

Optimizing Multiple Airport Charges Considering the Marginal Cost of Public Funds

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Airport management costs are financed by revenues from multiple airport-related charges (e.g., passenger service facility charge, and aviation fuel tax) and general government funds. A change in the rate of charges affects revenues from other charges through changes in airlines supply (airfares and flight frequency) and passengers' trip decisions. That is, the charges depend on each other in terms of the total revenue. This study quantitatively explores one of the efficient level of three airport-related charges (hereafter remedy charges) to improve social welfare. The model includes consumers (demand side), airlines (supply side) and a government that sets the charge rates. The number of airlines is limited, so the airline market is an oligopoly. Our quantitative analyses show that the oligopolistic effects affect both airfare and flight frequency. We find the remedy charges (subsidy of per-passenger charge and the larger per-flight charge) can correct these distortions and improve social welfare by 48%.

Key Words : *Airport-related charge, Optimal taxation, Marginal cost of public funds*

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1. INTRODUCTION

An airline industry is an important infrastructure for long-distance transportations. So, it is important to optimize airport-related charges that finance airport managing cost such as airport facilities. In this study, we consider three main airport-related charges. One is aviation fuel tax, which airlines pay according to fuel consumption. The second is a per-passenger charge which contains a passenger-service-facility charge and a passenger-security-service charge. Per-passenger charge is imposed according to number of passengers. The third is a per-flight charge, which is a landing fee paid by airlines according to the number of landings.

There are several studies about optimization of airport-related charges. Zhang and Zhang (2006)

show that from the viewpoint of social welfare, airport-related charge revenue cannot finance airport managing cost and general funds is needed. But Zhang and Zhang (2006) is focus on only one airport charge. Silva and Verhoef (2013) show the roles of per-passenger and per-flight charges. They suggest that at optimal, a subsidy to passengers corrects airlines' market power effects, while per-flight charge corrects inefficiency of congestion in airports. Czerny et al. (2017) optimize per-flight and per-passenger charges simultaneously. They show that from the viewpoint of social welfare, a subsidy to flights is necessary at optimal. These two studies do not consider the government budget constraint, and accordingly, do not explore the marginal cost of public funds (hereafter MCPF).

Actually, for road investments, many studies

consider the MCPF to optimize toll and car-related taxes (Parry and Small (2005) and Kono et al. (2021)). There are, however, no studies which explore optimal airport-related charges in the airport-related budget with the MCPF.

This paper calculates the optimal airport-related charges quantitatively from the viewpoint of social welfare considering MCPF. To the best of our knowledge, our study is the first to provide an empirical framework in which airport-related charges are investigated in consideration of MCPF. In addition to MCPF, we take account of oligopolistic competition and airport budget constraint as in previous papers.

Moreover, we calculate the optimal airport-related charges simultaneously. A change in the rate of one of the airport-related charges affects revenues from other airport-related charges through changes in airlines' supply (airfares and flight frequency) and passengers' trip decisions. That is, the airport-related charges are dependent on each other in terms of the total revenue. So, we optimize all the airport-related charges simultaneously.

In this paper, we quantitatively explore one of the efficient level of the airport-related charges (hereafter remedy charges) which can improve social welfare.

We find that remedy charges improve the welfare by about 48 % of the present level. We furthermore find that distortions due to the oligopolistic competition in the airline markets increase airfares and decrease flight frequencies. As the result, we find the remedy charges (subsidy of per-passenger charge and the larger per-flight charge) can correct these distortions.

2. THE MODEL

We extend a model of Doi (2022). The model includes airlines (supply side), consumers (demand side) and a tax-and-charge collecting agency (government). We analyze annual trips and a static situation.

Airlines simultaneously decide their airfares, flight frequency and aircraft weight to maximize their own profits route by route. The maximization problem of airline j on route r_s at time t is assumed

$$\pi_{jrt} = \sum_{k \in \{peak, off-peak\}} d^k \times \left[\begin{array}{l} (p_{jrt} - \overline{mc}^Q_{jrt} - AFC^Q_{jrt}) q_{jrt}(p_{jrt}, f_{rt}) \\ - \left\{ \begin{array}{l} mc^E_{jrt}(MTOW_{jrt}) \\ + AFC^E_{jrt}(MTOW_{jrt}) \\ + (\overline{pFuel}_t + TFuel_t) cFuel_{jrt}(MTOW_{jrt}) \end{array} \right\} f_{jrt} \end{array} \right] \quad (1)$$

where π_{jrt} is the profit of airline j on route r_s at time t , p_{jrt} is airfare, f_{jrt} is flight frequency and $MTOW_{jrt}$ is aircraft weight. q_{jrt} is the number of passengers which is a function of airfares and flight frequency of all airlines that operate on a

route r_s at time t . \overline{mc}^Q_{jrt} and mc^F_{jrt} are the marginal cost with respect to the number of passengers and flight frequency respectively, and $cFuel_{jrt}$ expresses the fuel consumption on a round trip. The three charges are represented by AFC^Q_{jrt} (per-passenger charge), AFC^E_{jrt} (per-flight charge) and $TFuel_t$ (aviation fuel tax). \overline{pFuel}_t is the fuel price, so $(\overline{pFuel}_t + TFuel_t) \times cFuel_{jrt}$ expresses total fuel cost. The number of seats, the marginal cost of flight frequency mc^F_{jrt} and the fuel consumption on a round trip $cFuel_{jrt}$ is considered as the function of the aircraft weight, so in the simulation, we use linear functions with respect to weight.

In this model, we suppose peak time and off-peak time. Ratio of peak time and off-peak time is expressed by d ($d^{peak} + d^{off-peak} = 1$). Because having idle seat capacity only decreases profit, in the peak time, the number of passengers q_{jrt}^{peak} is expressed as multiplication of flight frequency and the number of seat. In addition, the number of passengers in peak time is fixed to \bar{Q}_{jrt} . In the off-peak time, $q_{jrt}^{off-peak}$ is expressed as logit model (We explain in the following session). So, in the peak time, the load factor is fixed to 1 and in case of off-peak, the load factor is endogenous.

Airlines decide their airfares, flight frequency and aircraft weight to satisfy the first-order conditions of Eq. (1). Because the peak time demand is fixed and expressed to multiplication of flight frequency and the number of seat ($f_{jrt} \times seat_{jrt}(MTOW_{jrt}) = \bar{Q}_{jrt}$), the number of seats (the aircraft weight) determines the flight frequency. So, airlines decide only their airfares and flight frequency.

Moreover, we consider the constraint on landing slots for each airline at Haneda Airport instead of congestion function. Specifically, the total number of landings at Haneda Airport is fixed. Airlines change the number of their routes to maximize their profits. The Landing slots increases if the government invests in runway.

A consumer decides his/her traveling decisions δ_{jrt}^i on every route, his/her quantity of composite goods z^i and his/her leisure time y^i to maximize his/her utility. The consumer's time and budget constraints are

$$z^i + \sum_j \sum_r \sum_t \delta_{jrt}^i p_{jrt} + \sum_r \sum_t \left(1 - \sum_j \delta_{jrt}^i \right) \bar{p}_{ort} = (\bar{w}^i - \tau) L^i, \quad (2)$$

$$y^i + L^i + \sum_j \sum_r \sum_t \delta_{jrt}^i T_{jrt}(f_{jrt}) + \sum_r \sum_t \left(1 - \sum_j \delta_{jrt}^i \right) \bar{T}_{ort} = \bar{M} \quad (3)$$

where $(\bar{w}^i - \tau) L^i$ is the income composed of pretax wage \bar{w}^i less the labor tax τ and labor time

L^i for consumer i . p_{jrt} is airfare and T_{jrt} is travel time on route r . \bar{p}_{0rt} is cost and \bar{T}_{0rt} is time consumption of outside option (e.g. travel by train).

The Consumer's decision of traveling is specified by a nested logit model. From the two constraints, the consumer's indirect utility function is specified as follows.

$$v_{jrt} = \alpha p_{jrt} + \beta f_{jrt}^p + \tilde{\alpha}_{jrt} \gamma + \xi_{jrt} + v_{irt} + (1 - \sigma_r) \epsilon_{ijrt} \quad (4)$$

$\tilde{\alpha}_{jrt}$ expresses the observable airline-route characteristics such as aircraft size and ξ_{jrt} is the unobserved characteristics. v_{irt} and ϵ_{ijrt} are error terms which produce the nest structure. When σ_r is zero, the model is a standard logit model. As σ_r approaches one, the substitutability between airlines becomes high.

The government set the charge rates to finance an expenditure for airports \bar{G} . The government budget constraint is

$$\bar{G} = K + T - \sum_j \sum_r \sum_t \{ AFC_{jrt}^q \times q_{jrt}(\cdot) + (AFC_{jrt}^e + TFuel \times cFuel_{jrt}) \times f_{jrt} \} + a \sum_i \tau L^i \quad (5)$$

The total charge revenue is K , the first term of the right-hand side and the labor subsidy from labor tax revenue is T , the second term. The subsidy rate is expressed by parameter a . This rate is set endogenously as well as exogenously for our study. \bar{G} is set exogenously.

We quantitatively explore one of the efficient level of the airport-related charges (remedy charges) which can improve social welfare.

The social welfare function is composed of consumer surplus CS_{rt} and producer surplus PS_{rt} and environmental externality E_{jrt} . The Lagrangian formulation of social welfare maximization problem with the budget constraint is

$$\Phi = \sum_s \sum_r \sum_t CS_{rt} + \sum_j \sum_r \sum_t PS_{jrt} + \sum_j \sum_r \sum_t E_{jrt} + \varphi (K - \bar{K} - C(Capacity)) \quad (6)$$

\bar{K} is the present total charge revenue and $C(Capacity)$ is the investment in runway by the government. Lagrange multiplier φ express $-MCPF$.

3. PARAMETERS

This study uses monthly data by route and airline from 2000 to 2005.

We estimate the demand parameters by using a generalized method of moments (GMM) approach with the population moment condition of a product of ξ_{jrt} and the exogenous variables. We use the method of instrumental variables to address endogeneity problem between ξ_{jrt} and airfares, flight frequency

and share within airlines.

The result of estimation is omitted.

4. REMEDY CHARGES

The per-flight charge depends on the aircraft weight. In the current system, the weight of the aircraft is divided into three classifications, and each charge rate is applicable to each classification. From zero to 25 tons, 1,100 yen per ton is charged; from 25 to 100 tons, 1,500 yen per ton is charged; from 100 to 200 tons, 1,700 yen per ton is charged. When we explore remedy per-flight charges, we simplify these per-ton charges to one per-ton charge and the base charge.

We calculate the remedy airport-related tax and charges and labor tax τ with the real data in October in 2005 (186 routes). Table 1 shows that the remedy charges are important to improve social welfare.

Table 1 Optimal tax and charges under scenario 1 and 2

	Reference (present level)	Remedy charges
Airport related charges		
Per-passenger charge [1,000 yen]	0.1	-0.5
Per-flight charge		
base part [yen]	0	0
weight related part [yen / ton]	1,500	2,000
Fuel tax [1,000 yen / kL]	26,000	40,000
Surpluses [10⁹ yen]		
Consumer surplus	4,430	7,510
Producer surplus	2,680	2,980
General government funds	400	410
Social welfare	7,110	10,500
Airfare, flight frequency and weight		
Average airfare [1,000 yen]	23.2	22.4
Average flight frequency [round trip / day]	2.8	3.2
Average weight [ton]	86.3	75.8

Result of remedy charges indicates that per-passenger charge rates are negative (i.e. subsidies to passengers). A negative charge means a subsidy from the government. This result is the same as Silva and Verhoef (2013).

This per-passenger subsidy arises from the oligopolistic competition in the airlines. The oligopolistic effects affect both airfare and flight frequency. Because of the subsidy of passengers, the average airfare decrease. The larger per-flight charge and fuel tax causes a reduction in aircraft weight, which in turn increase flight frequency.

The subsidy of per-passenger charge reduces airport charge revenue but the large per-flight charge and fuel tax increase airport charge revenue. As a result, the general government funds is almost equal to present level.

The remedy charges can improve social welfare by 48%. From the viewpoint of social welfare, the present flight frequency is not sufficient and it should be corrected to improve the social welfare with the per-flight charge and fuel tax.

5. CONCLUSION

This study theoretically derives the formula for simultaneously optimizing airport-related charges. The formulas take account of the marginal cost of public funds. We consider a per-passenger charge, per-flight charges and aviation fuel tax.

Our quantitative analyses contribute to the literature in the sense that we show how much welfare gain can be expected by remedy charges. The result has shown that we can improve the social welfare to about 148 % of the present level. We find the present level of airfare is higher than ideal level because of the oligopolistic competition in the airlines. In addition, the present flight frequency is not sufficient and it should be corrected by higher per-flight charge and fuel tax. High per-flight charge and fuel tax reduce in aircraft weight, which in turn increase flight frequency.

We need to consider constraints on the number of seats and the number of passengers. And more, we will explore optimal airport charges and capacity with respect to social welfare. In this study, we will also compare optimal airport charges and capacity under different MCPF.

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