport Analysis System and MLIT, but we use only regular economy class fares and apply only one fare to each OD pair. Data on the frequency of aviation and aircraft size originates from the JTB timetable. Rates of fuel and other costs against total variable costs are obtained from data in securities reports published by All Nippon Airways and Japan Airline in 2005, according to which we set the fuel rate as 25%. CO_2-emission per unit is 111(g-CO_2/capita/km) for aviation and 11 (g-CO_2/capita/km) for railway.

5.2 Parameter estimation

The equations for estimating the parameter are as follows.

$$\ln \frac{x_{ij}}{x_i} = \ln \frac{\alpha_{ij}}{\alpha_i} - \sigma_1 \ln \frac{c_{ij}}{c_i} \quad (5\text{-}1a)$$

$$\ln \frac{x_{ij}^{rail}}{x_{ij}^{air}} = \ln \frac{\alpha_{ij}^{rail}}{\alpha_{ij}^{air}} - \sigma_2 \ln \frac{c_{ij}^{rail}}{c_{ij}^{air}} \quad (5\text{-}1b)$$

The estimating parameter is equal to the estimate, *σ_1 and σ_2,* as explained in Section 4.3.1. Equation (5-1a) calculates the alternative elasticity variable between traffic and other consumer products. Equation (5-1b) calculates the alternative elasticity variable between railways and airlines. The regression analysis enables us use these equations to evaluate the alternative elasticity variable from the existing data.

The parameter estimation method follows the study of Okuda (2008), which can be referenced for more information on calculating α and σ. The number of the total samples is 2,231. This sample aggregates data of OD trips between 50 regions, but it excludes certain data such as transportation demands for inner-city areas and between each prefecture in a metropolitan. First, the result of an alternative elasticity variable between traffic and other consumed products is $\sigma_1 = 2.42$. The R-squared is 0.7, and the multiple correlation coefficients are 0.836. Second, the result of an alternative elasticity variable between railways and airlines is $\sigma_2 = 6.58$. The R-squared is 0.70, and the multiple correlation coefficients are 0.838. This finding suggests that mutual airline and railway substitution occurs easily for the same transportation route.

The last parameter, σ_3, is only set by scenario because of no data between each company. This study sets σ_3 equal to 10, which is greater than σ_2 to satisfy the assumption of theory that σ_3 has to be greater than σ_2.

6. CALCULATION RESULTS

6.1 Current intercity network structure in Japan, 2005

Fig-10 depicts the aviation-network structure in Japan, 2005. This study focuses on the traffic leaving from Aichi Prefecture to other regions. The size of the gray-colored circle indicates the aviation mode share, and the thickness of the solid black arrows indicates aviation frequency. Fig-11 depicts Japan's high-speed rail network in 2005. The size of the gray-colored circle indicates the railway mode share. In this calculation, the environmental taxation rate is set to 4,000 (JPY/ton-carbon), which is greater than 2,400 (JPY/ton-carbon) proposed by Ministry of the Environment, to assume more severe conditions.

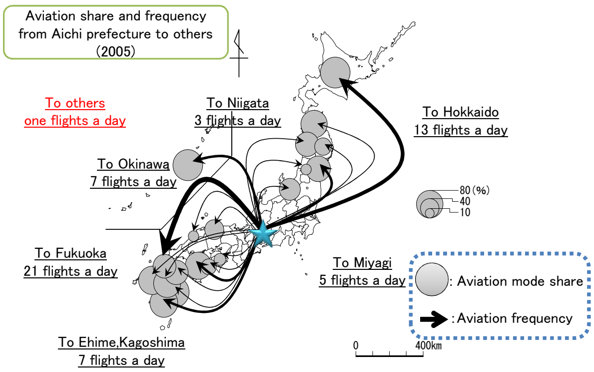

Figure 10 – Aviation network in Aichi

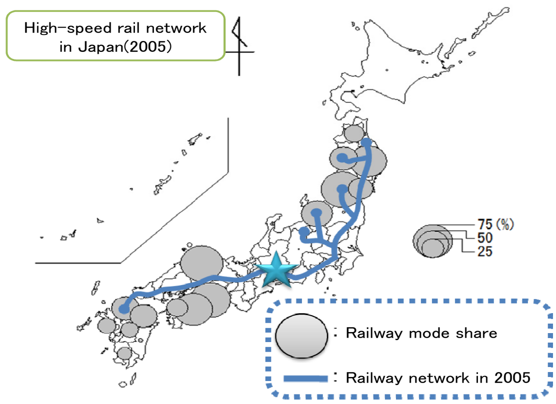

Figure 11– High-speed railway network in Japan prefecture

6.2 Impact analysis by environmental taxation (Environmental taxation: Supply-side)

Fig-12 depicts the amount of air-fare increase for flights departing from the Aichi prefecture. For example, fares increase to 1,400 (JPY/person) in the Iwate prefecture, approximately to 1,000 (JPY/person) in Yamagata and Aomori prefectures, for which aviation is a major access mode but which are areas with less total demand, and approximately to 400 (JPY/person) in other prefectures. The reason for these fare increases is the increased mark up, considering equation (4.23). Fig-13 depicts the increasing rate of mark-up (μ) after taxation. In Iwate and Yamagata prefectures, it is 3.2%, and in Aomori it is 1.9%. From the relationship in equation (4.26 decreasing aviation frequencies increase the mark-up rate (Fig-14).The rates of decreasing frequency in Iwate, Yamagata, and Akita Aomori prefectures are 9.1%, 13.7%, and 6.1%, respectively, although for other areas, it is only 1.5%. From the above-described

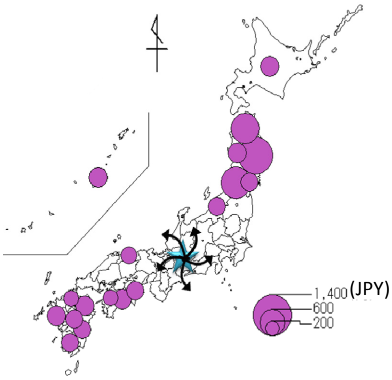

Figure 12 — Increasing amount of aviation fare after taxation

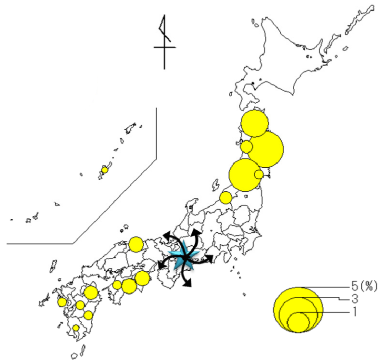

Figure 13 — Increasing rate of the mark-up after taxation

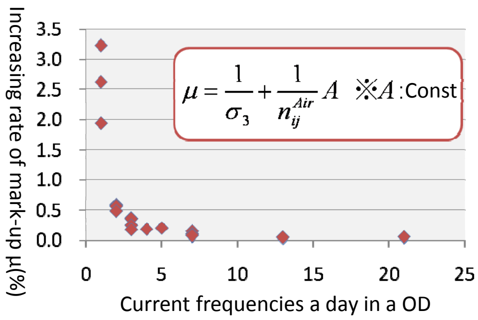

Figure 14 — Relationship between the increasing rate of mark-up and current frequencies a day of aviation in an OD trip

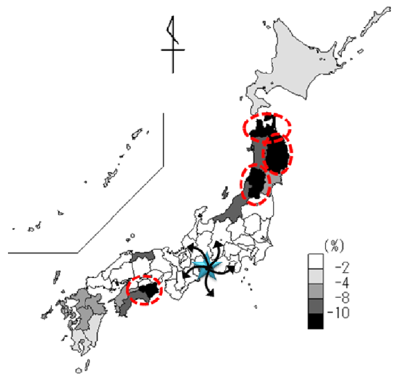

Figure 15 — Decreasing rate of the frequencies of aviation after

results, the decreased numbers of flights (Fig-15) operated by aviation companies increased the airlines' pricing power, so that they could raise fares to obtain greater profit.

6.3 Impact analysis by environmental taxation (Environmental taxation: Demand-side)

Fig-16 depicts the decreasing rate of total traffic demand (frequencies) after taxation. In Fig-16, Iwate and Aomori prefectures experienced the greatest impacts of reduced volume, 7.2% and 6.3%, respectively, with

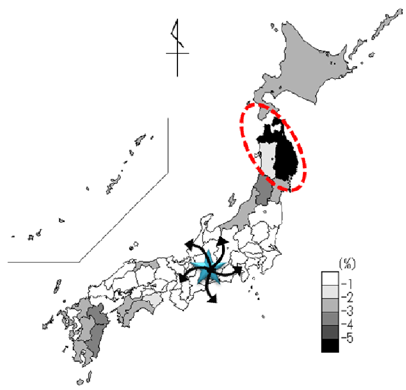

Figure 16 — Decreasing rate of total demand after taxation in Aichi

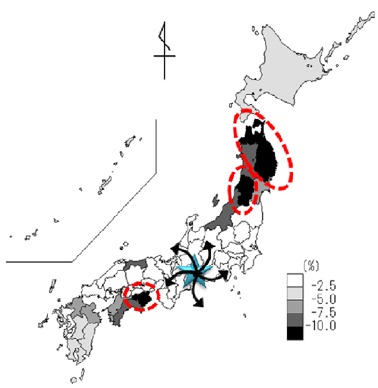

Figure 17 — Decreasing rate of aviation-traffic volume after taxation in Aichi

other prefectures, such as big cities, receiving less impact; for example, Hokkaido, northern in Japan, had a 2.8% decrease, Fukuoka, biggest city in western Japan, 2.2%, and Tokyo only 0.2%. A decreasing amount of total traffic demand (volume) per year, for Hokkaido, Fukuoka, and Tokyo, is 19,000 (person/year), 12,000 (person/year), and 15,000 (person/year), respectively. Especially in Tokyo, people can more easily change their transportation mode from aviation to railway than the residents of other regions because Tokyo's high-speed rail service level has a high frequency, so residents need not decrease transportation after taxation.

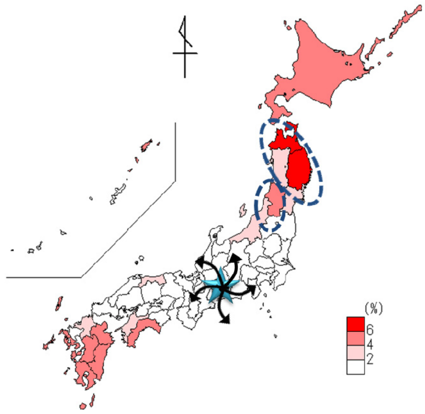

Figure 18 — Increasing rate of the railway demand after taxation in Aichi

Decreasing aviation demand and increasing railway demand reflect the factors that influence the reduction of the amount of total traffic demand after taxation. Fig-17 depicts the decreasing rates of aviation leaving from the Aichi prefecture: Aomori is 10.7%, Iwate 1.3%, and Yamagata 24.7%o. Yamagata has the Yamagata–Shinkansen line (High-Speed Rail), making it easy for residents to change the transportation mode from aviation to railway. Fig-18 shows the increasing rates of railway demand from the same region. However, all prefectures must accept the situation that they cannot convert the entire decrease in aviation demand to increased railway demand because railway fares also increase with taxation. Thus, factors causing a decrease in the total traffic demand with the introduction of environmental tax have been found to be different in that they can easily convert to another transportation mode. Low capability for a shift from aviation to railway causes a greater reduction of total traffic.

If parameter σ_3 = 7, the impact by taxation is increased to 10% compared with the current condition that the parameter σ_3 = 10. However, when σ_3 = 20, the impact is decreased to 15%. Future studies should set parameter σ_3 carefully to simulate reality more accurately.

6.4 Impact analysis by environmental taxation (Environmental taxation and technological improvement)

This section analyzes the results of the simulation considering both the impacts of environmental tax and technological improvement. The taxation rate is set at 4,000 (JPY/ton-carbon), as mentioned in Section 6.3. Technological improvement is set at 5.0% fuel efficiency improvement in aircraft engines over current engine performance. This simulate is useful for understanding the balance between the speed of technological improvement and environmental tax

Fig-19 depicts the change rate in the total traffic demand from Aichi prefecture compared with no taxation and the technological-improvement condition. Fig-20 depicts the rate of change of only aviation frequency. Technological improvement increases the total traffic demand under the taxation of 4,000 (JPY/ton-Carbon) because the impacts of taxation as a cost-up factor for airlines are less than those of fuel-efficiency improvements as cost-down factors. For example, in Iwate and Aomori prefectures, increased aviation demand up to 2.0% is observed before taxation. In addition, the frequency before taxation also increases up to 3.0% in these regions. However, this simulation does not include technological improvements

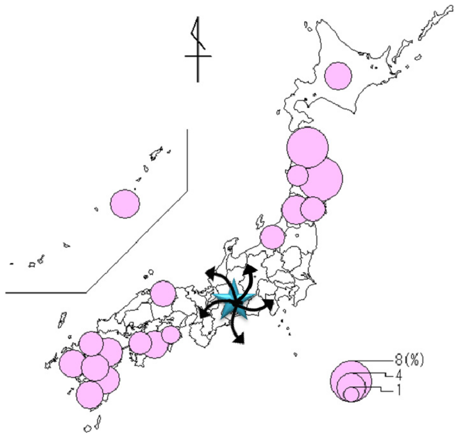

Figure 19 – Increasing rate of total traffic demand after taxation from Aichi

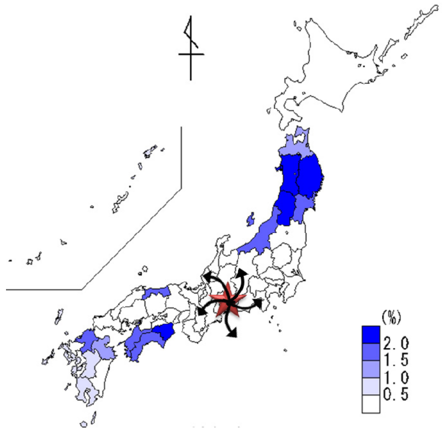

Figure 20 – Increasing rate of aviation frequencies after taxation from Aichi

in railways; so, regions such as the Aichi prefecture in which the railway share is high show a decreased total demand because they do not benefit from aviation innovations.

7. CONCULUSION AND FUTURE STUDIES

In this study, a model was developed by applying the monopolistic competition theory to express the airline market's vicious circle under deregulation and the influence of taxation was evaluated by quantitatively assuming the introduction of upstream taxation as an environmental tax in the intercity transportation passenger-traffic sector. Therefore, the environmental tax of 4,000(JPY/t-C) was found to have the following three effects.

1) The upstream taxation's effect on the transportation demand changed according to area with a degree of alternative difficulty to railroad access. As in a case study for OD from Aichi, in areas with few operation facilities originally, the rate of decrease in air-transportation use was especially remarkable, for example, arriving at Iwate decreased by approximately 19%. In addition, in areas with alternative difficulty to railroad access, a main factor in the decreasing total transport demand was a cancelation of using air transportation caused by fare's increase reflecting taxation. Thus, the local distribution of taxation's effect became clear.
2) Taxation caused the number of operation facilities to decrease by approximately 10% in areas with few operation facilities such as Iwate and Aomori. Because of the model used for the mark-up as a function of the number of operation facilities, the increased rate of a mark--up in Iwate and Aomori was approximately 5% higher. Airfare also increased in Iwate by approximately 1,400 (JPY/person) and in others by an average of 400 (JPY/person). This increase resulted from a vicious circle, which decreased the number of operation facilities, increased the mark-up. and fares, and decreased the demand, represented by a monopolistic competition model.
3) Technological improvement of the efficiency of aircraft engine up to 5% increases the total traffic demand under the taxation of 4,000 (JPY/ton-Carbon) because taxation's effects as cost-up factor for airlines were less than those from fuel-efficiency improvements as cost-

down factors. The result of this simulation suggests that the taxation rate for fuel should be set considering technological improvement to decrease the impact by taxation and to keep balance between economic and environmental efficiency.

Future studies should simulate reality more strictly by, for example, increasing the number of case studies, including road and freight transportations. Taxation's economic impact is also important in controlling the total demand. Future studies should adopt the Melitz model structure, which is improves upon the Dixit-Stilgitz model that does not consider differences in productivity.

8. REFERENCE

＜Papers＞

Anger, A (2010): Including Aviation in the EU ETS: Impacts on the Industry, CO2 Emissions and Macroeconomic Activity in the EU, Journal of Air Transport Management No. 16, 2010, pp. l00–105.

Baumol, W J , Panzer, J C and Willig, R D (1986): Contestable Markets and the Theory of Industrial Structure. New York: Harcourt Brace Jovanovich

Brander, J A and Zhang, A (1990): Market Conduct in the Airline Industry: An Empirical Investigation, RAND Journal of Economics, Vol.21, No.4, pp. 567–583

Chamberlin, E H (1933).: The Theory of Monopolistic Competition, Cambridge, Mass.: Harvard University Press,Vol.8,

Dixit, A K and Stiglit, J E (1977): Monopolistic Competition and Optimum Product Diversity, The American Economic Review, Vol. 67, No. 3 (Jun., 1977), pp. 297–308

Fujii, H (1995): Deregulation and Social Welfare in Monopolistic Competition,

Hattori, Y, Morimoto, R, Shibahara, N, Kato H and Ito, Y (2010): Applying LCA to Inter-regional Ultra-High-Speed Passenger and Freight Transport System, Journal of Infrastructure Planning Review,Vol.41, CD-ROM(28)

Helpman and Elhanan (1990): Monopolistic Competition in Trade Theory, Special Paper in International Finance, No. 16

Ishikura, T and Tansei, K (2008): A domestic Air Demand Model for Analysis of Airport Competition Situation, Research Report of National Institute for Land and Infrastructure Management,Vol.38

Kikuchi, T (2006): New Developments in Monopolistic Competition Trade Theory, National economy journal 194(2), pp. 77–92

Krugman, P R (1979): Increasing Returns, Monopolistic Competition and International Trade, Journal of International Economics, Vol.9, pp.469–479

Mayor, K and Richard, S J Tol (2007): The Impact of the UK Aviation Tax on Carbon Dioxide Emissions and Visitor Numbers, Working Paper FNU-131

Mimuro, A and Okuda, T (2009): A study on introducing Baumol-Oates tax and re¬distribution of the tax revenues into intercity transport sector in Japan, Journal of global environment, Vol.17, pp. 61–67

Okumura, M (2003): Proposing Approach for Intercity Transportation(Special session No.805), Journal of Infrastructure Planning Review Vol.27, CD-ROM

Okumura, M, Nakagawa, D, Yamaguchi, K, Tsuchiya, K, Okumura, Y, Hino, S and Tsukai, M (2002): Topics on Analysis and Evaluation of Inter-Urban Transportation (Special session), Journal of Infrastructure Planning Review Vol.25, CD-ROM

Proceedings of the Conference on Energy, Economy, and Environment, Vol. 11, 13–18
Takeda, S (2007): The lecture of Applied General Equilibrium Analysis for Trade Policies," RIETI Discussion Paper Series 07-J -010

＜Book＞
Murakami H, Takahashi, N, Katou, K and Sakakibara, Y (2006): Minerva Text Library pp. 75–121, Minerva Bookstore

＜Data on government office＞
Ministry of Land, Infrastructure, Transport and Tourism (2005): The actual condition of the Trunk Traveler Flow -Analysis of national trunk passenger pure flow data ~
Ministry of Land, Infrastructure, Transport and Tourism , NITAS(National Integrated Transport Analysis System)
Ministry of Land, Infrastructure, Transport and Tourism (2006) , Transition of the greenhouse effect gas emission in a transportation section, etc.

＜Others＞
All Nippon Airways Co., Ltd., The 56th term financial report
Japan Airlines Co., Ltd., The Heisei 17 fiscal-year term financial report ended March
JTBtimetable(2005), JTBpublishing