Effectiveness of Different Pricing Strategies at Reducing the Workload of Home Delivery Services

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Abstract. Owing to a declining birthrate, aging population, and labor shortage, the Japanese logistics industry is at risk of collapse. In particular, coming restrictions on overtime hours for truck drivers are expected to have a major effect on home delivery services. Japan's delivery companies generally charge the same delivery fee for both face-to-face attended delivery, which may include redelivery, and unattended delivery, where the item may just be placed in front of door. In this study, we investigated whether differentiating the delivery fee by charging a premium for attended delivery or offering a discount for unattended delivery of a delivery company. We formulated a game theoretic model to consider a delivery company and users with different service preference. We then determined the conditions under which price differentiation can achieve separating equilibrium where users choose attended or unattended delivery according to their service preference. We also consider the conditions under which both the company and user select the same price differentiation strategy.

Keywords: Home Delivery Service, Pricing, Workload Reduction.

1 Introduction

The Japanese logistics industry faces a crisis due to a labor shortage. The expansion of e-commerce has greatly increased the total amount of small parcels being delivery, but, a declining birthrate and aging population have made it difficult for delivery companies to maintain the required workforce, especially truck drivers. Some possible solutions include introducing automation, such as unmanned warehouses and autonomous driving, or improving the work environment to reduce the turnover rate and increase job offers. However, the government is enacting a policy to limit the total overtime hours of truck drives in 2024 with the intention of improving the work environment, but this is expected to exacerbate the labor shortage in the near future (Mitsui & Co., 2023). Another approach used elsewhere is to introduce a sharing economy, which includes hare riding and shared bicycles. However, a sharing economy remains unpopular in Japan.

For home deliveries in Japan, the same delivery fee is charged for both attended delivery, which may include redelivery, and unattended delivery. However, the workloads of the two delivery odes are quite different. A uniform pricing strategy may cause a moral hazard for users: some users may choose attended delivery even if unattended delivery is sufficient. Charging different delivery fees according to the delivery workload and the service preference of a user is a reasonable approach, and it may help mitigate the labor shortage.

There are two main types of price differentiation strategies. The *price reduction strategy* is to offer a discount if the user chooses unattended delivery. Pizza chains such as Domino's Pizza and Pizza Hut usually offer a much lower price for orders that are picked up rather than delivered. The home delivery of small products such as books and CDs is highly labor-intensive, so the fee is usually much lower if face-to-face delivery is not demanded. In contrast, the *additional price strategy* is to charge a premium for attended delivery with redelivery. This is the approach used by postal services, which impose an additional charge for services such as express and registered mail.

In this study, we evaluated price strategies as a tool to reduce the delivery workload. We developed a game theoretic model comprising a delivery company and a user. We assumed two types of users: Type *H* prefers a high service quality, and Type *L* does not care about service quality. We then address the following questions:

(1) Can the price reduction strategy provide an adequate choice of delivery modes that satisfies the service preferences of the user?
(2) Can the additional price strategy do so?
(3) Which pricing strategy is more profitable for the company?

We analyzed the effect of using a pricing differentiation strategy rather than the uniform pricing strategy currently favored by delivery companies in Japan on the workload reduction under the expectation that appropriate pricing will induce Type *L* users to choose unattended delivery.

2 Literature Review

This study is related to three research streams: home delivery, modeling social concerns, and price bundling and unbundling. Logistics researchers have considered the home delivery of small parcels from various viewpoints. Agatz et al. (2011) analyzed time slot management for home delivery services. Wang et al. (2016) found that users first classify last-mile delivery according to safety (e.g., risk of theft) and then according to the pick-up location. Koch and Klein (2020) used route-based approximate dynamic programming to solve dynamic vehicle routing and dynamic pricing problems for home delivery groceries. To mitigate the urban problems caused by last-mile delivery (e.g., congestion or pollution), Deng et al. (2021) formulated a game theoretic model comprising an urban consolidation center and carriers and analyzed the conditions under which last-mile carriers use consolidation. Olsson et al. (2022) concluded that users evaluate unattended delivery from three aspects: time, flexibility, and ease of use. Reed et al. (2023) investigated under what geographic conditions autonomous vehicle-assisted last-mile delivery becomes viable.

Logistics researchers have also become interested in addressing social concerns, such as compliance, resource saving, and environmental issues. As noted above, Deng et al. (2021) considered how delivery consolidation can resolve delivery-related problems in urban areas, such as traffic congestion and pollution. Alptekinoğlu and Örsdemir (2022) addressed the environmental impact of mass customization of fashion item. Calmon et al. (2022) modeled the problem of getting poor people to buy new products that would improve their quality of life. Gao et al. (2022) discussed the optimal combination of directly reducing CO2 emissions through technological innovation and indirectly reducing emissions by carbon offsets. Siddiq et al. (2022) investigated the types of policies (e.g., subsidies, taxes) that local governments should implement in cooperation with share-riding services to improve the convenience of public transportation.

Price bundling is generally applied by marketers as a tool for increasing revenue, switching costs, and encouraging cross-buying. Shugan et al. (2017) explained why the decision of bundling a core product with ancillary services differs among industries based on the paradoxical observation that airlines bundle high-end services while hotels bundle low-end services. Cui et al. (2018) considered price unbundling when analyzing the relationship between main and ancillary services. Wang et al. (2019) analyzed the problem of purchasing ancillary services as a subscription separately from the main service. He et al., (2022) used the pricing strategy of Spirit Airlines to theoretically and empirically examine how charging a fee for carry-on baggage influenced the pricing of competitors.

3 Model and Assumptions

We develop a game theoretic model based on the work of Cho et al. (2019). In our model, the company decides the difference in price $\Delta r (> 0)$ and delivery quality (high e_H or low e_L). Meanwhile, the user decides the delivery mode: attended delivery with redelivery ($d = 0$) or unattended delivery ($d = 1$). The notation is summarized below.

Objective functions:
$\Pi = \Pi(e, r|d)$: Company profit
$U = U(d|e, r)$: User's utility
Decision variables:
$\Delta p (> 0)$: Discount for unattended delivery
$\Delta r (> 0)$: Premium for attended delivery
$e \in \{e_H, e_L\}$: Quality of attended delivery; $e_H \in (0, 1]$ is controlled by the company, and $e_L = 0$ for simplicity
$d \in \{0,1\}$: User's choice of delivery model; 0 for attended and 1 for unattended
Parameters
α $(0 < \alpha < 1)$: Coefficient representing the positive effect of unattended delivery on the company
β_i $(0 < \beta < 1)$: Coefficient representing the positive effect of unattended delivery on the user
$k (> 0)$: Coefficient representing the cost related to attended delivery
$h (> 0)$: Coefficient representing the disutility related to attended delivery
$c_P, c_T (> 0)$: Un attended delivery cost to the company and the user, respectively
$u_0 (> 0)$: Minimum utility required by a user

$\tau(>0)$: Benefit of attended delivery realized by the company
$\Delta\Pi_{i-j}$: Difference in profits between strategies i and j, where $i, j \in \{R, A, O\}$ and $i \neq j$
ΔU_{R-A}: Difference in optimal utility between pricing strategies

Superscripts and subscripts

R, A, and O: Price reduction, additional price, and uniform Pricing strategy, respectively
H and L: High and low delivery service quality, respectively

We assumed two types of users with respect to delivery service preferences: Type H users prefer attended delivery with redelivery and Type L users are satisfied with unattended delivery. Note that we assumed only two levels of service quality: e_H is the service quality preferred by Type H users, and e_L is the service quality sufficient for Type L users. Note that e_L was set to zero for simplicity (i.e., $e_L = 0$).

4 Price Reduction Strategy

4.1 Profit and Utility Functions

In the price reduction strategy, the profit function of the company is given by

$$\Pi^R = \Pi^R(e, \Delta p|d) = p - ke^2 + \tau e(1-d) + \left\{-\Delta p + \alpha ke^2 - c_p(1-e)\right\}d. \quad (1)$$

To maximize profit, the company optimizes the delivery quality (e) and discount for unattended delivery (Δr). On the right-hand side of Eq. (1), the first term is the unit revenue, the second term is the delivery cost represented by a quadratic function of the service quality e, and the third term is the benefit gained from attended delivery (e.g., a high service may generate brand value). The terms inside the braces denote the benefit and costs of unattended delivery: Δp is the discount in price, αke^2 is the reduction in cost due to attended delivery, and $c_p(1-e)$ is a penalty term for potential trouble that may occur (e.g., theft).

The utility function of Type $i(\in \{L, H\})$ users is given by

$$U_i^R = U_i^R(d|e, \Delta r) = v - p - h(1-e)^2 + \{\Delta p + \beta_i h(1-e)^2 - c_T(1-e)\}d. \quad (2)$$

In Eq. (2), the utility is maximized differently depending on $d \in \{0, 1\}$. On the right-hand side of Eq. (2), the first term is the base utility level, and the second term is the base price. The third term is a concave function that denotes the effect of the service quality e on utility. The terms inside the braces denote the benefit and costs to the user when choosing unattended delivery: Δp is the discount in price, $\beta_i h(1-e)^2$ is the benefit from choosing unattended delivery (e.g., not necessary to wait at home, privacy concerns), and $c_T(1-e)$ is the risk of a problem with delivery (e.g., theft). Here β_L and β_H represent the preferences for unattended delivery of Type L and Type H users, respectively. Note that we assumed $0 < \beta_H < \beta_L$. Finally, we assumed that a minimum level of utility should be guaranteed for users, which is given by

$$U_i^R \geq u_0, i \in \{H, L\}. \quad (3)$$

4.2 Decision Sequence

The decision sequence is as follows. In Stage 1, the company determines the discount for unattended delivery Δp for a given base delivery price p. In Stage 2, the user determines the delivery mode ($d = 0$ for attended or $d = 1$ for unattended) to maximize utility and the company determines the quality level (e_L or e_H).

In a game of asymmetric information, *separating equilibrium* refers to a solution where the type of player can be determined from their action. In our model, Type *H* users choose attended delivery while Type *L* users choose unattended delivery. Hereafter, we refer to this separating equilibrium as the *ideal situation*. To achieve the ideal situation, Types *H* users need to satisfy the condition $U_H^R(d = 0| \, e_H) > U_H^R(d = 1| \, e_L)$, and Type L users need to satisfy the condition $U_L^R(d = 1| \, e_L) > U_L^R(d = 0| \, e_H)$. These conditions can be respectively rewritten as

$$v - p - h(1 - e_H)^2 > v - r - h(1 - e_L)^2 + \{\Delta p + \beta_H h(1 - e_L)^2 - c_T(1 - e_L)\}. \quad (4a)$$

$$v - r - h(1 - e_L)^2 + \{\beta_L h(1 - e_L)^2 - c_T(1 - e_L)\} > v - r - \Delta r - h(1 - e_H)^2. \quad (4b)$$

For the price reduction strategy, Stage 2 of the decision sequence is solved as follows. Eqs. (4a) and (4b) are compared to determine which delivery mode (i.e., attended (A) or unattended (U)) each type of user (*H* or *L*) will choose. Lemma 1 summarizes the choice of delivery mode by a Type *H* or *L* user for a given discount price Δp.

Proposition 1. *For a price reduction strategy with a given discount Δp, the ideal situation that a Type H user chooses attended delivery and a Type L user chooses unattended delivery is achieved in Cases II, III, and IV.*

Table 1. Choice of delivery mode by a type of user for a given Δp.

Case	*Value of* Δp	*Type H users*	*Type L users*
I	$\Delta p < -h(1 - e_H)^2 + h(1 - \beta_L) + c_T$	*A*	*A*
II	$\Delta p = -h(1 - e_H)^2 + h(1 - \beta_L) + c_T$	*A*	*A or U*
III	$-h(1 - e_H)^2 + h(1 - \beta_L) + c_T < \Delta p < -h(1 - e_H)^2 + h(1 - \beta_H) + c_T$	*A*	*U*
IV	$\Delta p = -h(1 - e_H)^2 + h(1 - \beta_H) + c_T$	*A or U*	*U*
V	$-h(1 - e_H)^2 + h(1 - \beta_H) + c_T < \Delta p$	*U*	*U*

A: attended delivery; *U*: unattended delivery

Proof. Using simple mathematical operations for Eqs. (4a) and (4b) obtains this result (QED).

4.3 Profits in the Ideal Situation

We can standardize the total number of users to one where the proportion of Type L users is represented by ω $(0 < \omega < 1)$ and the proportion of Type H users is represented by $1 - \omega$. The total profit of the company in the ideal situation is determined as follows:

$$\Pi^R = (1-\omega)\{p - ke_H^2 + \tau e_H\} + \omega\{p - ke_H^2 - \Delta p + \alpha k e_H^2 - c_P(1-e_H)\}.$$

Equivalently,

$$\Pi^R = p - ke_H^2 + \tau e_H - \omega\{-\alpha k e_H^2 + (\tau - c_P)e_H + \Delta p + c_P\}. \tag{5}$$

Eq. (5) implies that the discount Δp should be minimized to maximize the profit for the company. Table 1 indicates that the smallest value of Δp that achieves the ideal situation is obtained in Case II. Therefore, Proposition 2 summarizes the optimal discount.

Proposition 2. *According to the price reduction strategy, the optimal discount is given by*

$$\Delta p^* = -h(1-e_H)^2 + h(1-\beta_L) + c_T. \tag{6}$$

5 Additional Price Strategy

5.1 Profit and Utility Functions

The additional price strategy is a different pricing strategy in which the company charges a premium to Type H users who prefer attended delivery. The basic structure of the model is the same as that of the price reduction model. Accordingly, the profit function, Π^A of the company and utility function U_i^A of the Type *i* user are respectively given by

$$\Pi^A = \Pi^A(e, \Delta r|d) = p - ke^2 + (\Delta r + \tau e)(1-d) + \left\{+\alpha k e^2 - c_p(1-e)\right\}d.$$

$$\begin{aligned} U_i^A = U_i^A(d|e,\Delta r) = v - p - h(1-e)^2 - \Delta r(1-d) \\ +\{\beta_i h(1-e)^2 - c_T(1-e)\}d. \end{aligned}$$

In the ideal situation, the Type H user chooses attended delivery and the Type L user chooses unattended delivery. Thus, the Type H user need to satisfy the condition $U_H^A(d=0|\, e_H) > U_H^A(d=1|\, e_L)$ and the Type L user needs to satisfy the condition $U_L^A(d=1|\, e_L) > U_L^A(d=0|\, e_H)$. These conditions can be respectively rewritten as

$$\begin{aligned} v - p - h(1-e_H)^2 - \Delta r \\ > v - p - h(1-e_L)^2 + \beta_H h(1-e_L)^2 - c_T(1-e_L). \end{aligned} \tag{7a}$$

$$\begin{aligned} v - p - h(1-e_L)^2 + \beta_L h(1-e_L)^2 - c_T(1-e_L) \\ > v - p - h(1-e_H)^2 - \Delta r. \end{aligned} \tag{7b}$$

Proposition 3 summarizes the delivery mode (i.e., attended (A) or unattended (D)) that Type H and L users choose with the additional price strategy. Table 2 summarizes the choices of Type H and L users for a given value of the premium Δr.

Proposition 3. *With the additional price strategy,*

(a) *The ideal situation is achieved when the value of the premium (Δr) satisfies Cases II, III, or IV in Table 2.*

(b) *The ideal situation is the same as that of the price reduction strategy.*

Table 2. Choice of delivery mode by a type of user for a given Δr.

Case	*Value of* Δr	*Type H users*	*Type L users*
I	$\Delta r < -h(1-e_H)^2 + h(1-\beta_L) + c_T$	*A*	*A*
II	$\Delta r = -h(1-e_H)^2 + h(1-\beta_L) + c_T$	*A*	*A or U*
III	$-h(1-e_H)^2 + h(1-\beta_L) + c_T < \Delta r < -h(1-e_H)^2 + h(1-\beta_H) + c_T$	*A*	*U*
IV	$\Delta r = -h(1-e_H)^2 + h(1-\beta_H) + c_T$	*A or U*	*U*
V	$-h(1-e_H)^2 + h(1-\beta_H) + c_T < \Delta r$	*U*	*U*

A: attended delivery; *U*: unattended delivery

Proof. Using simple mathematical operations for Eqs. (7a and 7b) obtains this result (QED).

5.2 Profit in the Ideal Situation

We can standardize the total amount of users to one, where ω ($0 < \omega < 1$) represents the proportion of Type L users and $1-\omega$ represents the proportion of Type H users. The profit of the company in the ideal situation is given by

$$\Pi^A = (1-\omega)\{p - ke_H^2 + \tau e_H + \Delta r\} + \omega\{p - ke_H^2 + \alpha k e_L^2 - c_P(1-e_H)\}.$$

which is equivalently to

$$\Pi^A = p - ke_H^2 + \tau e_H + \Delta r - \omega\{-\alpha k e_H^2 + (\tau - c_P)e_H + \Delta r + c_P\}. \tag{8}$$

To increase the profit, Eq. (8) implies that the premium should be maximized. According to Table 2, the largest value of Δr that achieves the ideal situation is in Case IV. Therefore, Proposition 4 summarizes the optimal premium.

Proposition 4. *According to the additional price strategy, the optimal premium is given by*

$$\Delta r^* = -h(1-e_H)^2 + h(1-\beta_H) + c_T. \tag{8}$$

6 Comparison between Pricing Strategies

We compared three pricing strategies: the price reduction strategy, the additional price strategy, and the uniform pricing strategy. The last is the conventional strategy used in Japan where all users pay the same delivery fee regardless of their choice of delivery mode. First, we analyzed whether the price reduction or additional price strategy outperformed the uniform pricing strategy. Then, we explored under what conditions both the company and user would choose the same price differentiation strategy. This is a desirable market situation because a price differentiation strategy may not work properly if users prefer a different pricing strategy than the one selected by the company.

6.1 Price Reduction and Uniform Pricing Strategies

First, we compared the profitability of the price reduction and uniform pricing strategies for the company. The profit of the uniform pricing strategy Π^O can be described by

$$\Pi^O = p - ke_H^2 + \tau e_H. \tag{10}$$

We can compare Eq. (10) with Eq. (5) to determine which strategy is more profitable. The difference in profits $\Delta\Pi_{R-O}$ is then defined as follows:

$$\begin{aligned}\Delta\Pi_{R-O} \equiv \Pi^{R*} - \Pi^O &= [p - ke_H^2 + \tau e_H - \omega\{-\alpha ke_H^2 + (\tau - c_P)e_H + \Delta p^* + c_P\}] \\ &\quad -\{p - ke_H^2 + \tau e_H\} \\ &= \omega(\alpha ke_H^2 - \tau e_H - \Delta p^* - c_P). \end{aligned}\tag{11}$$

The optimal discount given by Eq. (6) can then be substituted into Eq. (11). Then, the price reduction strategy is more profitable than the uniform pricing strategy when

$$(\alpha k + h)e_H^2 - (\tau + 2h - c_P)e_H + h\beta_L - c_T - c_P > 0. \tag{12}$$

Proposition 5 compares the profitability of the price reduction and uniform pricing strategies.

Proposition 5.

(a) *If* $\alpha k - \tau - h(1 - \beta_L) - c_T \leq 0$, *then* $\Delta\Pi_{R-O}|r < 0$.

(b) *If* $\alpha k - \tau - h(1 - \beta_L) - c_T > 0$, *there exist* $\widetilde{e_H} \in (0,1)$ *that satisfy* $H(\widetilde{e_H}) = 0$. *Then,*

$If\ 0 < e_H < \widetilde{e_H}, then\ \Delta\Pi_{R-O}|r < 0.$

$If\ e_H = \widetilde{e_H}, then\ \Delta\Pi_{R-O}|r = 0.$

$If\ \widetilde{e_H} < e_H < 1, then\ \Delta\Pi_{R-O}|r > 0.$

$H(e_H)$ *is defined by*

$$H(e_H) = (\alpha k + h)e_H^2 - (\tau + 2h - c_P)e_H + \beta h - c_T - c_P. \tag{13}$$

Proof. The right-hand-side of Eq. (13) is the same as the left-hand-side of Eq. (12). Therefore, if $H(e_H) > 0$, then $\Delta\Pi_{R-O}|r > 0$. The behavior of $H(e_H)$ is given by

$$H(e_H = 0) = h\beta_L - c_T - c_P. \tag{14}$$

$$H(e_H = 1) = \alpha k - \tau - h(1 - \beta_L) - c_T - c_P. \tag{15}$$

Here, we can reasonably assume that

$$h\beta - c_T - c_P < 0. \tag{16}$$

If the benefit of unattended delivery $h\beta$ is greater than the negative effect $c_T + c_P$ of a delivery problem actually occurring (e.g., a parcel is stolen), then the company will always accept unattended delivery, but this is too trivial. Therefore, Eq. (16) is necessary to make a meaningful comparison between attended unattended delivery.

For Proposition 5(a), Eq. (14) indicates that $H(e_H = 0) < 0$. In addition, if $\alpha k - \tau - h(1 - \beta_L) - c_T - c_P > 0$,then Eqs. (15) and (16) indicate that $H(e_H = 0) < 0$ while $H(e_H = 1) > 0$. Therefore, we can use the midpoint theorem to state that there exists $\widetilde{e_H} \in (0,1)$ that satisfies $H(\widetilde{e_H}) = 0$. We obtain Proposition 5(b) by considering whether or not e_H is less than $\widetilde{e_H}$ (QED).

Proposition 5 implies that, if the penalty for a delivery problem is sufficiently high, then the uniform pricing strategy dominates the price reduction strategy. If the penalty is not critical, then the price reduction strategy outperforms the uniform pricing strategy.

6.2 Comparison Between the Additional Price and Uniform Pricing Strategies

Next, we compared the profitability of the additional price strategy and uniform pricing strategy. The difference in profits between Eq. (8) at the optimal premium Δr^* and Eq. (10) is given by:

$$\Delta\Pi_{A-O}|r \equiv \Pi^{A*} - \Pi^{O} = \Delta r^* + \omega(\alpha k e_H^2 - (\tau - c_P)e_H - \Delta r^* - c_P).$$

Proposition 6 compares the profitability.

Proposition 6.

(a) If $\alpha k \leq \tau$, then there exist $\widetilde{\omega} \in [0,1]$ that satisfy $G(\widetilde{\omega}|e_H) = 0$.

Then, if $0 \leq \omega < \widetilde{\omega}$, then $\Delta\Pi_{A-O}|r > 0$.

If $\omega = \widetilde{\omega}$, then $\Delta\Pi_{A-O}|r = 0$.

If $\widetilde{\omega} < \omega \leq 1$, then $\Delta\Pi_{A-O}|r < 0$.

(b) If $\alpha k > \tau$, then there exists $\widehat{e_H} \in (0,1)$ that satisfy $G(\omega = 1|\widehat{e_H}) = 0$.

Then, if $e_H < \widehat{e_H}$, then $\Delta\Pi_{A-O}|r > 0$ under the same conditions as listed in Proposition 6(a). Otherwise, always $\Delta\Pi_{A-O}|r > 0$.

Note that $G(\omega|e_H)$ is defined as

$$G(\omega|e_H) = \Delta r^* + \omega\{\alpha k e_H^2 - (\tau - c_P)e_H - \Delta r^* - c_P\}. \tag{17}$$

Proof. According to Eq. (17), the behavior of $G(\omega|e_H)$ is determined as follows:

$G(\omega = 0|e_H) = \Delta r^* > 0$ from the assumptions.

$$G(\omega = 1|e_H) = \alpha k - \tau. \tag{18}$$

$$G(\omega = 1|e_H = 0) = -c_P < 0. \tag{19}$$

$$G(\omega = 1|e_H = 1) = \alpha k - \tau. \tag{20}$$

For Proposition 6(a), Eq. (18) indicates that, if $\alpha k - \tau \leq 0$, then $G(\omega = 1|e_H) \leq 0$ for any $e_H \in (0,1)$. Therefore, the midpoint theorem can be used to prove that there exist $\widetilde{\omega} \in [0,1]$ that satisfy $G(\widetilde{\omega}|e_H) = 0$. For Proposition 6(b), if $\alpha k - \tau > 0$, then Eqs. (19) and (20) indicate that there exist $\widehat{e_H} \in (0,1)$ that satisfies $G(\omega = 1|\widehat{e_H}) = 0$ based on the midpoint theorem. Therefore, if $e_H < \widehat{e_H}$, the results are the same as for Proposition 6(a). Otherwise, always $G(\omega|e_H) > 0$, which results in always $\Delta\Pi_{A-O}|r > 0$ (QED).

Propositions 6 shows that, if the benefit of attended deliver (τ) is high and/or if the benefit of unattended delivery (αk) is low for the company, then the additional price strategy outperforms the uniform pricing strategy when the proportion of Type L users is relatively small. Otherwise, the uniform pricing strategy should be selected. In contrast, if τ is sufficiently low and αk is sufficiently high, then the additional price strategy outperforms the uniform pricing strategy when the service quality preference of Type H users is set over a threshold value.

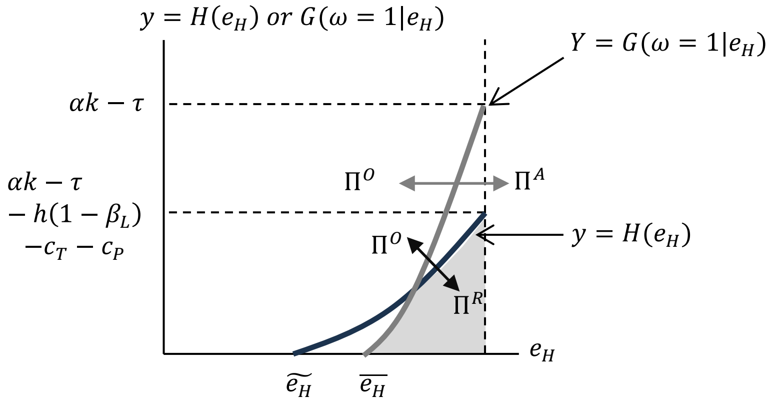

Fig. 1. Conditions under which both the price reduction and additional price strategies outperform the uniform pricing strategy (shaded area) when $\alpha k > \tau$ and $\widetilde{e_H} < \overline{e_H}$.

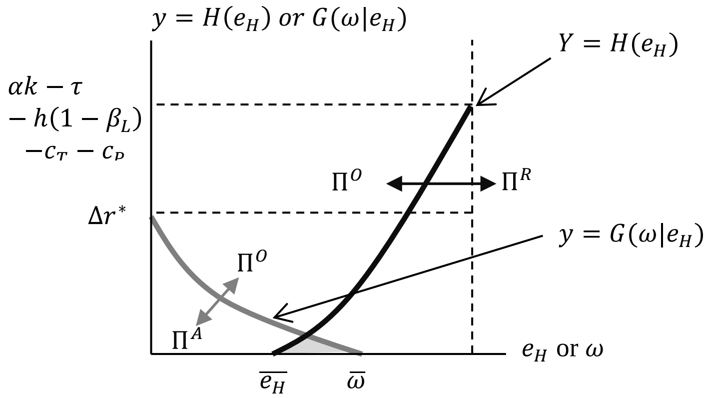

Fig. 2. Conditions under which both the price reduction and additional price strategies outperform the uniform pricing strategy (shaded area) when $\alpha k \leq \tau$ and $\overline{e_H} < \overline{\omega}$.

Comparison between Propositions 4 and 5. Figs. 1 and 2 graph when both the price reduction and additional price strategies are more profitable for the company than the uniform pricing strategy. Although the positional relationships of the curves depend on the values of $\overline{e_H}$, $\widetilde{e_H}$, and $\overline{\omega}$, we can obtain the following general outcomes. If $\alpha k > \tau$, then both the price reduction and additional price strategies outperform the uniform pricing strategy when e_H is sufficiently high (see the shaded area in Fig. 1). If $\alpha k \le \tau$, both the price reduction and additional price strategies are more profitable for the company than the uniform pricing strategy when e_H is at a moderate level (see the shaded area in Fig. 2). Therefore, setting of the quality level of the high-quality delivery service is a key to making a price differentiation strategy work properly, which requires adequately understanding the benefits of attended and unattended deliveries.

6.3 Comparison Between the Price Reduction and Uniform Pricing Strategies

Next, we compared the two price differentiation strategies at their optimal prices (i.e., Δp^* and Δr^*). The profit difference at the optimal prices is given by

$$\Delta\Pi_{R-A} \equiv \Pi^R(\Delta p^*) - \Pi^A(\Delta r^*) = -\omega h(\beta_L - \beta_H) + h(1-e_H)^2 - h(1-\beta_H) - c_T. \quad (21)$$

From Eq. (21), we obtain Proposition 7.

Proposition 7. *The optimal strategy between the price reduction and additional price strategies is determined by:*

$$\Delta\Pi_{R-A} > 0 \text{ if}$$
$$\omega < \widehat{\omega} \equiv \frac{-e_H^2 + 2e_H - \beta_H + c_T/h}{\beta_L - \beta_H}. \quad (22)$$

Proof. This is easily derived from Eq. (22) (QED).

Proposition 7 implies that the price reduction strategy should be adopted when the proportion of Type L users is relatively small. This is intuitive because a large proportion of Type *L* users may reduce the total revenue if the company offers a discount for unattended deliveries.

6.4 Optimal Utility for Users

Finally, we explored which price differentiation strategy optimized the utility for users. The optimal utilities with each pricing strategy are given in Lemma 1.

Lemma 1. *The optimal utility values of the types of users in the ideal situation are as follows:*

(a) For the price reduction strategy,

$$U_H^{R*} = v - p - h(1-e_H)^2. \quad (23a)$$

$$U_L^{R*} = v - p - h(1-e_H)^2. \quad (23b)$$

(b) For the additional price strategy,

$$U_H^{A*} = v - p - h(1-\beta_L) - c_T.$$

$$U_L^{A*} = v - p - h(1-\beta_L) - c_T.$$

Proof. (a) Using Eqs. (2) and (6) can be used to easily determine the values of $U_H^{R*} = U_H^R(d^* = 0, e^* = e_H, \Delta r^* = 0)$ and $U_L^{R*} = U_H^R(d^* = 1, e^* = e_L, \Delta r^* = -h(1 -$

$e_H)^2 + h(1-\beta_L) + c_T)$ as given in Eqs. (23a) and (23b). (b) The same logic as in Lemma 1(a) can be used (QED).

Lemma 1 shows that, for each pricing strategy, the optimal utilities for Type *H* and *L* users are equivalent. The maximum utility of the price reduction strategy depends on the quality level of attended delivery (e_H), while the maximum utility of the additional price strategy depends on the user's preference for unattended delivery (β_L) and the penalty due to delivery problems (c_T). In other words, the price reduction strategy allows the company to directly influence the maximum utility for the user because the quality level of attended delivery is controlled by the company. However, the additional price strategy does not allow the company to directly control the utility for the user because the user preferences and perceived risk due to delivery problem are out of their control.

Next, we compared the utility values of the two strategies. The difference between the two utilities is defined by

$$\Delta U^*_{R-A} \equiv U_H^{R*} - U_H^{A*} = -h(1-e_H)^2 + h(1-\beta_L) + c_T. \tag{24}$$

We then obtain Proposition 8.

Proposition 8

$$\Delta U^*_{R-A} > 0 \ iff$$
$$e_H > \widehat{e_H} = 1 - \sqrt{1-\beta_L + c_T/h}. \tag{25}$$

Proof. It is easily obtained this result from Eq. (24) (QED).

Proposition 8 shows that the price reduction strategy results in higher utility for the user than the additional price strategy when the quality level of attended delivery is higher than the threshold value $\widehat{e_H}$ in Eq. (25). The threshold value $\widehat{e_H}$ becomes larger when Type *L* users are more sensitive to the service quality and becomes smaller as the risk of delivery problems increases.

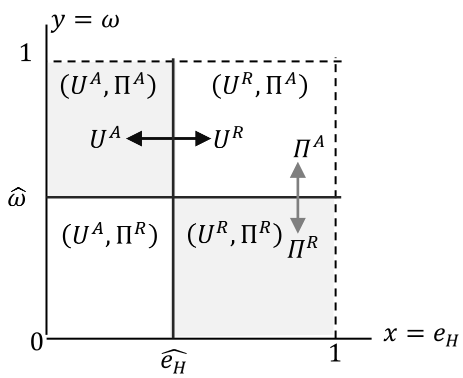

Fig. 3. Choice of pricing strategy by the company and user. The shaded areas denote the conditions under which the two players choose the same pricing strategy.

Comparison between Propositions 7 and 8. Fig. 3 graphs the conditions under which the company and user choose the same pricing strategy. The shaded areas indicate the combination of values of e_H and ω that cause both players to choose the same pricing strategy. The company and users prefer the additional price strategy when the proportion of Type L users is relatively high and the quality level of attended delivery is relatively low. In contrast, the price reduction strategy is preferred when the proportion of Type H users is relatively high and the quality level of attended delivery is relatively high.

7 Discussion and Concluding Remarks

Based on our analysis, we obtained the following findings. First, adequately differentiating delivery fees for attended and unattended deliveries can separate Type H users who prefer the former and Type L users who are satisfied with the latter and thus reduce the workload of delivery workers. This implies that either the price reduction strategy or additional price strategy can be used to mitigate the labor shortage currently faced by the Japanese logistics industry. Second, the choice of the price reduction or additional price strategy is determined by the proportion of Type H and Type L users. In general, increasing the proportion of Type L users increases the suitability of the additional price strategy. Therefore, understanding consumers' service quality preference is required to determine the best price differentiation strategy for offering unattended delivery in an effort to reduce the delivery workload. Third, the quality level of the attended delivery service is another key for a price differentiation strategy to work properly. In detail, when the benefit of unattended delivery is more than that of attended delivery, the quality level of the latter should be set high. When the benefit is less, then the quality level should be set moderate. This implies that, if a company benefits more from unattended delivery than from attended delivery, unnecessary high-quality services should be eliminated. In fact, it has been pointed out that Japan has many unneeded customs (e.g., delivery workers are not allowed to use holes on the sides of cardboard boxes when carrying them) that increases the workload of delivery workers.
Concluding Remarks Owing to a declining birthrate, aging population, and labor shortage, the Japanese logistics industry is at risk of collapse. Home delivery user's preference to delivery service is heterogenous. Some users prefer high-quality service of attended delivery with redelivery, while some users are quite satisfied with simple unattended delivery. Aiming at reduction of delivery workload, this study investigated how an adequate price differentiation strategy can separate low-quality-oriented users from high-quality-oriented users, and then verifies that the separating equilibrium obtained by the price differentiation ultimately contributes to reducing the workload. Based on the model analysis, we propose several managerial implications.

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