Does Entry Regulation in the Airline Market Improve Social Welfare ?*

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Abstract

This paper presents an analysis of whether entry regulation in the airline market improves social welfare or not. When an entrant enters the market, airline companies undertake price competition. Consequently, the flight frequency of each airline company might decrease. When the flight frequency of each airline decreases, operation costs decrease; the benefit for passengers also decreases. Therefore, this paper uses price competition with a product differentiation model, showing that entry regulation in the airline market improves social welfare or not depending on the degree of product differentiation.

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Keywords: entry regulation, deregulation, undercut-proof equilibrium, network effect, entry deterrence

1 Introduction

In the airline market, many countries have promoted deregulation since 1978, when airline markets in America were deregulated. The progress of deregulation was accelerated by contestable market theory in 1980.

Until now, we have considered that fixed costs to enter the airline market (e.g. aircraft lease or equipment investment) are large. Destructive competition can occur if free entry is allowed. Therefore, entry regulations have been imposed. However, the entry costs for airline markets are increasingly shrinking because of the development of markets for used aircraft or other technologies: airline markets are now contestable. Consequently, various regulations in the airline market have been relaxed or abolished.

In Japan, as entry regulation has become relaxed in recent years, some new airline companies have entered the market and have typically competed on the basis of price. Passenger demand thereby became divided between the incumbent airline company and entrant; in addition, the price for airline service has decreased. In that case, the possibility to decrease flight frequency

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for each airline company exists because the marginal revenue of one flight decreases. When flight frequency decreases, passengers' benefits decrease, which is disadvantageous, but the total operation costs also decrease, providing an advantage for operators. These advantages and disadvantages mark a trade-off also for social welfare.

This study examines whether entry regulation in the airline market improves social welfare or not, using the price competition with product differentiation model to consider the trade-off described above. Here, it is noteworthy that these analyses ignore price regulation or flight frequency regulation that accompanies entry regulation[1]. This paper presents discussion only of the efficiency of entry regulation. Analyses described herein show that entry regulation improves social welfare depending on the degree of airline service differentiation.

In addition, this paper introduces heterogeneity of marginal operating costs between incumbents and entrants. This assumption expresses that entrant airline companies can serve their markets at a lower operation cost per flight than the incumbent company. This study describes how heterogeneity influences each airline's decision: each airline company's price, flight frequency and incentive for entry deterrence.

Up to now, few studies have examined entry regulation's effects on social welfare. In one study, Kim (1997) presents the inefficiency of entry regulation for a general market. Kim (1997) considers the existence of a fixed cost and uses a model in which companies determine the product quantity and level of equipment investment, showing that entry regulation allows incumbents to deter entrants easily. Thereby, entry regulations worsen social welfare.

Kim (2003) analyzes the entry deterrence problem for intertemporal markets, showing that limit pricing can be an equilibrium strategy. In addition, Kim (2003) considers whether entry regulation improves social welfare. Kim (2003) shows that entry regulation worsens social welfare because entry regulation allows incumbents to deter entrants easily. This conclusion is identical to that for Kim (1997). However, these studies are not suitable for an airline market. For example, airline companies decide price and flight frequency, not quantity and level of investment. Thereby, this paper uses a suitable model for airline markets and analyzes whether entry regulation improves social welfare.

De Vany (1975), Schipper et al. (2003), and others attack the problem for entry regulation in the airline market. However, these studies' objectives differ from those of this paper. De Vany (1975) analyzes how entry regulation and price regulation affect flight frequency, cost and the number of passengers. Schipper et al. (2003) analyzes the effect of liberalization for the airline market, including the influence of an external market (e.g. environment).

Kawasaki (2006) discusses the inefficiency of free entry into the airline market: inefficiency

[1] In future studies, we must relax this assumption.

without entry regulation. Kawasaki (2006) considers that two airline companies decide to enter the market simultaneously, showing that excessive entry can occur even when fixed costs do not exist. This reason is as follows: when airline companies undertake price competition, each airline's service price decreases and the marginal revenue of each flight decreases. For those reasons, the airline company decreases flight frequency. When an airline company decreases flight frequency, the benefit for passengers decreases and social welfare worsens. Based on the above discussion, Kawasaki (2006) proposes that entry regulation might be necessary to prevent excessive entry.

This paper changes the model of Kim (1997), which describes the general market, to that of Kawasaki (2006), which is applicable to the airline market. In addition, a slight change is made from Kawasaki (2006). In Kawasaki (2006), each airline company enters the market simultaneously. Herein, only potential entrants decide to enter the market. Incumbents have already entered the market. In addition, each airline company chooses the flight frequency sequentially; the incumbent airline is the leader and the entrant is the follower. Therefore, the incumbent airline company can take an entry-deterrent strategy. This paper shows that entry regulation can improve social welfare, which is different from Kim (1997).

The remainder of the paper is organized as follows. The model is set up in Section 2. Section 3 analyzes the service prices for an incumbent airline and entrant, and the flight frequency of the entrant. Section 4 analyzes whether potential entrants actually enter the market, and analyzes whether regulators allow entry for potential entrants if entry regulation is imposed. Section 5 analyzes the flight frequency for an incumbent airline. Here, whether an incumbent deters the entry is analyzed. In section 6, social welfare with entry regulation is compared with those without entry regulation. Section 7 offers conclusions.

2 The Model

A three-city model is used, with cities A, B, and H. Two airline companies, airline A in city A and airline B in city B, are assumed to serve the needs of residents. Potential passengers reside in cities A and B. Suppose that passengers in each city are identical [2]. Passengers in each city go to city H.

Assume that another airline company (or train, bus) is situated between cities A and B; using it, passengers can move between those cities. When passengers in city A (or B) move to city B (or A), they incur an additional cost δ (e.g. a time cost).

Each passenger has an equal willingness to pay for service, expressed as R. When passengers

[2] Using a Hotelling-type model, the analysis is complex. For that reason, this paper does not use such a model, but future research will use one for analyses.

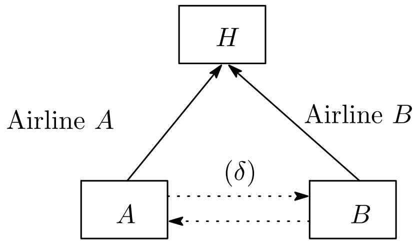

Figure 1: The Model

use the airline, they gain extra benefit R. Each airline flies to each city pair by $f_i(i = a, b)$. When an airline increases its flight frequency, each passenger enjoys greater convenience, so passengers' benefits increase. These analyses presume that passengers' marginal benefit is constant. Each passenger's utility function is presented as follows. The passengers' utility function in city A is expressed as U_a; the passengers' utility function in city B is U_b.

$$U_a = \begin{cases} R + f_a - p_a & \text{using airline } A \\ R + f_b - \delta - p_b & \text{using airline } B \end{cases} \quad (1)$$

$$U_b = \begin{cases} R + f_a - \delta - p_a & \text{using airline } A \\ R + f_b - p_b & \text{using airline } B \end{cases} \quad (2)$$

Here, $p_i(i = A, B)$ expresses the price for airline i. Assume that when both airlines form a network, all passengers use airline companies. All passengers have sufficiently high willingness to pay. Formally, assume that $R \geq 2\delta$.

Assume that the cost per passenger is constant and zero. Each airline, when it flies f_i times, incurs operating costs. These costs increase with frequency, and marginal costs increase. For example, landing fees increase with frequency because of airport congestion[3]. In addition, this study introduces heterogeneous marginal operation costs, as expressed by c_i. We subsume that the setup cost is zero (or negligible) because these analyses incorporate the idea that the present airline market has sufficiently small setup costs. Therefore, the cost function of each airline is $C_i(f_i)(i = a, b)$. This function is

$$C_i(f_i) = c_i(f_i)^2 \ (i = a, b).$$

Entrants cannot take the strategy that incumbents cannot earn a non-positive profit. In other words, the entrant cannot send away incumbent airlines [4].

Timeline This paper presents the following timeline. In the first stage, incumbent airline A reports a navigation plan to the government. This report is necessary for operation of incumbent

[3] This interpretation follows Hassin and Shy (2000).
[4] Future studies will relax this assumption.

airlines, even without entry regulation. It is obligatory for an airline reporting a navigation plan to the Ministry of Land, Infrastructure and Transport. Here, assume that government does not regulate navigation plans, and airlines must follow the navigation plans. In the second stage, entrant airline B chooses to enter the market or not. If entry regulation is imposed for the entrant, government decides to allow airline B's entry or not. Here, we presume that when airline B applies for entry, airline B need not determine flight frequency (f_b) and price (p_b). In the third stage, airline A determines the price, and when airline B enters the market, airline B determines the flight frequency and price. Each airline reports these decisions to the government. Here, government does not regulate the flight frequency and price[5].

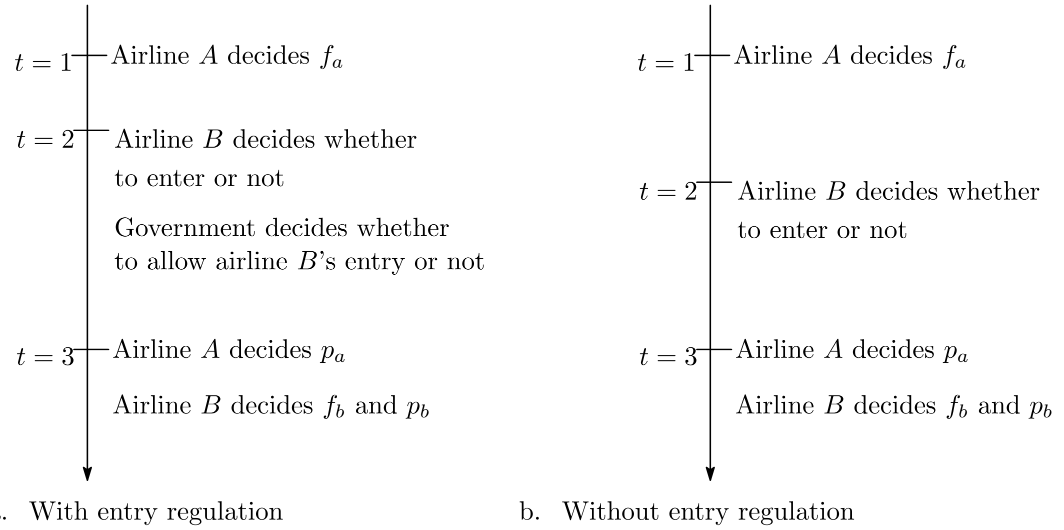

Figure 2: Timeline

Below, we solve this problem through backward induction and derive a sub-game perfect equilibrium. Social welfare with entry regulation and that without entry regulation are compared.

3 The Price for each Airline and Flight Frequency for Airline B

This section presents how each airline determines a price and airline B decides flight frequency.

3.1 The Case that Airline A is a Monopoly

First, analyze the case: in the second stage, airline B does not enter the market, so airline A is a monopoly. Airline A has the opportunity to set a price at which all passengers use it, or only

[5]This study examines the efficiency of entry regulation alone. However, future research efforts will relax these assumptions.

city A' s passengers use it. If airline A sets the price for all passengers to use, the price is

$$p_a = R + f_a - \delta. \tag{3}$$

Thereby, the profit for airline A is

$$\pi_a = 2(R + f_a - \delta) - c_a f_a^2. \tag{4}$$

If airline A sets the price for only city A's passengers to use, the price is

$$p_a = R + f_a. \tag{5}$$

Therefore, the profit for airline A is

$$\pi_a = R + f_a - c_a f_a^2. \tag{6}$$

Here, compare the profit when all passengers use airline A with that when only passengers in city A. We obtain the following Lemma.

Lemma 1 *Presume that airline A is a monopoly. Then, the profit for all passengers to use is larger than that for city A's passengers to use.*

Proof Let the differentiation between the profit for all passengers using an airline and that for only city A's passengers use of it be expressed as $\Delta\pi$.

$$\Delta\pi = R + f_a - 2\delta. \tag{7}$$

From the assumption that $R \geq 2\delta$, eq. (7) is positive. Therefore, the profit for all passengers to use an airline is larger. □

3.2 The Case in which Airline B Enters the Market

Next, consider the following case. Airline B enters the market and the market is a duopoly. When airline B enters the market, each airline undertakes price competition. This paper uses *Undercut-Proof equilibrium* for the equilibrium concept of price competition[6].

Derive the demand function for each airline. We express airline i's demand as $D_i (i = a, b)$.

$$D_a = \begin{cases} 2 & (p_a < (f_a - f_b) - \delta + p_b) \\ 1 & ((f_a - f_b) - \delta + p_b \leq p_a \leq (f_a - f_b) + \delta + p_b) \\ 0 & (p_a > (f_a - f_b) + \delta + p_b) \end{cases} \tag{8}$$

$$D_b = \begin{cases} 2 & (p_b < (f_b - f_a) - \delta + p_a) \\ 1 & ((f_b - f_a) - \delta + p_a \leq p_b \leq (f_b - f_a) + \delta + p_a) \\ 0 & (p_b > (f_b - f_a) + \delta + p_a) \end{cases} \tag{9}$$

[6] Regarding the undercut-proof equilibrium, see Shy (2001) or Kawasaki (2006).

The undercut-proof equilibrium denotes the following: the profit when only passengers who prefer airline A use it is larger than that when each airline undercuts the price and lets all passengers use it. Therefore, the condition for airline A to protect itself, to "undercut-proof" its operations, is as follows: the profit when $p_a = p_a^U$ and only city A's passengers use it is larger than that when $p_a = (f_a - f_b) - \delta + p_b$ and all passengers use it. This condition is expressed as follows:

$$p_a^U \geq 2\{(f_a - f_b) - \delta + p_b\} \tag{10}$$

For the same reason, the condition for airline B to undercut-proof is

$$p_b^U \geq 2\{(f_b - f_a) - \delta + p_a\}. \tag{11}$$

Summarizing eq. (10) and eq. (11), Fig. 3 is expressed as follows. The domain under eq. (10)

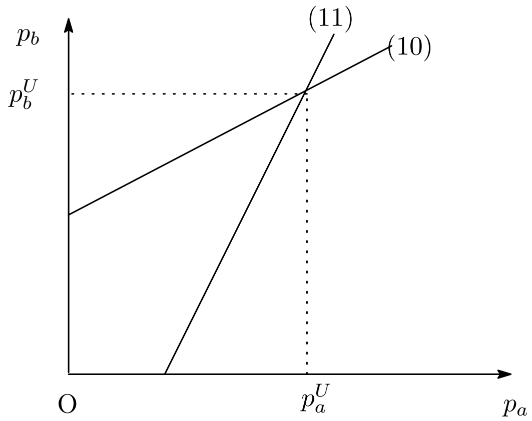

Figure 3: Undercut-proof equilibrium

means that airline A does not undercut the price. Furthermore, the domain above eq. (11) means that airline B does not undercut the price. Each airline sets the highest price in this domain, so the undercut-proof equilibrium is (p_a^U, p_b^U), which is a point of intersection. The undercut-proof equilibrium is

$$p_a^U = \frac{2}{3}(f_a - f_b) + 2\delta \tag{12}$$

$$p_b^U = \frac{2}{3}(f_b - f_a) + 2\delta. \tag{13}$$

Consequently, each airline's profit is

$$\pi_a = \frac{2}{3}(f_a - f_b) + 2\delta - c_a f_a^2 \tag{14}$$

$$\pi_b = \frac{2}{3}(f_b - f_a) + 2\delta - c_b f_b^2. \tag{15}$$

Airline B chooses its flight frequency in this stage. Solving the maximization problem for airline B, the flight frequency for airline B is

$$f_b = \frac{1}{3c_b}. \tag{16}$$

The above discussions imply that each airline's profit is the following.

$$\pi_a = \frac{2}{3}\left(f_a - \frac{1}{3c_b}\right) + 2\delta - c_a f_a^2 \tag{17}$$

$$\pi_b = \frac{1}{9c_b} + 2\delta - \frac{2}{3} f_a \tag{18}$$

4 Entry Decision for Airline B

This section presents whether airline B enters the market, and whether regulators allow airline B to enter the market when entry regulation is imposed for airline B.

4.1 Case: Entry Regulation is not Imposed

Presume that entry regulation is not imposed. Without positive profit, airline B does not enter the market. In other words, if eq. (18) is non-positive, airline B does not enter the market. Therefore, the condition in which airline B does not enter the market is

$$f_a \geq \frac{1}{6c_b} + 3\delta. \tag{19}$$

From the above discussion, eq. (19) is the condition by which airline A deters airline B's entry.

4.2 Case: Entry Regulation is Imposed

Suppose that entry regulation is imposed. Airline B enters the market when (1) it gains positive profit, and (2) regulators allow airline B's entry. The case in which regulators allows airline B's entry is the following: social welfare in stage two when airline B enters the market is larger than that when airline B does not enter the market.

When airline B enters the market, the social welfare in stage two is expressed as $W_2^D(f_a)$.

$$W_2^D(f_a) = 2R + \frac{2}{9c_b} + f_a - c_a f_a^2 \tag{20}$$

When airline B does not enter the market, the social welfare in stage two is the following:

$$W_2^M(f_a) = 2R + 2f_a - \delta - c_a f_a^2 \tag{21}$$

Here, the case in which only passengers in city A use airline A is ignored because this strategy never occurs.

Comparing the social welfare when airline B enters the market (eq. (20)) with that when airline B does not enter the market (eq. (21)), and if eq. (21) is larger than eq. (20), then regulators do not allow airline B's entry. In other words, if

$$f_a \geq \frac{2}{9c_b} + \delta, \tag{22}$$

airline B's entry is not allowed.

Considering that airline B does not enter the market without positive profits, the condition that airline A deters airline B's entry is the following.

$$f_a \geq \min\{\delta + \frac{2}{9c_b}, 3\delta + \frac{1}{6c_b}\} \tag{23}$$

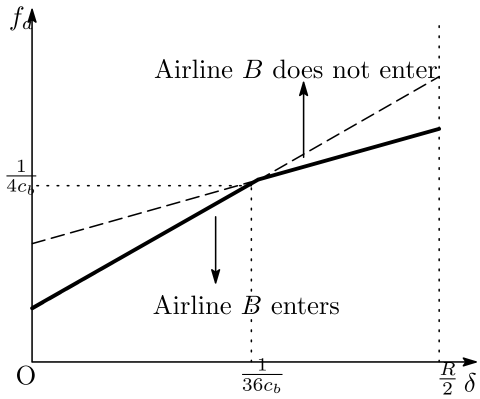

Figure 4: Condition to deter airline B's entry

This condition is expressed as Fig. 4, which shows the following: assume that $\delta \leq \frac{1}{36c_b}$. When $f_a \geq 3\delta + \frac{1}{6c_b}$, airline B does not enter the market. Next assume that $\delta > \frac{1}{36c_b}$. When $f_a \geq \delta + \frac{2}{9c_b}$, airline B does not enter the market. Thereby, we find that when $\delta \leq \frac{1}{36c_b}$, airline A can deter airline B's entry through offering a lower flight frequency if entry regulation is imposed.

5 Airline A's Flight Frequency and Entry Deterrence for Airline B

In this section, we analyze airline A' s flight frequency. Notice that airline A has two strategies: one is to allow airline B's entry; the other is to deter airline B's entry.

5.1 Without Entry Regulation

5.1.1 When airline A is a Monopoly

First, analyze the following case: airline A, a monopoly, deters airline B's entry. Airline A anticipates that, in stage three, airline A sets the price that all passengers must use. Thereby, airline A's profit function is

$$\pi_a = 2(R + f_a - \delta) - c_a f_a^2. \tag{24}$$

Airline A determines the flight frequency to maximize this profit subject to the condition that airline B does not enter the market. In other words, airline A's profit maximization problem is the following:

$$\max_{f_a} \quad \pi_a \tag{25}$$

$$s.t. \quad f_a \geq 3\delta + \frac{1}{6c_b} \tag{26}$$

Solving this problem, airline A's flight frequency is as follows.

$$f_a = \begin{cases} \frac{1}{c_a} & (\delta \leq \frac{1}{3c_a} - \frac{1}{18c_b}) \\ 3\delta + \frac{1}{6c_b} & (\delta > \frac{1}{3c_a} - \frac{1}{18c_b}) \end{cases} \tag{27}$$

Therefore, the profit when airline A is a monopoly is the following.

$$\pi_a^M = \begin{cases} 2R + \frac{1}{c_a} - 2\delta & (\delta \leq \frac{1}{3c_a} - \frac{1}{18c_b}) \\ 2R + 4\delta + \frac{1}{3c_b} - c_a \left(3\delta + \frac{1}{6c_b}\right)^2 & (\delta > \frac{1}{3c_a} - \frac{1}{18c_b}) \end{cases} \tag{28}$$

5.1.2 When airline B enters the market

Next, analyze the following case: airline B enters the market and the market is a duopoly. In this case, each airline undertakes price competition. Therefore, airline A's profit maximization problem is

$$\max_{f_a} \quad \frac{2}{3}\left(f_a - \frac{1}{3c_b}\right) + 2\delta - c_a f_a^2. \tag{29}$$

Solving this profit maximization problem, the flight frequency of airline A is $\frac{1}{3c_a}$. Here, notice the following: when $\delta \leq \frac{1}{9c_a} - \frac{1}{18}c_b$, airline B does not gain positive profit and does not enter the market. Therefore, the condition in which this case exists is $\delta > \frac{1}{9c_a} - \frac{1}{18}c_b$.

When airline B enters the market, airline A's profit is as follows.

$$\pi_a^D = \frac{2}{9c_a} - \frac{2}{9c_b} + 2\delta \tag{30}$$

In addition, airline B's profit is

$$\pi_b^D = \frac{2}{9c_b} - \frac{2}{9c_a} + 2\delta. \tag{31}$$

When the marginal operation cost of airline A (or B) increases, airline A (or B)'s profit decreases. Airline B (or A)'s profit increases. When the marginal operation cost of airline A increases, airline A decreases flight frequency. This lowers airline A's service price. In addition, operation costs increase. Consequently, airlines A's profit decreases. When airline A's flight frequency decreases, airline B can set a higher price: airline B's profit increases.

5.1.3 Airline A's entry deterrence strategy

Here, we analyze the situation when airline A deters airline B's entry, comparing airline A's profit when airline A is a monopoly with that when airline B enters the market.

Figure 5 expresses each case's profit for airline A: (1) when airline A is a monopoly, and (2) when market is a duopoly. In Fig. 5, $\delta^* = \frac{1}{18c_a}\left(2 - \frac{c_a}{c_b} + \sqrt{\frac{16c_a}{c_b} + 72c_aR}\right)$.

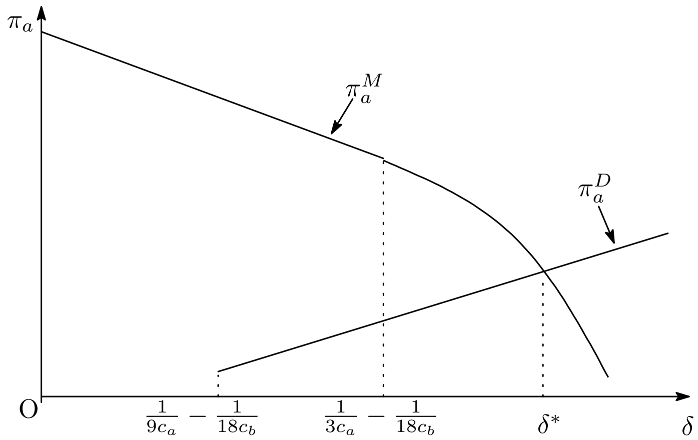

Figure 5: Comparison of monopoly and duopoly profits

Here, presume that when $\delta = \frac{1}{3c_b} - \frac{1}{18c_b}$, airline A's duopoly profit is positive: formally, assume that $c_a \leq \frac{8}{3}c_b$. This assumption is valid for the following analysis. The above discussion suggests the following proposition.

Proposition 1 *Suppose that entry regulation is not imposed. If $\delta \leq \delta^*$, market is a monopoly. If $\delta > \delta^*$, the market is a duopoly.*

Here, consider the characteristics for δ^* using comparative static analysis. When the marginal operation cost of airline A increases,

$$\frac{\partial \delta^*}{\partial c_a} = -\frac{(3\delta + \frac{2}{6c_b})^2 - \frac{2}{9c_a^2}}{6c_a(3\delta + \frac{1}{6c_b}) - 2}.$$

For δ^* to exist, $\delta^* \geq \frac{1}{3c_a} - \frac{1}{18c_b}$ must hold because, for the range that $\delta < \frac{1}{3c_a} - \frac{1}{18c_b}$, the monopoly's profit is always larger than duopoly's profit. Therefore, both the denominator and numerator are positive. Consequently, the domain in which airline A is a monopoly decreases when the marginal operation cost of airline A increases.

When the marginal operation cost of airline B increases,

$$\frac{\partial \delta^*}{\partial c_b} = \frac{\frac{1}{9c_b^2}(9c_a\delta + \frac{c_a}{2c_b} - 5)}{6c_a(3\delta + \frac{1}{6c_b}) - 2}. \tag{32}$$

From eq. (32), the following lemma is obtained.

Lemma 2 *Suppose that $c_a \leq \frac{64c_b}{1+72c_bR}$. The incentive for airline A to deter airline B's entry weakens when the marginal operation cost of airline B increases. Assume that $c_a > \frac{64c_b}{1+72c_bR}$. That incentive strengthens as the marginal operation cost of airline B increases.*

The sign of eq. (32) depends on the following: the degree of monopoly profit's change and that of duopoly profit's change when c_b increases. Figure 6 expresses the marginal profit of each case when c_b increases.

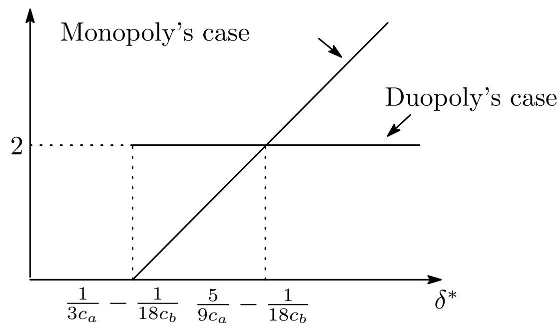

Figure 6: Comparison of each case's marginal profit

When $\delta^* \leq \frac{5}{9c_a} - \frac{1}{18c_b}$ ($c_a \leq \frac{64c_b}{1+72c_bR}$), the duopoly's marginal profit is greater than the monopoly's. Therefore, airline A has an incentive to be a duopoly. On the other hand, when $\delta^* > \frac{5}{9c_a} - \frac{1}{18c_b}$ ($c_a > \frac{64c_b}{1+72c_bR}$), the monopoly's marginal profit is larger than the duopoly's. Thereby, airline A has an incentive to exist as a monopoly.

5.2 With Entry Regulation

5.2.1 When airline A is a Monopoly

First, analyze the following case: airline A, which is a monopoly, deters airline B's entry. Airline A sets the price for all passengers to use. Therefore, airline A's profit function is

$$\pi_a = 2(R + f_a - \delta) - c_a f_a^2. \tag{33}$$

Airline A determines the flight frequency to maximize this profit subject to the condition that airline B does not enter the market. In other words, airline A's profit maximization problem is the following:

$$\max_{f_a} \quad 2(R + f_a - \delta) - c_a f_a^2, \tag{34}$$

$$s.t. \quad f_a \geq \min\{3\delta + \frac{1}{6c_b}, \delta + \frac{2}{9c_b}\}. \tag{35}$$

From Fig. 4, the constraint equation (eq. (35)) apparently changes depending on δ.

When $\delta \leq \frac{1}{36c_b}$ In this case, the constraint condition for airline A is $f_a \geq 3\delta + \frac{1}{6c_b}$. Solving this problem, the flight frequency for airline A is $f_a = \frac{1}{c_a}$; this satisfies the condition from the assumption. Therefore, airline A's profit is as follows.

$$\pi_a = 2R + \frac{1}{c_a} - 2\delta \tag{36}$$

When $\delta > \frac{1}{36c_b}$ In this case, the constraint condition for airline A is $f_a \geq \delta + \frac{2}{9c_b}$. Solving this problem, the flight frequency for airline A is determined depending on δ:

$$f_a = \begin{cases} \frac{1}{c_a} & (\delta \leq \frac{1}{c_a} - \frac{2}{9c_b}) \\ \frac{1}{6c_b} + 3\delta & (\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}) \end{cases} \tag{37}$$

Thereby, the profit for airline A is the following.

$$\pi_a = \begin{cases} 2R + \frac{1}{c_a} - 2\delta & (\delta \leq \frac{1}{c_a} - \frac{2}{9c_b}) \\ 2R + \frac{4}{9c_b} - c_a \left(\delta + \frac{2}{9c_a}\right)^2 & (\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}) \end{cases} \tag{38}$$

Those discussions show that when entry regulations are imposed, airline A's monopoly profit is expressed as follows.

$$\pi_a^M = \begin{cases} 2R + \frac{1}{c_a} - 2\delta & (\delta \leq \frac{1}{c_a} - \frac{2}{9c_b}) \\ 2R + \frac{4}{9c_b} - c_a \left(\delta + \frac{2}{9c_b}\right)^2 & (\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}) \end{cases} \tag{39}$$

5.2.2 When airline B enters the market

Next, analyze the case in which airline B enters the market; the market is a duopoly. From previous discussions, the flight frequency of airline A is $\frac{1}{3c_a}$. Here, it is noteworthy that when $\delta \leq \min\{\frac{1}{9c_a} - \frac{1}{18c_b}, \frac{1}{3c_a} - \frac{2}{9c_b}\}$, airline B does not gain positive profit and does not enter the market. When airline B enters the market, airline A's profit is as follows.

$$\pi_a^D = \frac{2}{9c_a} - \frac{2}{9c_b} + 2\delta \tag{40}$$

In addition, airline B's profit is

$$\pi_b^D = \frac{2}{9c_b} - \frac{2}{9c_a} + 2\delta. \tag{41}$$

5.2.3 Airline A's entry deterrence strategy

Here, we analyze when airline A deters airline B's entry, comparing airline A's profit when airline A is a monopoly with that when airline B enters the market.

Figure 7 expresses each case's profit for airline A: (1) when airline A is a monopoly, and (2) when the market is a duopoly. In Fig. 7, $\delta^{**} = \frac{1}{c_a}\left(-\frac{2c_a}{9c_b} - 1 + \sqrt{\frac{8}{9} + \frac{10c_a}{9c_b} + 2c_a R}\right)$.

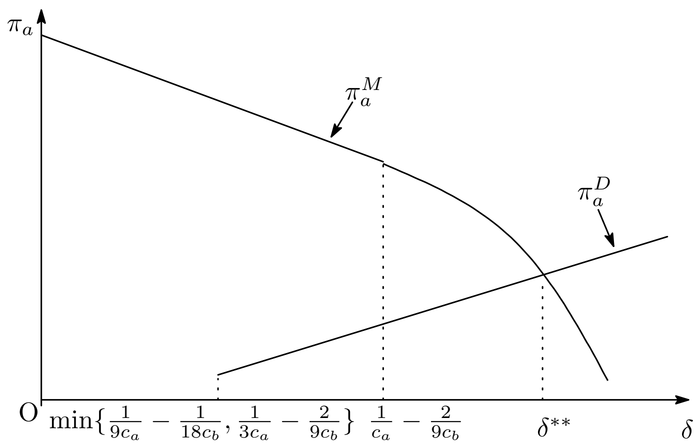

Figure 7: Comparison of monopoly's profit with duopoly's profit

From the above discussion, the following proposition is gained.

Proposition 2 *Assume that entry regulation is imposed. If $\delta \leq \delta^{**}$, then the market is a monopoly. If $\delta > \delta^{**}$, the market is a duopoly.*

Here, consider the characteristic for δ^{**} using comparative static analyses. When the marginal operation cost of airline A increases,

$$\frac{\partial \delta^{**}}{\partial c_a} = -\frac{(\delta + \frac{2}{9c_b})^2 - \frac{2}{9c_a^2}}{2c_a(\delta + \frac{2}{9c_b}) + 2}.$$

For δ^{**}, $\delta^{**} \geq \frac{1}{c_a} - \frac{2}{9c_b}$ must hold. Therefore, both the denominator and numerator are positive. For that reason, the domain in which airline A is a monopoly decreases when the marginal operation cost of airline A increases.

When the marginal operation cost of airline B increases,

$$\frac{\partial \delta^{**}}{\partial c_b} = -\frac{\frac{1}{9c_b^2}(-4c_a(\delta + \frac{2}{9c_b}) + 6)}{2c_a(\delta + \frac{2}{9c_b}) + 2} \tag{42}$$

From eq. (42), the following lemma is obtained.

Lemma 3 *Suppose that* $c_a \leq \frac{197c_b}{8(10+18c_bR)}$*. The incentive for airline A to deter airline B's entry weakens when the marginal operation cost of airline B increases. Suppose that* $c_a > \frac{197c_b}{8(5+9c_bR)}$*. The incentive strengthens when the marginal operation cost of airline B increases.*

A sign of eq. (42) depends on the following: the degree of monopoly profit's change and that of duopoly profit's change when c_b increases. Figure 8 expresses the marginal profit of each case when c_b increases.

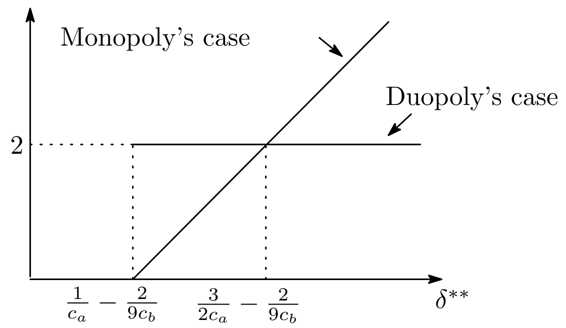

Figure 8: Comparison of each case's marginal profit

When $\delta^{**} \leq \frac{3}{2c_a} - \frac{2}{9c_b}$ ($c_a \leq \frac{197c_b}{8(5+9c_bR)}$), the duopoly's marginal profit is greater than the monopoly's. For that reason, airline A has an incentive to embrace duopoly. In contrast, when $\delta^{**} > \frac{3}{2c_a} - \frac{2}{9c_b}$ ($c_a > \frac{197c_b}{8(5+c_bR)}$), the monopoly's marginal profit is greater than the duopoly's. Thereby, airline A has an incentive to be a monopoly.

6 Comparison of the case with entry regulation and the case without entry regulation

6.1 Incentive to deter entry

First, compare δ^*, which denotes a boundary between monopoly and duopoly without entry regulation, and δ^{**}, which means a boundary with entry regulation. Each equation is changed as follows to compare those by simulation.

$$\Delta^* \equiv c_a \cdot \delta^* = \frac{1}{9} - \frac{1}{18}c + \sqrt{\frac{4}{81}c + \frac{2}{9}\overline{R}} \tag{43}$$

$$\Delta^{**} \equiv c_a \cdot \delta^{**} = -1 - \frac{2}{9}c + \sqrt{\frac{8}{9} + \frac{10}{9}c + 2\overline{R}} \tag{44}$$

We define that $c \equiv \frac{c_b}{c_a}$ and $\overline{R} \equiv c_a \cdot R$. Assume that $\delta^{**} \geq \frac{1}{c_a} - \frac{2}{9c_b}$ to compensate δ^* and δ^{**}. In addition, it holds that $R \geq 2\delta$[7] and $c \leq \frac{8}{3}$ from the model's assumptions.

[7] In other words, $\overline{R} \geq 2 - \frac{4}{9}c$.

Here, δ^* and δ^{**} can be shown as a three-dimensional figure with two variables: $\overline{R}$ and c. Thereby, Fig. 9 is expressed, showing the range that $0 \leq c \leq \frac{8}{3}$ and $\frac{22}{27} \leq \overline{R} \leq 5$[8].

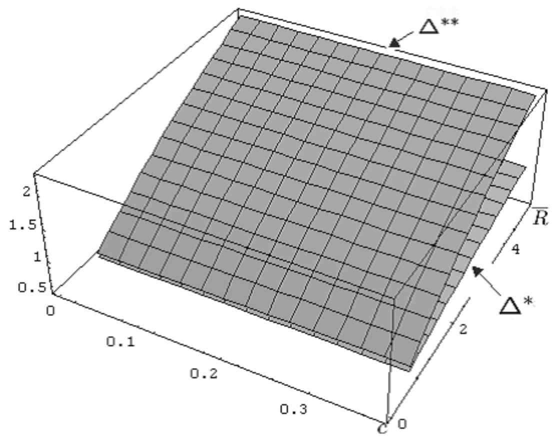

Figure 9: Comparison of δ^* with $\delta**$

Figure 9 shows that $\delta^{**} > \delta*$: the range that airline A is a monopoly with entry regulation is larger than that without entry regulation. Airline A can deter airline B's entry by low flight frequency when entry regulations are imposed because airline A need not increase flight frequency until airline B's profit is non-positive. Therefore, when entry regulations are imposed, airline A can more readily deter airline B's entry.

6.2 Social Welfare

Here, analyze whether government must impose entry regulation for potential entrants, comparing the social welfare with entry regulation and that without entry regulation. Social welfare is defined as the sum of passengers' utility and the airlines' profits:

$$SW = U_a + U_b + \pi_a + \pi_b$$

6.2.1 Social welfare without entry regulation

First, derive social welfare without entry regulation.

[8]The reason for defining $\frac{22}{27} \leq \overline{R} \leq 5$ is as follows. The minimum of $\overline{c}$ is when $\frac{8}{3}$. Therefore, $\overline{R} \geq \frac{22}{27}$ is defined. In addition, an upper limit is not without generality.

The case in which $\delta \leq \frac{1}{3c_a} - \frac{1}{18c_b}$ In this case, airline A is a monopoly, and $f_a = \frac{1}{c_a}$. Therefore, the social welfare is

$$SW = 2(R + f_a) - \delta - c_a f_a^2$$
$$= 2R + \frac{1}{c_a} - \delta. \tag{45}$$

When the distance between two cities is large, city B's passengers incur larger disutility: social welfare is small. When the marginal operation cost of airline A increases, the flight frequency decreases and operation costs increase; consequently, social welfare decreases.

The case in which $\frac{1}{3c_a} - \frac{1}{18c_b} \leq \delta \leq \delta^*$ In this case, airline A is a monopoly and takes an entry deterrence strategy, and $f_a = 3\delta + \frac{1}{6c_b}$. Thereby, the social welfare is

$$SW = 2(R + f_a) - \delta - c_a f_a^2$$
$$= 2R + 5\delta + \frac{1}{3c_b} - c_a \left(3\delta + \frac{1}{6c_b}\right)^2. \tag{46}$$

When the distance between two cities is great, airline A increases flight frequency to deter airline B's entry: passengers enjoy convenience. However, operation cost increases and disutility for city B's passenger increases. Considering the above, the sum of disutility and increased costs is greater than the passengers' convenience. Consequently, social welfare decreases.

When the marginal operation costs of airline A increase, the operation cost increases: social welfare decreases. When the marginal operation costs of airline B increase, the flight frequency of airline A decreases; consequently, the operation cost of airline A decreases, along with passengers' convenience. Comparing these, the former effect is larger than the latter effect and social welfare increases.

The case in which $\delta \geq \delta^*$ In this case, airline B enters the market and the market is a duopoly. Each airline's flight frequency is $f_a = \frac{1}{3c_a}$, and $f_b = \frac{1}{3c_b}$. Therefore, social welfare is calculated as the following.

$$SW = 2R + f_a + f_b - c_a f_a^2 - c_b f_b^2$$
$$= 2R + \frac{2}{9c_a} + \frac{2}{9c_b} \tag{47}$$

Each passenger uses the airline that exists in each city: there is no disutility δ. When marginal operation cost of airline $i(i = A, B)$, the flight frequency decreases and operation costs increase: social welfare decreases.

Each case's social welfare is expressed in Fig. 10. It is noteworthy that the social welfare is discontinuous in δ^* and monopoly's welfare is less than duopoly's welfare.

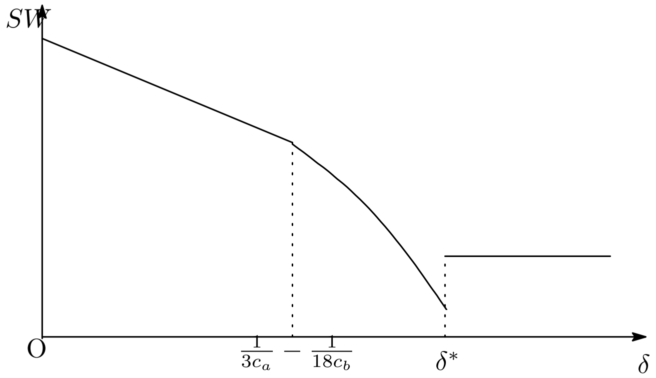

Figure 10: Social welfare without entry regulation

6.2.2 Social welfare with entry regulation

Next, derive the social welfare with entry regulation.

The case in which $\delta \leq \frac{1}{c_a} - \frac{2}{9c_b}$ In this case, airline A is a monopoly and $f_a = \frac{1}{c_a}$. Therefore, social welfare is

$$\begin{aligned} SW &= 2(R + f_a) - \delta - c_a f_a^2 \\ &= 2R + \frac{1}{c_a} - \delta. \end{aligned} \tag{48}$$

The case in which $\frac{1}{c_a} - \frac{2}{9c_b} \leq \delta \leq \delta^{**}$ In this case, airline A is a monopoly and takes an entry-deterrent strategy, and $f_a = \delta + \frac{2}{9c_b}$. Thereby, social welfare is

$$\begin{aligned} SW &= 2(R + f_a) - \delta - c_a f_a^2 \\ &= 2R + \delta + \frac{4}{9c_b} - c_a \left(\delta + \frac{2}{9c_b}\right)^2. \end{aligned} \tag{49}$$

When the marginal operating cost of airline B increases, the flight frequency of airline A decreases; the operating cost of airline A decreases and passengers' convenience also decreases. Comparing these, the former effect is greater than the latter effect and social welfare increases.

The case in which $\delta \geq \delta^{**}$ In this case, airline B enters the market, which is a duopoly. Each airline's flight frequency is $f_a = \frac{1}{3c_a}$ and $f_b = \frac{1}{3c_b}$. As a result, social welfare is as follows.

$$\begin{aligned} SW &= 2R + f_a + f_b - c_a f_a^2 - c_b f_b^2 \\ &= 2R + \frac{2}{9c_a} + \frac{2}{9c_b} \end{aligned} \tag{50}$$

Each case's social welfare is expressed in Fig. 11. It is noteworthy that the social welfare is discontinuous in δ^{**} and that the monopoly's welfare is less than duopoly's welfare.

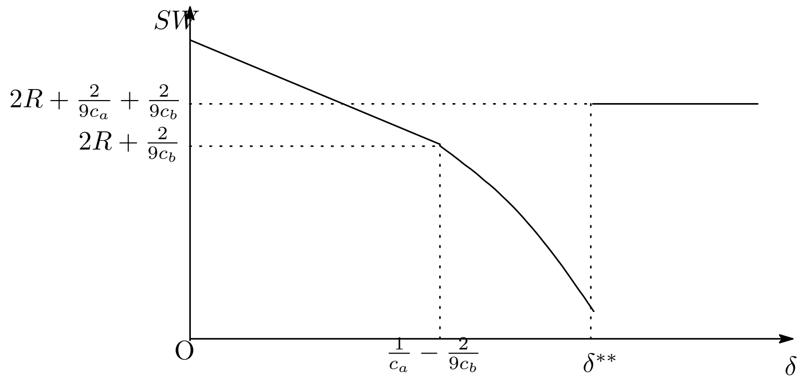

Figure 11: Social welfare with entry regulation

6.2.3 Comparison of each social welfare outcome

Finally, we compare social welfare outcomes. Summarizing each case's social welfare, Fig. 12 is produced. In Fig. 12, the bold line expresses social welfare with entry regulation. The thin

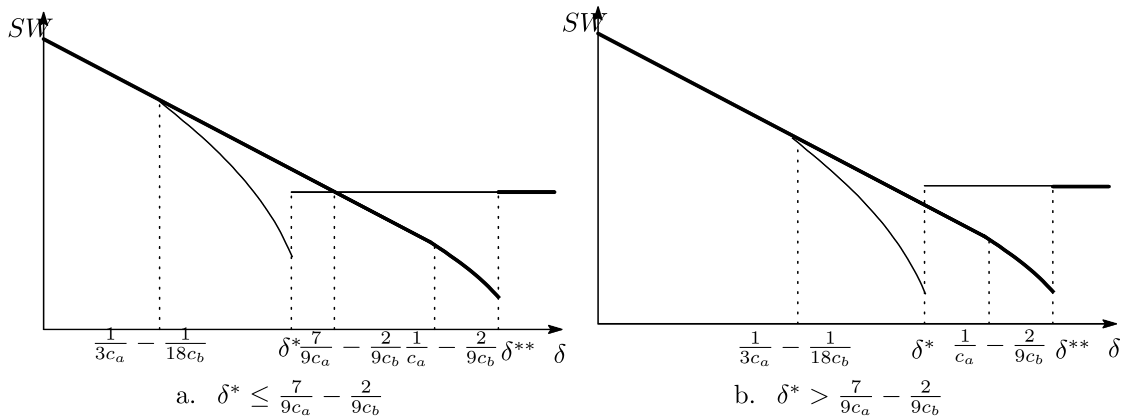

Figure 12: Comparison of social welfare

line expresses social welfare without entry regulation. Here, it remains unclear which is larger: δ^* or $\frac{1}{c_a} - \frac{2}{9c_b}$. However, this unclear condition does not influence the discussions presented below [9]. Figure 12 gives the following proposition.

Proposition 3 *Suppose that* $\frac{1}{3c_a} - \frac{1}{18c_b} \leq \delta \leq \max\{\delta^*, \frac{7}{9c_a} - \frac{2}{9c_b}\}$. *Then social welfare improves by entry regulation. However, suppose that* $\max\{\delta^*, \frac{7}{9c_a} - \frac{2}{9c_b}\} \leq \delta \leq \delta^{**}$, *then entry regulation worsens social welfare.*

Presume that $\delta^* \leq \frac{7}{9c_a} - \frac{2}{9c_b}$. Suppose that $\frac{1}{3c_a} - \frac{1}{18c_b} \leq \delta \leq \delta^*$. Then flight frequency without entry regulation is $f_a = 3\delta + \frac{1}{6c_b}$; flight frequency with entry regulation is $f_a = \frac{1}{c_a}$.

[9] See the appendix regarding the following case: $\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}$

Comparing those, the former is larger than the latter. In other words, when entry regulation is not imposed, airline A adopts excessive flight frequency to deter airline B's entry. This excessive flight frequency worsens social welfare. Therefore, entry regulation improves social welfare.

Suppose that $\delta^* \leq \delta \leq \frac{1}{c_a} - \frac{2}{9c_b}$. When entry regulation is imposed, airline A is a monopoly: airline A's flight frequency is $f_a = \frac{1}{c_a}$. When entry regulation is not imposed, the market is a duopoly; each airline 's flight frequency is $f_a = \frac{1}{3c_a}$ and $f_b = \frac{1}{3c_b}$. The difference between the monopoly's flight frequency and the duopoly's aggregate flight frequency exerts two effects: a network effect influences passengers' benefit, and operational costs change. The former effect is $\frac{5}{3c_a} - \frac{1}{3c_b}$; the latter effect is $\frac{8}{9c_a} - \frac{1}{9c_b}$. In addition, when a market is a duopoly, city B's passenger need not move between two cities. Consequently, they do not incur costs δ. Comparing the above two effects with δ, it is socially optimal that the market be a duopoly if:

$$\delta \geq \left(\frac{5}{3c_a} - \frac{1}{3c_b}\right) - \left(\frac{8}{9c_a} - \frac{1}{9c_b}\right) = \frac{7}{9c_a} - \frac{2}{9c_b}.$$

Demonstrably, if the above condition holds, it is socially optimal not to impose entry regulation.

Presuming that $\frac{1}{c_a} - \frac{2}{9c_b} \leq \delta \leq \delta^{**}$. When an entry regulation is imposed, airline A is a monopoly; airline A's flight frequency is $f_a = \delta + \frac{2}{9c_b}$. When entry regulations are not imposed, the market is a duopoly; each airline's flight frequency is $f_a = \frac{1}{3c_a}$ and $f_b = \frac{1}{3c_b}$. In that case, the sum of network effect, the changed operating costs, and δ imply the following equation:

$$\Delta = c_a\delta^2 + \left(\frac{4c_a}{9c_b} - 1\right)\delta + \frac{2}{9c_a} - \frac{1}{9c_b} + \frac{4c_a}{81c_b^2}.$$

As shown there, Δ is increasing with δ. When $\delta = \frac{1}{c_a} - \frac{2}{9c_b}$, it holds that $\Delta > 0$: duopoly's social welfare is greater than monopoly's social welfare. Consequently, it is always socially optimal that entry regulation not be imposed and that the market be a duopoly.

It is noteworthy that although government regulates airline B' entry to improve social welfare in stage two, entry regulation worsens social welfare for some range. Airline A can easily deter airline B's entry when government regulates airline B's entry in stage two. Notice that the timing by which government chooses whether to allow airline B's entry is after airline A chooses f_a. In stage two, government compares city B' passenger cost δ, the change of network effects, and airline B's operating cost. Airline B is allowed to enter the market if δ is larger than the change of network effects and airline B's operating cost. Here, government does not consider airline A's operating cost. Airline A's operating cost might be excessive. This possibility is the reason for worsening of social welfare.

7 Concluding Remarks

This study used an equilibrium concept to describe price competition, and the undercut-proof equilibrium to investigate whether entry regulation improves social welfare or not. These analyses demonstrate the following: if the differences between two airline companies (or the distance two cities) is small, entry regulation improves social welfare because entry regulation prevents excessive flight frequency of airline A. However, if the difference between the two airline companies is large, entry regulation worsens social welfare because airline A can easily deter airline B's entry.

This paper ignores some important problems that affect the efficiency of entry regulation. First, generally, price regulation is within entry regulation. Price regulation might influence an airline's decision regarding whether to deter a rival airline or not. In addition, flight frequency regulation might exist. Future studies must include such regulations.

Finally, this paper ignores the possibility that entrants take a strategy for an incumbent to exit from the market. Recently, low-cost airline companies have appeared and incumbent airlines have exited from some markets. Future research should address these strategies.

Appendix

Here, we prove the following: when $\delta^* \geq \frac{1}{c_a} - \frac{2}{9c_b}$, the social welfare with entry regulation is greater than social welfare without entry regulation for $\delta^* \leq \delta^{**}$. Notice that for the range except $\delta^* \leq \delta^{**}$, as Fig. 12 shows. Social welfare with entry regulation is expressed as SW^R. Without entry, regulation is expressed as SW^{NR}. These are the following:

$$SW^{NR} = 2R + 5\delta + \frac{1}{3c_b} - c_a\left(3\delta + \frac{1}{6c_b}\right)$$
$$SW^R = 2R + \delta + \frac{4}{9c_b} - c_a\left(\delta + \frac{2}{9c_b}\right).$$

The difference between SW^R and SW^{NR} is

$$SW^R - SW^{NR} = \left(-2\delta + \frac{1}{18c_b}\right)\left(2 - c_a\left(4\delta + \frac{7}{18c_b}\right)\right). \tag{51}$$

Below, check the sign of eq. (51). First, the second bracket of eq. (51) is checked. This equation is changed as follows.

$$\textit{Second bracket } = -4\delta + \frac{2}{c_a} - \frac{7}{18c_b}$$

This is decreasing with δ. Note that the range considered here is $\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}$. When $\delta = \frac{1}{c_a} - \frac{2}{9c_b}$, from the assumption that $c_a \leq \frac{8}{3}c_b$,

$$-\frac{2}{c_a} + \frac{1}{2c_b} < 0.$$

Consequently, the following relationships always hold.

$$2 - c_a \left(4\delta + \frac{7}{18c_b} \right) < 0$$

Next, the first bracket of eq. (51) is checked. Considering that $\frac{1}{c_a} - \frac{2}{9c_a} \geq \frac{1}{36c_b}$, it holds that $\delta \geq \frac{1}{36c_b}$. Therefore, the first bracket of eq. (51) is negative. Therefore, (51) is always positive: social welfare with entry regulation is greater than that without entry regulation.

The reason is the following: considering that $\delta \geq \frac{1}{36c_b}$, the monopoly airline's flight frequency without entry regulation is greater than that with entry regulation. That incurs excessive operation costs when entry regulation is not imposed.

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