

Entry Regulation and Strategic Entry Deterrence in the Airline Market

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Entry Regulation and Strategic Entry Deterrence in the Airline Market*

Akio Kawasaki[†]

1 Introduction

Many countries have promoted deregulation of airline markets since 1978, when airline markets in the United States were deregulated. The progress of deregulation was hastened by contestable market theory in 1980.

To date, we have considered that fixed costs to enter an airline market (e.g. aircraft lease or equipment investment) are large. Destructive competition can occur if free entry is allowed. For that reason, entry regulations have been imposed. However, the entry costs for airline markets are 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 based on price. Passenger demand thereby became divided between the incumbent airline company and an entrant; in addition, the price for airline service has decreased. In that case, the possibility to decrease the flight frequency exists for each airline company because the marginal revenue of one flight decreases. When the flight frequency decreases, passengers' benefits decrease, which is disadvantageous, but the total operating costs also decrease, providing an advantage for operators. These advantages and disadvantages mark a tradeoff for social welfare.

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This study examines whether entry regulation in the airline market improves social welfare or not, using a model with price competition and product differentiation to consider the tradeoff described above. Here, it is noteworthy that these analyses ignore price regulation and flight frequency regulation that accompanies entry regulation¹. 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 operating cost per flight than the incumbent company. This study describes how heterogeneity influences each airline's decisions: each airline company's price, flight frequency, and incentive for entry deterrence.

To date, few studies have examined entry regulation's effects on social welfare. The possibility exists that entry regulation is used strategically. This argument is proposed by Kim (1997). Kim (1997) describes 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 made by Kim (1997). However, these studies are unsuitable for an airline market. For example, airline companies decide price and flight frequency, not the quantity and level of investment. Consequently, 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 the present paper. De Vany (1975) analyzes how entry regulation and price regulation affect flight frequency, costs, and the number of passengers. Schipper et al. (2003)

¹In future studies, we must relax this assumption.

analyzes the effect of liberalization for the airline market, including the influence of an external market (e.g. environment).

Kawasaki (2007) discusses the inefficiency of free entry into the airline market: inefficiency without entry regulation. Kawasaki (2007) 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 the flight frequency. When an airline company decreases the flight frequency, the benefit for passengers decreases and social welfare worsens. Based on the discussion presented above, Kawasaki (2007) proposes that entry regulation might be necessary to prevent excessive entry.

This paper addresses the possibility that entry regulation in the airline market can be used strategically, as suggested by Kim (1997). However, the method outlined in this paper is distinct from the model of Kim (1997), which describes the general market, in preference to that of Kawasaki (2007), which is applicable to the airline market. In addition, a slight change is made from Kawasaki (2007). In Kawasaki (2007), each airline company enters the market simultaneously. Herein, only potential entrants decide to enter the market. Of course, incumbents already participate 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 adopt an entry-deterrent strategy. The arguments presented in this paper show that entry regulation can improve social welfare, which differs 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 entry is analyzed. In section 6, social welfare with entry regulation is compared to that 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 residents' needs. Potential passengers reside in cities A and B . Assume that passengers in each city are identical and that there is one in each city². 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), each incurs an additional cost δ (e.g. a time cost)³.

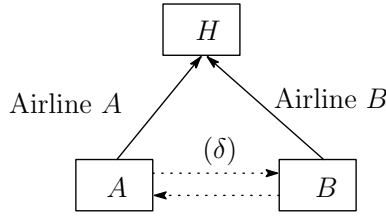


Figure 1: The model

Each passenger has an equal willingness to pay for service, expressed as R . When passengers 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 follows⁴. The passengers' utility function in city A is expressed as U_a ; the passengers' utility function in city B is U_b .

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

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

²This paper assumes that the demand is constant. However, we must consider the case that demand is elastic. In future studies, we will relax this assumption.

³In this paper, the parameter δ signifies the distance between two cities. However, without loss of generality, we can interpret δ as the degree of differentiation. Of course, the degree of differentiation is chosen by each airline. However, this paper gives δ exogenously. For instance, δ can be interpreted as each airline's mileage.

⁴Using a Hotelling-type model, the analysis is complex. For that reason, the explanation in this paper uses no such model, but future research will use one for analyses.

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 congestion⁵. Furthermore, this study introduces heterogeneous marginal operating costs, as expressed by c_i . We subsume that the set-up cost is zero (or negligible) because these analyses incorporate the idea that the present airline market has sufficiently low set-up costs. Consequently, the cost function of each airline is $C_i(f_i)(i = a, b)$. This function is

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

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

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 airlines, even without entry regulation. It is obligatory for an airline to report a navigation plan to the Ministry of Land, Infrastructure and Transport. In addition, airline firm A must obey the navigation plan⁶. Here, assume that the government does not regulate navigation plans, and that airlines must follow the navigation plans⁷. In the second stage, entrant airline B chooses to enter the market or not. The government decides to allow airline B 's entry or not if entry regulation is imposed for the entrant. Here, we presume that when airline B applies for entry, airline B need not determine the flight frequency (f_b) and price (p_b)⁸. In the third stage, both airlines engage in price competition if airline B enters the market⁹. Therefore, airline A determines the price,

⁵This interpretation follows Hassin and Shy (2000).

⁶For example, a government divides a slot at the city H airport along the navigation plan of each airline because of congestion. Airline A must serve flights in the limit of the provided slot. As a result, the airline firm's decision in the first stage is committed.

⁷We might wonder why airline A decides the price in the first stage. In this paper, the airline's price is not regulated. Therefore, this stage's price announcement cannot be committed. Consequently, airline A does not set the price in this stage.

⁸Future studies will relax this assumption.

⁹The strategy of pricing is important. It can set a monopoly price if airline A successfully deters airline B 's entry. Otherwise, airline A must set a competitive price that is lower than the monopoly price. Consequently, in the first stage, airline A decides whether to deter the entry of airline B , considering the pricing of this stage.

and when airline B enters the market, airline B determines the flight frequency and price in this stage. Each airline reports these decisions to the government. Here, government does not regulate the flight frequency and price¹⁰.

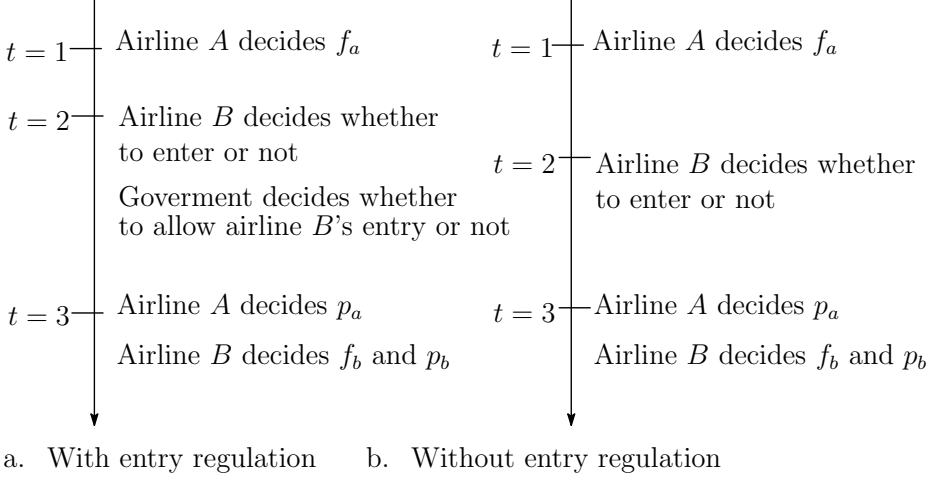


Figure 2: Timeline

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 how airline B decides flight frequency.

3.1 The Case in which Airline A is a Monopoly

First, we analyze the case: in the second stage, airline B does not enter the market. Plainly, airline A is a monopoly. Airline A has the opportunity to set a price at which all passengers use it, or only city A 's passengers use it. The price is $p_a = R + f_a - \delta$ if airline A sets the price for all passengers to use. Thereby, the profit for airline A is

$$\pi_a = 2(R + f_a - \delta) - c_a f_a^2. \quad (3)$$

¹⁰This study examines the efficiency of entry regulation alone. However, future research efforts will relax these assumptions.

The price is $p_a = R + f_a$ if airline A sets the price for only city A 's passengers to use. Therefore, the profit for airline A is

$$\pi_a = R + f_a - c_a f_a^2. \quad (4)$$

Here, compare the profit that pertains when all passengers use airline A to that when only passengers in city A do so. We obtain the following Lemma considering the assumption that $R \geq 2\delta$.

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

Two effects occur if airline A sets a high price at which passengers in city B do not use the airline service: one is to increase the revenues from the passengers in city A ; the other is to lose the revenues from those in city B . Comparison of these two effects shows that the loss of revenues is greater than the increase.

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 adopts price competition. This paper uses the *undercut-proof equilibrium* for the equilibrium concept of price competition¹¹.

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

$$D_a = \begin{cases} 2 & (p_a < (f_a - f_b) - \delta + p_b) \\ 1 & ((f_a - f_b) - \delta + p_b \leq p_a \leq (f_a - f_b) + \delta + p_b) \\ 0 & (p_a > (f_a - f_b) + \delta + p_b) \end{cases} \quad (5)$$

$$D_b = \begin{cases} 2 & (p_b < (f_b - f_a) - \delta + p_a) \\ 1 & ((f_b - f_a) - \delta + p_a \leq p_b \leq (f_b - f_a) + \delta + p_a) \\ 0 & (p_b > (f_b - f_a) + \delta + p_a) \end{cases} \quad (6)$$

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

¹¹Regarding the undercut-proof equilibrium, see Shy (2001) or Kawasaki (2007).

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.

$$p_a^U \geq 2\{(f_a - f_b) - \delta + p_b\} \quad (7)$$

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

$$p_b^U \geq 2\{(f_b - f_a) - \delta + p_a\}. \quad (8)$$

Summarizing eq. (7) and eq. (8), Fig. 3 portrays the following. The domain under eq.

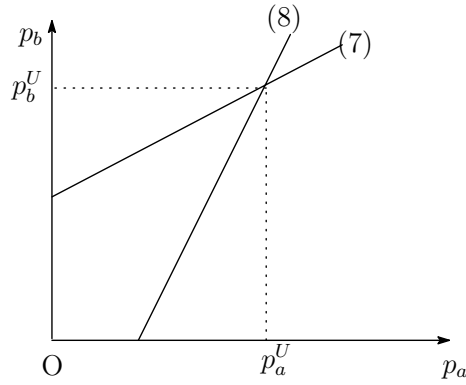


Figure 3: Undercut-proof equilibrium

(7) means that airline A does not undercut the price. Furthermore, the domain above eq. (8) 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

$$p_a^U = \frac{2}{3}(f_a - f_b) + 2\delta \quad (9)$$

$$p_b^U = \frac{2}{3}(f_b - f_a) + 2\delta. \quad (10)$$

Consequently, each airline's profit is

$$\pi_a = \frac{2}{3}(f_a - f_b) + 2\delta - c_a f_a^2 \quad (11)$$

$$\pi_b = \frac{2}{3}(f_b - f_a) + 2\delta - c_b f_b^2. \quad (12)$$

Airline B chooses its flight frequency in this stage. Solving the maximization problem for airline B , the flight frequency for airline B is $f_b = \frac{1}{3c_b}$.

The above discussion implies that each airline's profit is the following.

$$\pi_a = \frac{2}{3} \left(f_a - \frac{1}{3c_b} \right) + 2\delta - c_a f_a^2 \quad (13)$$

$$\pi_b = \frac{1}{9c_b} + 2\delta - \frac{2}{3}f_a \quad (14)$$

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. (14) is non-positive, airline B does not enter the market. Therefore, the condition in which airline B does not enter the market is

$$f_a \geq \frac{1}{6c_b} + 3\delta. \quad (15)$$

From the discussion presented above, eq. (15) is the condition by which airline A deters airline B 's entry.

4.2 Case: Entry Regulation is Imposed

Presume 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 the second stage 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 the second stage is expressed as $W_2^D(f_a)^{12}$.

$$W_2^D(f_a) = 2R + \frac{2}{9c_b} + f_a - c_a f_a^2 \quad (16)$$

When airline B does not enter the market, the social welfare in the second stage is the following.

$$W_2^M(f_a) = 2R + 2f_a - \delta - c_a f_a^2 \quad (17)$$

¹²Social welfare is defined as the sum of consumer surplus with both airlines' profits.

Here, the case in which only the 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. (16)) with that when airline B does not enter the market (eq. (17)), if eq. (17) is larger than eq. (16), then regulators do not allow airline B 's entry. In other words, if

$$f_a \geq \frac{2}{9c_b} + \delta, \quad (18)$$

then airline B 's entry is not allowed.

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

$$f_a \geq \min\left\{\delta + \frac{2}{9c_b}, 3\delta + \frac{1}{6c_b}\right\} \quad (19)$$

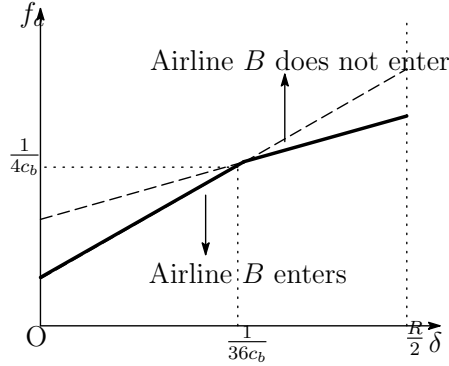


Figure 4: Condition to deter airline B 's entry

This condition is expressed as Fig. 4, which shows the following: 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. It is noteworthy that airline A has two strategies: allow airline B 's entry or deter airline B 's entry.

5.1 Free entry

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 the third stage, airline A sets the price that all passengers must use. Thereby, airline A 's profit function is

$$\pi_a = 2(R + f_a - \delta) - c_a f_a^2. \quad (20)$$

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.

$$\max_{f_a} \pi_a \quad (21)$$

$$s.t. \quad f_a \geq 3\delta + \frac{1}{6c_b} \quad (22)$$

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

$$f_a = \begin{cases} \frac{1}{c_a} & (\delta \leq \frac{1}{3c_a} - \frac{1}{18c_b}) \\ 3\delta + \frac{1}{6c_b} & (\delta > \frac{1}{3c_a} - \frac{1}{18c_b}) \end{cases} \quad (23)$$

The value of $\frac{1}{3c_a} - \frac{1}{18c_b}$ might be negative. However, the following analysis assumes that this value always becomes non-negative.

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

$$\pi_a^M = \begin{cases} 2R + \frac{1}{c_a} - 2\delta & (\delta \leq \frac{1}{3c_a} - \frac{1}{18c_b}) \\ 2R + 4\delta + \frac{1}{3c_b} - c_a \left(3\delta + \frac{1}{6c_b}\right)^2 & (\delta > \frac{1}{3c_a} - \frac{1}{18c_b}) \end{cases} \quad (24)$$

5.1.2 When airline B enters the market

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

$$\max_{f_a} \frac{2}{3} \left(f_a - \frac{1}{3c_b} \right) + 2\delta - c_a f_a^2. \quad (25)$$

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

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

$$\pi_a^D = \frac{1}{9c_a} - \frac{2}{9c_b} + 2\delta \quad (26)$$

In addition, airline B 's profit is

$$\pi_b^D = \frac{1}{9c_b} - \frac{2}{9c_a} + 2\delta. \quad (27)$$

5.1.3 Airline A 's entry deterrence strategy

Here, we analyze the situation in which airline A deters airline B 's entry, comparing airline A 's profit when airline A is a monopoly to 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, $\delta^* = \frac{1}{18c_a} \left(2 - \frac{c_a}{c_b} + \sqrt{\frac{16c_a}{c_b} + 72c_a R} \right)$.

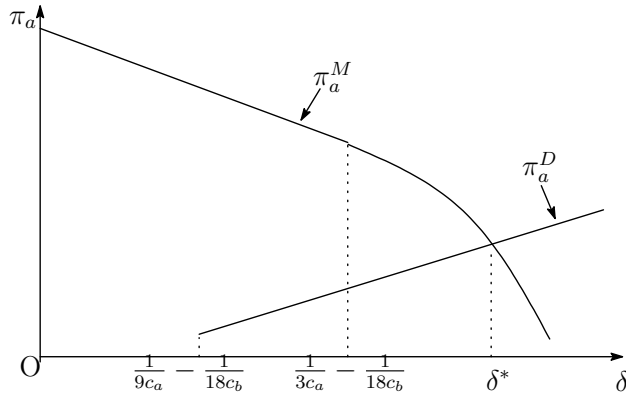


Figure 5: Comparison of profits under a monopoly and a duopoly

Figure 5 shows the following characteristics. When the distance between two cities (or the degree of product differentiation) is large, monopoly profits decrease: the profits under a duopoly increase. First, consider the case of a monopoly. When δ becomes large, airline A is expected to lower the price to let city B passengers use its services. Consequently, the monopoly profit decreases with δ . The subsequent discussion examines the case of duopoly. When δ becomes large, the degree of competition between the two airlines becomes small. Thereby, each airline can charge a higher price¹³. As a result, duopoly profits increase with δ .

¹³Each airline sets a (nearly) marginal cost pricing if the degree of competition between the two firms is sufficiently high.

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

Proposition 1 *Presuming that entry regulations are not imposed, the market is a monopoly if $\delta \leq \delta^*$. The market is a duopoly if $\delta > \delta^*$.*

Here, consider the characteristics for δ^* using comparative static analysis. When the marginal operating 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 in which $\delta < \frac{1}{3c_a} - \frac{1}{18c_b}$, the monopoly's profit is always larger than the 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 operating cost of airline A increases.

When the marginal operating cost of airline B increases,

$$\frac{\partial \delta^*}{\partial c_b} = \frac{\frac{1}{9c_b^2}(9c_a\delta + \frac{c_a}{2c_b} - 5)}{6c_a(3\delta + \frac{1}{6c_b}) - 2}. \quad (28)$$

Using eq. (28), the following lemma is obtained.

Lemma 2 *Presuming 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 operating cost of airline B increases. Assume that $c_a > \frac{64c_b}{1+72c_bR}$. That incentive strengthens as the marginal operating cost of airline B increases.*

The sign of eq. (28) depends on the following: the degree of monopoly profit's change and that of duopoly profit's change when c_b increases. Figure 6 depicts the marginal profit of each case when c_b increases.

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

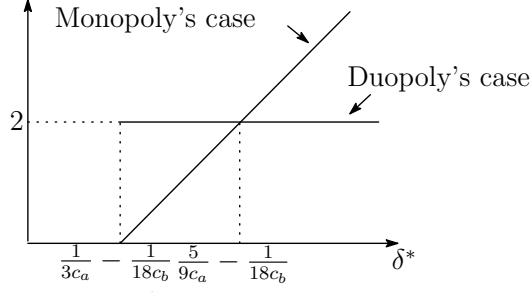


Figure 6: Comparison of respective cases' marginal profit

Lemma 2 presents the following implications. In the real world, some low-cost carriers (LCCs) are going to enter the market. Then, some incumbent airlines become willing to deter their entry; other airlines might accommodate the entry. This difference might cause differences between the marginal cost of incumbent airline and that of the entrant. In other words, when the potential entrant airline is a lower cost carrier, if the marginal operating costs of airline A are low, airline A is more willing to accommodate the entry of airline B ¹⁴; otherwise, airline A undertakes a strategy to deter the entrant.

5.2 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

$$\pi_a = 2(R + f_a - \delta) - c_a f_a^2. \quad (29)$$

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:

$$\max_{f_a} 2(R + f_a - \delta) - c_a f_a^2, \quad (30)$$

$$s.t. \quad f_a \geq \min\left\{3\delta + \frac{1}{6c_b}, \delta + \frac{2}{9c_b}\right\}. \quad (31)$$

As shown in Fig. 4, the constraint equation (eq. (31)) apparently changes depending on δ .

¹⁴In other words, δ^* becomes small.

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 the following.

$$\pi_a = 2R + \frac{1}{c_a} - 2\delta \quad (32)$$

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 .

$$f_a = \begin{cases} \frac{1}{c_a} & (\delta \leq \frac{1}{c_a} - \frac{2}{9c_b}) \\ \frac{1}{6c_b} + 3\delta & (\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}) \end{cases} \quad (33)$$

Thereby, when entry regulations are imposed, airline A 's monopoly profit is expressed as the following.

$$\pi_a^M = \begin{cases} 2R + \frac{1}{c_a} - 2\delta & (\delta \leq \frac{1}{c_a} - \frac{2}{9c_b}) \\ 2R + \frac{4}{9c_b} - c_a \left(\delta + \frac{2}{9c_b} \right)^2 & (\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}) \end{cases} \quad (34)$$

5.2.2 When airline B enters the market

Next, we analyze the case in which airline B enters the market; the market is then subject to competition. From previous discussion, the flight frequency of airline A is known to $\frac{1}{3c_a}$. 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 the following.

$$\pi_a^D = \frac{2}{9c_a} - \frac{2}{9c_b} + 2\delta \quad (35)$$

In addition, airline B 's profit is

$$\pi_b^D = \frac{2}{9c_b} - \frac{2}{9c_a} + 2\delta. \quad (36)$$

5.2.3 Airline A 's entry-deterrence strategy

Here, we analyze the case in which airline A deters airline B 's entry, comparing airline A 's profit when airline A is a monopoly to 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 has two competing firms. In Fig. 7, $\delta^{**} = \frac{1}{c_a} \left(-\frac{2c_a}{9c_b} - 1 + \sqrt{\frac{8}{9} + \frac{10c_a}{9c_b} + 2c_a R} \right)$. The characteristics of profits obtained under a monopoly and a duopoly are similar to those of the free entry case. From the above discussion, the following proposition is gained.

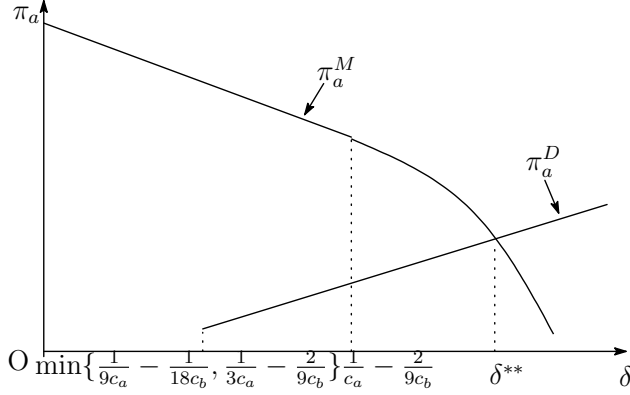


Figure 7: Comparison of profits under a monopoly and duopoly

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

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

When the marginal operating cost of airline B increases, then

$$\frac{\partial \delta^{**}}{\partial c_b} = -\frac{\frac{1}{9c_b^2}(-4c_a(\delta + \frac{2}{9c_b}) + 6)}{2c_a(\delta + \frac{2}{9c_b}) + 2}. \quad (37)$$

Using eq. (37), the following lemma is obtained.

Lemma 3 Assume 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 operating cost of airline B increases. Assume that $c_a > \frac{197c_b}{8(5+9c_bR)}$. The incentive strengthens when the marginal operating cost of airline B increases.

The sign of eq. (37) depends on the following: the degree of profit's change under monopoly and that under duopoly change when c_b increases. Figure 8 expresses the marginal profit of each case when c_b increases.

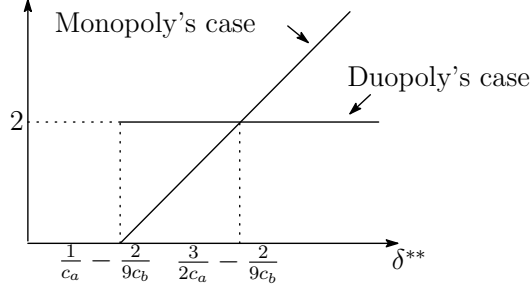


Figure 8: Comparison of each case's marginal profit

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

The interpretation of lemma 3 is similar to that for lemma 2. The only difference is the value of the boundary. In other words, if the marginal cost of airline B is small or $c_b \leq \frac{2363}{9576R}$, the value of a boundary without entry regulation is greater than that with entry regulation; otherwise, the opposite is true. This result demonstrates that entry regulation influences the incentive of entry deterrence when lower-cost carriers appear. Namely, when the lower-cost carrier is present, the following case exists¹⁵; the incumbent airline might be willing to deter the entry if entry regulation is imposed: if entry regulation is not imposed, it will seek to accommodate the entry.

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.

$$\Delta^* \equiv c_a \cdot \delta^* = \frac{1}{9} - \frac{1}{18}c + \sqrt{\frac{4}{81}c + \frac{2}{9}\bar{R}} \quad (38)$$

$$\Delta^{**} \equiv c_a \cdot \delta^{**} = -1 - \frac{2}{9}c + \sqrt{\frac{8}{9} + \frac{10}{9}c + 2\bar{R}} \quad (39)$$

¹⁵In this interpretation, we presume that the marginal cost of entrant airline is small.

We define that $c \equiv \frac{c_a}{c_b}$ and $\bar{R} \equiv c_a \cdot R$. Assume that $\delta^{**} \geq \frac{1}{c_a} - \frac{2}{9c_b}$ to compensate δ^* and δ^{**} . Additionally, it holds that $R \geq 2\delta^{16}$ and $c \leq \frac{8}{3}$ from the model's assumptions.

Here, δ^* and δ^{**} can be shown as a three-dimensional figure with two variables: \bar{R} and c . Thereby, Fig. 9 is expressed, showing the range that $0 \leq c \leq \frac{8}{3}$ and $\frac{22}{27} \leq \bar{R} \leq 5^{17}$.

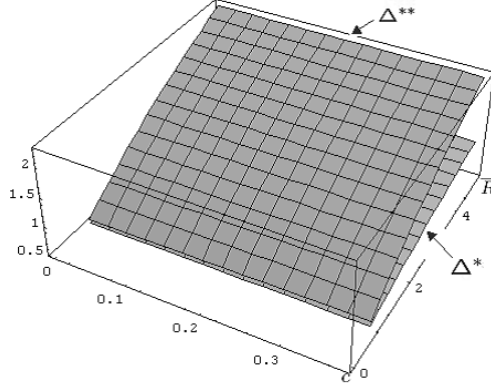


Figure 9: Comparison of δ^* with δ^{**}

Figure 9 shows that $\delta^{**} > \delta^*$: the range within which 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, we 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.

¹⁶In other words, $\bar{R} \geq 2 - \frac{4}{9}c$.

¹⁷The reason for defining $\frac{22}{27} \leq \bar{R} \leq 5$ is as follows. The minimum of \bar{c} is when $\frac{8}{3}$. Therefore, $\bar{R} \geq \frac{22}{27}$ is defined. In addition, an upper limit is not without generality.

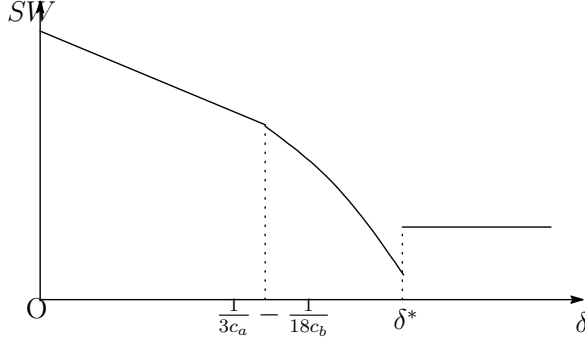


Figure 10: Social welfare without entry regulation

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

$$SW = 2R + \frac{1}{c_a} - \delta. \quad (40)$$

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

$$SW = 2R + 5\delta + \frac{1}{3c_b} - c_a \left(3\delta + \frac{1}{6c_b} \right)^2. \quad (41)$$

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.

$$SW = 2R + \frac{2}{9c_a} + \frac{2}{9c_b} \quad (42)$$

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

6.2.2 Social welfare with entry regulation

Next, derive 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 calculated as

$$SW = 2R + \frac{1}{c_a} - \delta. \quad (43)$$

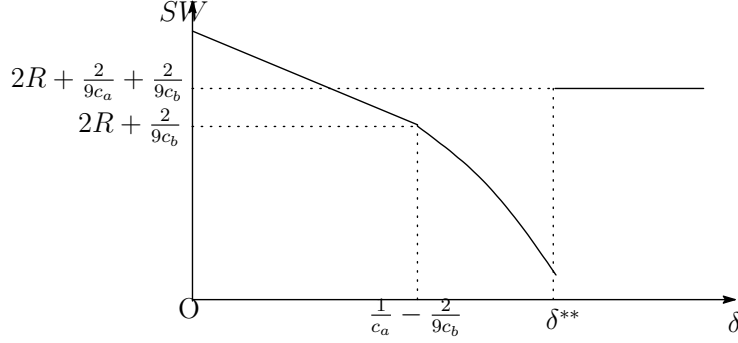


Figure 11: Social welfare with entry regulation

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 adopts an entry-deterrent strategy; also, $f_a = \delta + \frac{2}{9c_b}$. Thereby, social welfare is

$$SW = 2R + \delta + \frac{4}{9c_b} - c_a \left(\delta + \frac{2}{9c_b} \right)^2. \quad (44)$$

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 $f_b = \frac{1}{3c_b}$. Consequently, social welfare is calculated as the following.

$$SW = 2R + \frac{2}{9c_a} + \frac{2}{9c_b} \quad (45)$$

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

6.2.3 Comparison of each social welfare outcome

Finally, we compare social welfare outcomes. To summarize each case's social welfare, Fig. 12 is illustrative. In Fig. 12, the bold line represents social welfare with entry regulation. The thin 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 discussion presented below¹⁸. Figure 12 depicts the following proposition.

Proposition 3 Assume 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, presume that $\max\{\delta^*, \frac{7}{9c_a} - \frac{2}{9c_b}\} \leq \delta \leq \delta^{**}$, then

¹⁸See the appendix with respect to the following case: $\delta \geq \frac{1}{c_a} - \frac{2}{9c_b}$

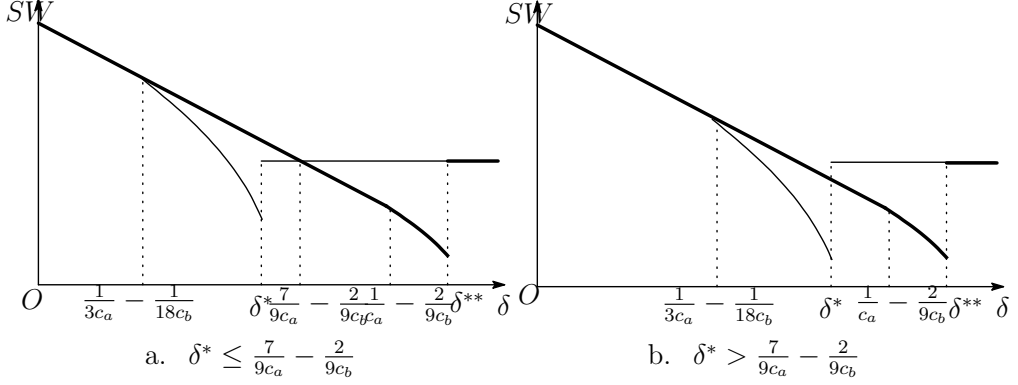


Figure 12: Comparison of social welfare

entry regulation worsens social welfare¹⁹.

Assume that $\delta^* \leq \frac{7}{9c_a} - \frac{2}{9c_b}$. Then presuming 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 $f_a = \frac{1}{c_a}$. 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.

Presuming 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 served by a duopoly, city *B*'s passenger need not move between two cities. Consequently, they incur no cost δ . Comparing the two effects described above with δ , it is apparently socially optimal that the market be served by 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.

¹⁹If we relax the assumption that demand is constant, whether entry regulation improves social welfare or not might also depend on the elasticity of demand.

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 presented there, Δ is increasing with δ . When $\delta = \frac{1}{c_a} - \frac{2}{9c_b}$, then $\Delta > 0$: 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 the 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 the government regulates airline B 's entry in stage two. 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 the 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, the government does not consider airline A 's operating cost. Airline A 's operating cost might be excessive. This possibility is the explanation for worsening of social welfare.

7 Concluding Remarks

This study used an equilibrium concept to describe price competition, and used 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 the excessive flight frequency of airline A . However, if the difference between the two airline companies is large, entry regulation exacerbates worsening of social welfare because airline A can easily deter airline B 's entry.

In addition, this paper introduces heterogeneity of the marginal cost between incumbent and entrant airlines. Results show that entry regulation influences the incentive to deter entry when a low-cost airline appears. Lemma 2 and Lemma 3 discuss these conclusions.

The discussion presented in this paper ignores some important problems that affect the efficiency of entry regulation. First, price regulation is generally allowed within entry regulation. Price regulation might influence an airline's decision with respect to whether to deter a rival airline or not. In addition, flight frequency regulation might pertain. Future studies must include assessment of such regulations.

Finally, this paper does not address 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 efforts must address these strategies specifically.

Appendix

Here, we prove the following: when $\delta^* \geq \frac{1}{c_a} - \frac{2}{9c_b}$, the social welfare level with entry regulation is higher than the social welfare level 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:

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

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

$$SW^R - SW^{NR} = \left(-2\delta + \frac{1}{18c_b} \right) \left(2 - c_a \left(4\delta + \frac{7}{18c_b} \right) \right). \quad (46)$$

Below, the sign of eq. (46) includes important information. First, the second bracket of eq. (46) is checked. This equation is changed as follows.

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

This is decreasing with δ . 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. (46) 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. (46) is negative. Therefore, (46) 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. When entry regulation is not imposed, excessive operating costs are incurred.

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