SERVICE PRODUCT PRICING STRATEGIES BASED ON TIME-SENSITIVE CUSTOMER CHOICE BEHAVIOR

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ABSTRACT. Product pricing strategy has a significant impact on a service company’s competitive edge. Considering the heterogeneous and time-sensitive customer choice behavior, monopoly service companies price their service products depending on cost parameters as well as time-sensitive customer choice behavior. According to the different time sensitivity, customers are classed into two groups (i.e., two market segments). By considering the impact of customer choice behavior, this paper investigates how a monopoly service firm decides its service product’s response time and price under two product design strategies, i.e., offering two service products respectively to two market segments, or offering one standard service product to two market segments. Results indicate that, under the two strategies, the service firm adopts a segmented pricing strategy based on the customer perceived values and time-sensitive degrees. Besides, the service firm’s profit under the strategy of offering two products is always higher than that under the other strategy. This indicates that, along with the individuation of customer demand, firms should firstly segment the market, and then, design targeted products for different customers. As a result, the degree of customer satisfaction can be increased, and firms can obtain higher profits.

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1. Introduction. With the improvement of people's living standard, the service industry has penetrated into people's daily life. In this environment, when people receive services, they not only pay attention to the price and quality of a service product, but also pay more attention to the response time \cite{11, 14, 31, 32, 36, 37} and greening \cite{43}. Customers will accept the service only when they can obtain non-negative utility from buying the service product, and they will choose the service product which can guarantee their maximal utility. This is called to be customer choice behavior \cite{8, 28, 42, 45, 50}. Besides, along with the diversification of customer demand, service enterprises have offered different products to form a product line for customers to choose \cite{4, 11, 15, 23, 44, 47}. Therefore, when pricing the service product line, service firms should consider the customer choice behavior as well as the competitive relationship among different products in the same product line.

Research about the pricing problem of service product has been investigated \cite{10, 12, 24, 27, 33, 35, 39, 46, 48}. Cachon and Feldman \cite{7} studied the service pricing problem, and investigated should a firm charge on a per-use basis or sell subscriptions when its service experiences congestion? Allon and Gruvich \cite{2} introduced a framework that combines many-server heavy-traffic analysis with the notion of Epsilon-Nash equilibrium and applied it to the study of equilibrium in a market with multiple large-scale service providers that compete on both the price and the response time. Bashyam \cite{5} investigated service design and price competition in business information service, and examined two competing technologies for delivering business information to professional subscribers: first, a package service that delivers information using physical media; second, an online service that allows subscribers to access information over online networks. Maglaras and Zeevi \cite{29} researched the pricing and design of differentiated services from the angle of approximate analysis and structural insights. The service provider's objective is to optimally design the system so as to extract maximum revenue. Hosanagar et al. \cite{19} studied the pricing and resource allocation problem in caching services with multiple levels of quality of service. Hu et al. \cite{20} studied the optimal product and pricing decisions in a crowd-funding mechanism by which a project between a creator and many buyers will be realized only if the total funds committed by the buyers reach a specified goal. The above researches only deal with the service capacity decision and pricing problem, but not consider the impact of customer selective preference and customer choice behavior.

By considering the effect of customer choice behavior, some researchers have investigated the service product pricing problem. Cachon and Swinney \cite{8} investigated how to design service product by considering strategic consumer behavior. Customer queue for the service based on service quality, delay costs, and price, Krishnan et al. \cite{25} studied how a service provider facing such customers makes the optimal “quality-speed trade-off”. Motivated by call centers, Armony and Mandelbaum \cite{3} studied large-scale service systems with homogeneous impatient customers and heterogeneous servers, the servers differ with respect to their speed of service. Zhang and Cooper \cite{49} considered the simultaneous seat-inventory control of a set of parallel flights between a common origin and destination with dynamic customer choice among the flights. Van Ryzin and Vulcano \cite{40} considered a revenue management, network capacity control problem in setting where heterogeneous customers choose among the various product offered by a firm. Chaneton and Vulcano \cite{9} analyzed a single-leg reserve management problem in which the buyers’ choice behavior
is modeled explicitly. Federgruen and Hu [16] addressed a generic price competition model in an industry with an arbitrary number of competitors, each offering all or a subset of a given line of \( N \) products. Zhang et al. [52] presented a mixed integer nonlinear programming model that combines the general discrete time/cost trade-off problem and the concept of soft logic. Based on describing the customer choice behavior, these researches investigated the service product pricing problem, but they do not consider the effect of time-sensitive customer behavior on service product pricing strategy.

Considering the impact of time-sensitive customer choice behavior, this paper investigates the decision problem of service product price and response time for a monopoly service firm under two service product design strategies, i.e., offering two service products with different response time respectively to two market segments, which is known to be Segment Strategy (SS strategy), and offering one standard service product to two market segments, which is known to be Mass Strategy (MS strategy). While Buratto et al. [6] and Sugandha et al. [38] only addressed the segment strategy for the segmented market. Research results indicate that, under the SS and MS strategies, the monopoly service firm adopts a segmented pricing strategy based on the customer perceived values and time-sensitive degrees of customers in different market segments, which is completely different from the pricing strategy by considering quality-sensitive customer behavior. Numerical experiments illustrate the impacts of customer perceived value on the optimal response time, price and profit, and the pricing strategies under two service product design strategies are compared. It can be observed that, along with the individuation of customer demand, firms should firstly segment the market, and then, design targeted products for different customers. As a result, the degree of customer satisfaction can be increased, and firms can obtain higher profits.

The remainder of this paper is structured as follows. In section 2, we describe the service product pricing strategy problem. In section 3, the optimal decision problem of service product response time and price under SS and MS strategies are analyzed, respectively. Numerical illustration is provided in section 5, and the paper ends with some conclusions in section 5.

2. Problem description. Considering the difference in degree of customer time sensitivity, we divide the market into two segments, i.e., a high-end market segment and a low-end market segment. Denote the indices of high and low-end market segments by \( h \) and \( l \). The customers in segment \( h \) are more sensitive on time than that in segment \( l \). We assume that the market demand is constant, and size of the market is 1. The proportion of segment \( h \) is assumed to be \( \theta \) (\( 0 < \theta < 1 \)), and \( l \) is assumed to be \( 1 - \theta \). A customer utility of buying a service product is a decreasing function of price and response time, i.e., the utility that a customer in segment \( i \) (\( i = h, l \)) derives from buying the product \( j \) (\( j = h, l \)) with price \( p_j \) and response time \( t_j \), \( U_{ij} \), is given by \( U_{ij} = v_i - p_j - \alpha_i t_j \) [37], \( i, j = h, l \). Where, \( v_i \) expresses the perceived value of customers in different market segments on the service product’s attribute (such as quality), and \( \alpha_i \) indicates the sensitive degree of customers in different market segments on the service product’s response time. We assume that, a customer in segment \( h \) has a higher perceived value than that a customer in segment \( l \), i.e., \( v_h > v_l > 0 \), and a customer in segment \( h \) has a higher time sensitivity, i.e., \( \alpha_h > \alpha_l > 0 \). It should be noted that to simplify
our analysis, though corner solutions may exist, we will focus our attention on the interior solutions throughout this paper, i.e., $\alpha_h v_l - \alpha_l v_h > 0$ ($v_l/\alpha_l > v_h/\alpha_h$).

Since the monopoly service firm has the option to design two service products with different response times for market segments $h$ and $l$, we denote the two service products also as products $h$ and $l$, with a short response time $t_h$ and a long response time $t_l$ ($0 < t_h < t_l$), respectively. The cost of offering a service product with response time $t_j$ ($j = h, l$) is assumed to be $C_j(t_j) = k_j/t_j$ ($k_j > 0$, $j = h, l$). Where $k_j$ is a scalar cost coefficient that recognizes the difference in cost of offering unit response time across products. So we have $k_h > k_l > 0$ [18], [34]. The monopoly service firm can adopt the strategy of offering two different service products respectively to two market segments, which is known simply as a $SS$ strategy, or adopt the strategy of offering one standard service product to two market segments, which is known simply as a $MS$ strategy. Under the two strategies, the firm decides the optimal price and response time to maximize its profit.

Since customers will buy the service product only when they can obtain non-negative utility, and they will choose the service product which can guarantee their maximal utility. Therefore, when the service firm designs one standard service product for two market segments, individual rationality constraints should be satisfied (i.e., customers have non-negative utility). In this paper, we assume the monopoly service firm is risk neutral [22]. When the firm designs two different service products respectively for two market segments, individual rationality and incentive compatibility constraints should all be satisfied, i.e., ensuring customers in market segment $h$ (or $l$) have the possibility to buy service product $h$ (or $l$) designed for them (individual rationality constraint), and ensuring customers in each market segment buy the service product specifically designed for them (incentive compatibility constraint) [13], [17], [21], [25], [30], [41], [51]. They are shown as follows,

$$v_h - p_h - \alpha_h t_h \geq 0,$$

(1)

$$v_l - p_l - \alpha_l t_l \geq 0,$$

(2)

$$v_h - p_h - \alpha_h t_h \geq v_h - p_l - \alpha_l t_l,$$

(3)

$$v_l - p_l - \alpha_l t_l \geq v_l - p_h - \alpha_h t_h.$$

(4)

Constraints (1) and (2) are termed the individual rationality constraints. Note that the utility of a customer in segment $h$ (or $l$) from buying the service product $h$ (or $l$) can be positive or negative. Constraints (3) and (4) are the termed incentive compatibility constraints. These constraints are necessary for making the market segmentation meaningful.

With the above constraints (1)–(4) on the customer valuation, we next show the optimal decisions of response time and price based on maximizing profit for service firms under the two product design strategies, respectively.

3. **Service product pricing strategy.** In the following section, we respectively analyze the decisions of response time and price under the two product design strategies, i.e., offering two service products to two market segments ($SS$ strategy) and offering one standard product to two market segments ($MS$ strategy).
3.1. Optimal decisions under SS service product design strategy. Under the SS strategy, a monopoly firm’s profit is denoted by $\pi_{ss}$, and then, we can have the following optimization model, through which the firm sets the optimal price and response time to maximize its profit under the constraints (1–4).

$$\begin{align*}
\max_{p_j,t_j,j,h,l} \{\pi_{ss} &= (p_h - k_h/t_h)\theta + (p_l - k_l/t_l)(1 - \theta)\} \\
\text{subject to constraints (1–4)}. 
\end{align*}$$

(5)

From the constraints (1–4) in problem given by (5), we have

$$p_l \leq v_l - \alpha_t t_l, p_h \leq v_h - \alpha_h t_h, p_h < p_l + \alpha_h t_l - \alpha_h t_h. \quad (6)$$

Since the firm’s profit is an increasing function of price, it will set the highest price to maximize its profit. As $t_l > t_h$ and $\alpha_h > \alpha_t$, the two equations $p_l = p_h + \alpha_h t_l - \alpha_t t_l$ and $p_h = p_l + \alpha_h t_l - \alpha_h t_h$ are not simultaneously satisfied, so only three cases exist. Therefore, we get the pricing strategy, as given in Lemma 3.1.

**Lemma 3.1.** The pricing strategy of problem given by (5) is as follows, (1) if $t_l \leq \frac{v_h - v_l}{\alpha_h - \alpha_t}$ and $t_l \geq \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $p_l^*(t_l,t_h) = v_l - \alpha_t t_l, p_h^*(t_l,t_h) = v_h - \alpha_h t_h$,

(2) if $t_l \leq \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $p_l^*(t_l,t_h) = v_l - \alpha_t t_l, p_h^*(t_l,t_h) = v_l - \alpha_l t_l + \alpha_h t_l - \alpha_h t_h$,

(3) if $t_l \geq \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $p_l^*(t_l,t_h) = v_l - \alpha_t t_l + \alpha_h t_l - \alpha_l t_l, p_h^*(t_l,t_h) = v_h - \alpha_h t_h$.

**Proof of Lemma 3.1** We can verify the Lemma 3.1 as the following three cases.

- Case(1): If $p_l = v_l - \alpha_t t_l, p_h = v_h - \alpha_h t_h$, and then we have

$$U_{lh} = 0, U_{hl} = v_h - v_l - (\alpha_h - \alpha_l) t_l, U_{ll} = 0, U_{lh} = (\alpha_h - \alpha_l) t_l - (v_h - v_l).$$

Since $t_h < t_l$ and $\alpha_h > \alpha_l$, then the following three subcases exist:

(i) if $t_h \leq \frac{v_h - v_l}{\alpha_h - \alpha_t}$ and $t_l \geq \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $U_{hl} \leq 0, U_{lh} \leq 0$, the four constraints of problem given by (6) are all satisfied, hence, $p_l = v_l - \alpha_t t_l, p_h = v_h - \alpha_h t_h$,

(ii) if $t_h > \frac{v_h - v_l}{\alpha_h - \alpha_t}$ and $t_l \geq \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $U_{hl} \leq 0, U_{lh} > 0$, the fourth constraint of problem given by (6) is not satisfied, there is no solution,

(iii) if $t_h < \frac{v_h - v_l}{\alpha_h - \alpha_t}$ and $t_l < \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $U_{hl} > 0, U_{lh} \leq 0$, the third constraint of problem given by (6) is not satisfied, there is no solution.

- Case(2): if $p_l = v_l - \alpha_t t_l, p_h = v_l - \alpha_l t_l + \alpha_h t_l - \alpha_h t_h$, and then we have

$$U_{hh} = U_{hl} = v_h - v_l - (\alpha_h - \alpha_l) t_l, U_{ll} = 0, U_{lh} = (\alpha_h - \alpha_l)(t_l - t_l) < 0.$$

Only if $t_l \leq \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $U_{hh} = U_{hl} \geq 0$, the four constraints of problem given by (6) are all satisfied, hence, $p_l = v_l - \alpha_t t_l, p_h = v_l - \alpha_l t_l + \alpha_h t_l - \alpha_h t_h$.

- Case(3): if $p_l = v_h - \alpha_h t_h + \alpha_l t_l + \alpha_h t_l - \alpha_h t_l$, and then we have

$$U_{hh} = 0, U_{hl} = (\alpha_h - \alpha_l)(t_l - t_l) < 0, U_{ll} = U_{lh} = (\alpha_h - \alpha_l) t_h - (v_h - v_l).$$

Only if $t_h \geq \frac{v_h - v_l}{\alpha_h - \alpha_t}$, then $U_{hl} = U_{lh} \geq 0$, the four constraints of problem given by (6) are all satisfied, hence, $p_l = v_h - \alpha_h t_h + \alpha_l t_l + \alpha_h t_l - v_h - \alpha_h t_h$.

Combining results in the above three cases proves the Lemma 3.1.

Substituting the optimal price described in Lemma 3.1 into the objective function of problem given by (5) gives the optimal response time and price, which is shown in Theorem 3.2 below.
Denote $V_1 = \sqrt{\frac{k_h \theta}{\alpha_h - \alpha_t + \alpha_h \theta}}$ and $V_2 = \sqrt{\frac{k_l (1-\theta)}{\alpha_t - \alpha_h \theta}}$. It is obvious that $V_1 < \frac{k_h}{\alpha_h} < \sqrt{k_l/\alpha_l} < V_2$.

**Theorem 3.2.** The optimal response time and price of problem given by (5) are as follows,

1. if $\frac{v_h - v_l}{\alpha_h - \alpha_l} < V_1$, then $t^*_l = \sqrt{k_l/\alpha_l}, t^*_h = V_1, \pi^*_l = v_h - (\alpha_l - \alpha_t)V_1 - \alpha_l \sqrt{k_l/\alpha_l}, p^*_h = v_h - \alpha_h V_1$,

2. if $V_1 \leq \frac{v_h - v_l}{\alpha_h - \alpha_l} < \sqrt{k_h/\alpha_h}$, then $t^*_l = \sqrt{k_l/\alpha_l}, t^*_h = \frac{v_h - v_l}{\alpha_h - \alpha_l}, \pi^*_l = v_l - \alpha_l \sqrt{k_l/\alpha_l}, p^*_h = \frac{v_h - v_l}{\alpha_h - \alpha_l}$,

3. if $\sqrt{k_h/\alpha_h} \leq \frac{v_h - v_l}{\alpha_h - \alpha_l} \leq \sqrt{k_l/\alpha_l}$, then $t^*_l = \sqrt{k_l/\alpha_l}, t^*_h = \sqrt{k_h/\alpha_h}, p^*_l = v_l - \alpha_l \sqrt{k_l/\alpha_l}, p^*_h = \frac{v_h - v_l}{\alpha_h - \alpha_l}$,

4. if $\sqrt{k_l/\alpha_l} < \frac{v_h - v_l}{\alpha_h - \alpha_l} < V_2$, then $t^*_l = \frac{v_h - v_l}{\alpha_h - \alpha_l}, t^*_h = \sqrt{k_h/\alpha_h}, \pi^*_l = \frac{v_h - v_l}{\alpha_h - \alpha_l}, \pi^*_h = \frac{v_h - v_l}{\alpha_h - \alpha_l}$,

5. if $\frac{v_h - v_l}{\alpha_h - \alpha_l} \geq V_2$, then $t^*_l = V_2, t^*_h = \sqrt{k_h/\alpha_h}, \pi^*_l = v_l - \alpha_l V_2, p^*_h = v_l + (\alpha_h - \alpha_l) V_2 - \alpha_h \sqrt{k_h/\alpha_h}$.

**Proof of Theorem 3.2.** Substituting the pricing strategies described in Lemma 3.1 into the objective function of problem given by (6) gives the following three cases.

Case(1): If $t_h \leq \frac{v_h - v_l}{\alpha_h - \alpha_l}$ and $t_l \geq \frac{v_h - v_l}{\alpha_h - \alpha_l}$, then $\pi_l = v_l - \alpha_l t_l, p_h = v_h - \alpha_h t_h$.

$$\pi_{ss} = (v_h - \alpha_h t_h - k_h/t_h)\theta + (v_l - \alpha_l t_l - k_l/t_l)(1-\theta).$$

The optimal conditions are

$$\frac{\partial \pi_{ss}}{\partial t_h} = (-\alpha_h + k_h/t_h^2) \theta, \frac{\partial \pi_{ss}}{\partial t_l} = (-\alpha_l + k_l/t_l^2) \theta,$$

$$\frac{\partial^2 \pi_{ss}}{\partial t_h^2} = -2k_h \theta/k_h^3 < 0, \frac{\partial^2 \pi_{ss}}{\partial t_l^2} = -2k_l(1-\theta)/t_l^3 < 0, \frac{\partial^2 \pi_{ss}}{\partial t_h \partial t_l} = 0,$$

$$\frac{\partial^2 \pi_{ss}}{\partial t_h^2} - (\frac{\partial^2 \pi_{ss}}{\partial t_h \partial t_l})^2 = \frac{4k_h k_l (1-\theta) \theta}{t_l^3 t_h^3} > 0.$$

From $\frac{\partial \pi_{ss}}{\partial t_h} = 0$ and $\frac{\partial \pi_{ss}}{\partial t_l} = 0$, we get $t_l = \sqrt{k_l/\alpha_l}, t_h = \sqrt{k_h/\alpha_h}$. Since $t_l > t_h > 0$, we assume that $k_h/\alpha_h < k_l/\alpha_l$. Hence, we have

(i) if $\sqrt{k_h/\alpha_h} \leq \frac{v_h - v_l}{\alpha_h - \alpha_l} \leq \sqrt{k_l/\alpha_l}$, then $t^*_l = \sqrt{k_l/\alpha_l}, t^*_h = \sqrt{k_h/\alpha_h}, p^*_l = v_l - \alpha_l \sqrt{k_l/\alpha_l}, p^*_h = v_h - \alpha_h \sqrt{k_h/\alpha_h}$,

(ii) if $\frac{v_h - v_l}{\alpha_h - \alpha_l} < \sqrt{k_h/\alpha_h}$, then $t^*_l = \sqrt{k_l/\alpha_l}, t^*_h = \frac{v_h - v_l}{\alpha_h - \alpha_l}, p^*_l = v_l - \alpha_l \sqrt{k_l/\alpha_l}, p^*_h = \frac{v_h - v_l}{\alpha_h - \alpha_l}$,

(iii) if $\sqrt{k_l/\alpha_l} < \frac{v_h - v_l}{\alpha_h - \alpha_l}$, then $t^*_l = \frac{v_h - v_l}{\alpha_h - \alpha_l}, t^*_h = \sqrt{k_h/\alpha_h}, p^*_l = \frac{v_h - v_l}{\alpha_h - \alpha_l}, p^*_h = v_h - \alpha_h \sqrt{k_h/\alpha_h}$.

Case(2): If $t_l \leq \frac{v_h - v_l}{\alpha_h - \alpha_l}$, then $p_l = v_l - \alpha_l t_l, p_h = v_l - \alpha_l t_l + \alpha_h t_l - \alpha_h t_h$.

$$\pi_{ss} = (v_l - \alpha_l t_l + \alpha_h t_l - \alpha_h t_h - k_h/t_h)\theta + (v_l - \alpha_l t_l - k_l/t_l)(1-\theta).$$

Similar to case(1), we have $t_h = \frac{k_h}{\alpha_h} t_l = \sqrt{\frac{k_l (1-\theta)}{\alpha_l - \alpha_h \theta}}$. Hence we have

(i) if $\frac{v_h - v_l}{\alpha_h - \alpha_l} \geq \sqrt{\frac{k_l (1-\theta)}{\alpha_l - \alpha_h \theta}}$, then $t^*_l = \sqrt{\frac{k_l (1-\theta)}{\alpha_l - \alpha_h \theta}}, t^*_h = \frac{k_h}{\alpha_h}, \pi^*_l = v_l - \alpha_l \sqrt{\frac{k_l (1-\theta)}{\alpha_l - \alpha_h \theta}}, p^*_h = \frac{v_l - \alpha_l \sqrt{\frac{k_l (1-\theta)}{\alpha_l - \alpha_h \theta}}}{\alpha_h - \alpha_h \theta}$. 


(ii) If \( \frac{v_h - v_l}{\alpha_h - \alpha_l} < \sqrt{\frac{k_l(1 - \theta)}{\alpha_l - \alpha_l}} \), then

\[
t_l^* = \frac{v_h - v_l}{\alpha_h - \alpha_l}, \quad t_h^* = \sqrt{\frac{k_l}{\alpha_h}}, \quad p_l^* = \alpha_h v_l - \alpha_l v_l, \quad p_h^* = v_h - \alpha_h \sqrt{\frac{k_l}{\alpha_h}}.
\]

**Case (3):** If \( t_h \geq \frac{v_h - v_l}{\alpha_h - \alpha_l} \), then \( p_l = v_h - \alpha_h t_h + \alpha_l t_h - \alpha_l t_l, p_h = v_h - \alpha_h t_h \).

\[
\pi_{ss} = (v_h - \alpha_h t_h - k_h/t_h)\theta + (v_h - \alpha_h t_h + \alpha_l t_h - \alpha_l t_l - k_l/t_l)(1 - \theta).
\]

Similar to case (1), we have \( t_h = \sqrt{\frac{k_h}{\alpha_h - \alpha_l + \alpha_l \theta}}, t_l = \sqrt{\frac{k_l}{\alpha_l}} \). Hence, we have

(i) If \( \frac{v_h - v_l}{\alpha_h - \alpha_l} \geq \sqrt{\frac{k_l \theta}{\alpha_h - \alpha_l + \alpha_l \theta}} \), then

\[
t_l^* = \sqrt{\frac{k_l}{\alpha_l}}, \quad t_h^* = \frac{v_h - v_l}{\alpha_h - \alpha_l}, \quad p_l^* = v_l - \alpha_l \sqrt{\frac{k_l}{\alpha_l}}, \quad p_h^* = \frac{\alpha_h v_l - \alpha_l v_l}{\alpha_h - \alpha_l},
\]

(ii) If \( \frac{v_h - v_l}{\alpha_h - \alpha_l} < \sqrt{\frac{k_l \theta}{\alpha_h - \alpha_l + \alpha_l \theta}} \), then \( t_l^* = \sqrt{\frac{k_l}{\alpha_l}}, \quad t_h^* = \sqrt{\frac{k_h \theta}{\alpha_h - \alpha_l + \alpha_l \theta}}, \quad p_l^* = v_l - \alpha_l \sqrt{\frac{k_l}{\alpha_l}}, \quad p_h^* = v_h - \alpha_h \sqrt{\frac{k_h \theta}{\alpha_h - \alpha_l + \alpha_l \theta}}.
\]

It can be easily verified that

\[
\sqrt{\frac{k_h \theta}{\alpha_h - \alpha_l + \alpha_l \theta}} < \sqrt{\frac{k_l}{\alpha_l}} < \sqrt{\frac{k_l(1 - \theta)}{\alpha_l - \alpha_l \theta}}.
\]

Combining results in the above cases (1-3) proves the Theorem 3.2.

Theorem 3.2 indicates that, under the SS strategy, the monopoly service firm adopts a segmented pricing strategy according to the customer perceived values \( v_h \) and \( v_l \) and time sensitive degrees \( \alpha_h \) and \( \alpha_l \), and sets different response times in different interval areas. From Theorem 3.2, it can be observed that, under some conditions, the optimal price and response time of one service product are not only affected by the market parameter of the market segment which the service product is designed for and cost parameter of this service product, but also affected by that of the other market segment and service product. If only, \( \sqrt{k_l/\alpha_l} \leq \frac{v_h - v_l}{\alpha_h - \alpha_l} \leq \sqrt{k_l/\alpha_l} \) is satisfied, the optimal response time and price of one service product designed for one market segment are not affected by the parameters of the other service product designed for the other market segment.

### 3.2. Optimal decisions under MS service product design strategy

Here we consider that a service firm offers a service product with price \( p \) and response time \( t \) to two market segments, which is denoted as MS strategy. Under this strategy, the production cost is supposed as \( k/t \), and the firm’s profit is denoted by \( \pi_{ms} \). Therefore, we have the following optimization model.

\[
\max_{p,t} \{\pi_{ms} = p - k/t\} \\
\text{s.t.} \ v_h - \alpha_h t \geq 0, \\
\quad \quad \quad \ v_l - \alpha_l t \geq 0.
\]

From the constraints in problem given by (7), we have

\[
p \leq \min\{v_h - \alpha_h t, v_l - \alpha_l t\}.
\]

Following the similar solving process as used in problem given by (5), we have the following Lemma 3.3 and Theorem 3.4 about the optimal decisions of price and response time under MS strategy.
Lemma 3.3. The pricing strategy of problem given by (7) is as follows,
(1) if \( v_h - \alpha_h t \geq v_l - \alpha_l t \), then \( p^*(t) = v_l - \alpha_l t \),
(2) if \( v_h - \alpha_h t < v_l - \alpha_l t \), then \( p^*(t) = v_h - \alpha_h t \).

Theorem 3.4. The optimal response time and price of problem given by (7) are as follows,
(1) if \( \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \leq \sqrt{k/\alpha_l} \), then \( t^* = \sqrt{k/\alpha_l}, p^* = v_h - \alpha_h \sqrt{k/\alpha_l} \),
(2) if \( \sqrt{k/\alpha_h} < \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \leq \sqrt{k/\alpha_l} \), then \( t^* = \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l}, p^* = \frac{2\alpha_h v_h - \alpha_l v_h}{\alpha_h - \alpha_l} \),
(3) if \( \sqrt{k/\alpha_l} < \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \), then \( t^* = \sqrt{k/\alpha_l}, p^* = v_l - \alpha_l \sqrt{k/\alpha_l} \).

Proof of Theorem 3.4. Substituting the pricing strategies described in Lemma 3.3 into the objective function of problem given by (7) gives the following two cases. 
Case(1): If \( v_h - \alpha_h t \geq v_l - \alpha_l t \), i.e., \( t \leq \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \),
then
\[
\pi_m = v_l - \alpha_l t - k/t = -\frac{\alpha_l t^2 - v_l t + k}{t}. 
\]
From \( \frac{\partial \pi_m}{\partial t} = -\alpha_l + k/t^2 = 0 \) and \( \frac{\partial^2 \pi_m}{\partial t^2} = -2k/t^3 < 0 \), we get \( t = \sqrt{k/\alpha_l} \). Therefore, we have
(1) if \( \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \leq \sqrt{k/\alpha_l} \), then \( t^* = \sqrt{k/\alpha_l}, p^* = \sqrt{k/\alpha_l} \).
(2) if \( \sqrt{k/\alpha_h} < \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \), then \( t^* = \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l}, p^* = \frac{2\alpha_h v_h - \alpha_l v_h}{\alpha_h - \alpha_l} \).

Case(2): If \( v_h - \alpha_h t < v_l - \alpha_l t \), i.e., \( t > \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \),
then
\[
\pi_m = v_h - \alpha_h t - k/t = -\frac{\alpha_h t^2 - v_h t + k}{t}. 
\]
From \( \frac{\partial \pi_m}{\partial t} = -\alpha_h + k/t^2 = 0 \) and \( \frac{\partial^2 \pi_m}{\partial t^2} = -2k/t^3 < 0 \), we get \( t = \sqrt{k/\alpha_h} \). Therefore, we have
(1) if \( \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \leq \sqrt{k/\alpha_h} \), then \( t^* = \sqrt{k/\alpha_h}, p^* = \sqrt{k/\alpha_h} \).
(2) if \( \sqrt{k/\alpha_h} < \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \), then \( t^* = \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l}, p^* = \frac{2\alpha_h v_h - \alpha_l v_h}{\alpha_h - \alpha_l} \).

Combining results in the above two cases proves the Theorem 3.4. 

Theorem 3.4 indicates that, under the MS strategy, the monopoly service firm decides the optimal response time and price based on the customer perceived values \( v_h \) and \( v_l \) and time sensitive degrees \( \alpha_h \) and \( \alpha_l \). When the difference in parameters of two market segments is smaller (i.e., \( \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \leq \sqrt{k/\alpha_h} \)), the optimal response time and price are affected only by the characteristic parameters of customers in high-end market segment. When the difference in parameters of two market segments is larger (i.e., \( \sqrt{k/\alpha_h} < \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \)), the optimal response time and price are affected only by the characteristic parameters of customers in low-end market segment. If only, \( \sqrt{k/\alpha_h} < \frac{\alpha_h - \alpha_l}{\alpha_h - \alpha_l} \leq \sqrt{k/\alpha_h} \) is satisfied, the optimal response time and price are simultaneously affected by customer characteristic parameters of two market segments.

4. Numerical illustration. The following numerical experiments are made to respectively illustrate the impacts of customer characteristic parameters on the optimal price and response time under the SS and MS strategies. In these numerical experiments, we set \( \alpha_h = 0.8, \alpha_l = 0.3, k_h = 200, k_l = 120, k = 160, \theta = 0.2, 1 - \theta = 0.8 \). Given these parameters, we change the perceived values \( v_h \) and \( v_l \), respectively.
4.1. Impacts of $v_h$ and $v_l$ on response time, price and profit under SS strategy. Under the SS strategy, we set $v_l = 60$, $v_h \in [60, 80]$, or $v_h = 80$, $v_l \in [60, 80]$, which indicates the change of perceived value $v_h$ or $v_l$, and then, the changes of response time, price and profit are shown by Fig.1–Fig.3.

![Figure 1](image1.png)

**Figure 1.** The impact of perceived values $v_h$ and $v_l$ on response time

From Fig.1 it can be observed that, with the increase in difference of two perceived values (i.e., $v_h - v_l$), the optimal response time is increasing, which indicates that, as the value of $v_h - v_l$ becomes bigger, the probability of self-selection becomes lower, meanwhile the impact of self-selection on response time also becomes lower. In order to satisfy incentive compatibility constraints, service firms will set a longer response time to reduce their manufacturing costs.

![Figure 2](image2.png)

**Figure 2.** The impact of perceived values $v_h$ and $v_l$ on price

It can be shown from Fig.2 that, with the increase in perceived value $v_l$, both optimal product prices are increased, and the price gap decreases, which indicates that, when the customer in low market segment is willing to pay more for the same product, the service firm will set higher price for low-end product to maximize its profit, and set higher price for high-end product to prevent customer self-selection behavior. Along with the increase in perceived value $v_h$, the price of high-end product increases, while the price of low-end service product decreases in the end. It can be seen that, greater the difference of perceived values of customers in two
market segments, the price gap between two service products becomes larger in order to satisfy the incentive compatibility constraints.

From Fig. 1–Fig. 3, it can be observed that, with the increase in customer perceived values (i.e., customers are willing to pay more for the same product), monopoly enterprises can set higher price and longer response time for the same product, and then, the revenues from selling products are increasing, and the manufacturing costs are decreasing. So the monopoly enterprises’ profits are increasing. This indicates that, the optimal decisions of response time and price are affected by customer self-selection behavior, which also affects the firms’ profits. Firms should pay more attention on customer choice behavior in different market segments when they make decisions.

4.2. Impacts of \( v_h \) and \( v_l \) on response time, price and profit under MS strategy. Under the MS strategy, we set \( v_l = 60, v_h \in [60, 80] \), or \( v_h = 80, v_l \in [60, 80] \), which indicates the change of perceived value \( v_h \) or \( v_l \), and then, the changes of response time, price and profit are shown by Fig. 1–Fig. 3.

It can be observed from Fig. 4 that, with the increase in difference of two perceived values (i.e., \( v_h - v_l \)), the optimal response time is increasing, which indicates that, as the value of \( v_h - v_l \) becomes bigger, the probability of self-selection becomes lower. And then, as the principle of profit maximization, firms can appropriately
increase response time to reduce the manufacturing cost, which is similar to the
decision under the SS strategy.

From Fig.5 it can be shown that, with the increase in customer perceived values,
both optimal prices are increasing, i.e., when customers are willing to pay more for
the same service product, service enterprises will set higher prices to obtain the
higher profits.

From Fig.4–Fig.6, it can be observed that, with the increase in customer per-
ceived values, i.e., customers are willing to pay more for the same product, firms
can set higher price and longer response time for the same product, and then, firms’
revenues are increasing, and their manufacturing costs are decreasing. So the mo-
nopoly firms’ profits are increasing. This also indicates that, firms should pay more
attention on customer choice behavior in different market segments when they make
decisions.

4.3. Comparing analysis of response time, price and profit under two
strategies. Setting $v_l = 60$, $v_h \in [60, 80]$, we can have the comparing results of
response time, price and profit under two strategies, which are illustrated by Fig.7–
Fig.9.
From Fig. 7, it can be shown that, the optimal response time under the MS strategy is between the response times of high and low-end products under the SS strategy. It indicates that, when the service firm adopts the MS strategy, it will consider the impact of time sensitivity of customers in two market segments. When the service firm adopts the SS strategy, in order to prevent customers in one market segment from buying the service product designed for the other market segment, it should increase the difference of two service products.

From Fig. 8, it can be observed that, under the MS strategy, by considering the individual rationality constraints (i.e., a customer in low market segment obtains a positive utility from buying a service product), the optimal price is set to be close to that of low-end product under the SS strategy. Under some conditions, it is lower than that of low-end product under the SS strategy.

It can be shown from Fig. 7–Fig. 9 that, when service firms adopt the MS strategy, the optimal response time is between that of two service products under the SS strategy.
strategy. The optimal price under the $MS$ strategy is close to that of low-end service product, and under some conditions, it is lower than that of low-end service product. Therefore, the optimal profit under the $MS$ strategy is lower than that under the $SS$ strategy. This indicates that, with the individuation of customer demand, in order to obtain higher profit, firms should firstly subdivide the market, and then, design targeted products for different customers. As a result, the degree of customer satisfaction can be increased, and firms can obtain higher profits.

5. Conclusions. Under the utility constraints of time-sensitive customers, this paper investigates the optimal decision problem of response time and price under the $SS$ and $MS$ strategies for a monopoly service firm. Under the $SS$ strategy the firm offers two difference service products respectively for two market segments, whereas under the $MS$ strategy one standard service product for two market segments is offered. Research results show that, under the two service product design strategies, service firms adopt a segmented pricing strategy based on the perceived values and time-sensitive degrees of customers in different market segments. And under some conditions, the optimal response time is also different.

On analyzing the effect of customer perceived values on response time, price and profit, it can be observed that, with the increase in the gap between the two perceived values, the optimal response time and price are increasing. So firms' revenues are increasing, and their manufacturing costs are decreasing. Therefore, their profits are increasing. That is to say, when customers are willing to pay more for the same product, firms can obtain more profits. So firms should pay more attention on customer choice behavior. Finally, we comparatively analyze the optimal response time, price and profit under the $SS$ and $MS$ strategies. It can be observed that, by considering the two customer utility constraints, the optimal response time under the $MS$ strategy should lie in the interval between the response times of high and low-end service products under the $SS$ strategy. The optimal price under the $MS$ strategy is more close to or even lower than that of low-end service product under the $SS$ strategy. Besides, the optimal profit under the $MS$ strategy is always lower than that under the $SS$ strategy. This shows that, with the individuation of customer demand, firms should firstly subdivide the market,
and then design targeted service product for different customers. As a result, the customer satisfaction can be increased, and firms can obtain higher profits.

This paper investigates the decision problem of price and response time under different service product design strategies under the assumption of fixed market demand. When the market demand is stochastic, or market demand is a function of price or response time, the optimal pricing strategy needs further investigation. In this paper, the quality factor and restrictive resource problem are not considered. Assuming a customer utility is a function of quality, and a service firm has limited resource, how the firm decides the optimal product quality, response time and price is also an important issue. Besides, we assume customers and service firms are risk neutral, but when they are risk aversion, the form of utility function should be changed. In this case, how to price the service product should be further investigated.

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