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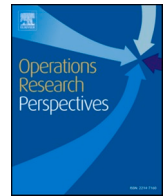
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Pricing strategy of supply chain considering response time of extended warranty service

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ABSTRACT

Extended warranty services (EWS) offers avenues for new profit sources and growth opportunities. In a time-sensitive market, the response time has an important impact on the pricing of EWS and satisfying consumer utility. Applying Stakelberg Game theory, a two-echelon product-service supply chain consisting of a manufacturer and two retailers (Self-owned, Franchised) is construct. Considering the EWS response time and price to characterize the consumer utility function, the EWS pricing strategies in different market stages are studied based on the scenarios of identical response time (IRT) and different response time (DRT). The research shows that: (1) under IRT scenario, the optimal EWS pricing and cost of the self-owned and franchised retailers are negatively related to the response time, therefore, both retailers should consider a trade-off strategy between the EWS price and the response time; (2) under DRT scenario, an EWS response time threshold exists, based on which the self-owned and franchised retailers should develop the optimal EWS pricing strategies; (3) under DRT scenario, the retailers' optimal EWS prices have a negative relationship with consumers' price sensitivity coefficient, and a positive relationship with consumers' time sensitivity coefficient. The manufacturer and the self-owned retailer can significantly reduce EWS response time with a limited increase in the prices. While the franchised retailer need to follow the self-owned retailer in developing its pricing strategy. The study construct a time-sensitive consumer utility function by integrating response time and pricing, more accurately portraying the expected value of EWS. Based on the market characteristics of EWS growth and maturity periods, the EWS pricing strategies are expanded regarding response time differentiation in multiple cycles. It helps companies better understand consumer demand for EWS, and assists them in formulating pricing strategies for different stages of EWS market development, and improving EWS supply chain management.

1. Introduction

The extended warranty service (EWS), as an important part of product-service supply chain (PSSC), is widely adopted in durable goods industries such as automobiles, home appliances, and electronics [1,2]. In some countries, retailers provide EWS to consumers. For example, in U.S.A., SquareTrade Inc. severs as a EWS retailer especially for electronic products and appliances in Amazon, Costco, BestBuy, etc., and its performance ranks among the top three in the Amazon U.S. [3]. Alternatively, in other countries, the EWS is provided by manufacturers (and self-owned retailers), such as BYD, Haier, Lenovo, etc., in China [4]. The franchised EWS retailers licensed by the manufacturers are also

available to the consumers together with the products selling, such as JD, TEMU, Tmall, Gome, etc. [5]. Consumers reduce the perceived risk by purchasing EWS and obtain a better product using experience [6]. Some consumers decide whether to purchase corresponding products based on the level of EWS service, thereby changing the profit structure of the companies' product and service.

The EWS has gradually become an important part of companies' profits [7]. Some companies realize that EWS is not just subsidiary services bundled with products for the purpose of promotion. Rather, enhancing the level of EWS can improve companies' profitability and competitiveness in the market [8]. For example, the automotive, computer, and mobile phone industries tend to prefer prompt resolution

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during a malfunction. In such scenarios with time-sensitive consumers, some companies have implemented strategies to expedite the delivery of EWS. For instance, Tmall commits to response in 24-hour and fulfill EWS before the end of the day. Similarly, Haier's response time for EWS is divided into 3 business days for appliances with spare parts in stock and a maximum of 10 business days for those without. Obviously, the companies' operating costs of EWS vary under different response times, and the EWS pricing will also differ.

Therefore, the EWS response time is closely related to business decisions, and pricing is one of the most critical factors for the decisions. In the time-sensitive consumer market, the EWS response time has great impact on consumer utility, EWS level and pricing [9]. In different market stages, companies may adopt different EWS strategies. In countries where the EWS market is expanding, such as China [10,11], since 2006, TWG has introduced its automotive EWS to the Chinese market. Some OEMs, dealers, and professional automotive EWS agencies have made attempts and explorations in this field, but the development is still relatively slow, and the average EWS penetration rate of automotive industry is only 10–20 % (can be considered as a growth stage in the product life cycle). A few high-end brands offer EWS with selling, and the penetration rate barely reach 30–40 %. EWS providers tend to adopt identical pricing standards and response time in order to promote their business and earn more market share. In countries where the EWS market is developed, such as European, the United States and Japan [11,12], the EWS penetration rate of automobile industry is much higher (can be considered as a maturity stage in the product life cycle). The penetration rate of EWS for automotive in the United States is about 75 %, and in Europe it is about 80 %. Japan market is more mature, and the EWS penetration rate of second-hand automotive is over 90 %. The EWS providers offer flexible and diversified pricing strategies and differentiated response times to enhance consumer utility and company competitiveness. However, regardless of the market stage, a reasonable determination of EWS response time strategy and pricing are crucial for business decision-making.

As a real-time service throughout the product life time, it is difficult to define the EWS response time. Therefore, the response time of the product operation and maintenance is adopted to represent the EWS response time. The response time of the product operation and maintenance is defined as the amount of time between the moment a service is applied and the request is fulfilled [13]. In some industries, companies implement differentiated response times to meet different needs of product operation and maintenance. For example, ZTE categorizes the level of services into three tiers—critical, important, and minor—based on the response time, and charge customers based on actual costs incurred. Boeing divides the services into High impact, Critical request and Routine request, and sets standards of response time and price for different levels of requests.

Generally, the product operation and maintenance services charge the customers according to the actual costs incurred and the urgency degree of the response. While EWS price considers the potential failures in the use of the product, combined with the urgency degree of the response time. That is, the product operation and maintenance services are priced in real time and EWS is priced in advance [14]. In the other words, the EWS is a prepaid model for the product operation and maintenance services. Concurrently, the EWS response time can be regarded as a predetermined value. When these two factors are superimposed, they have a profoundly deleterious effect on the consumer's expectations regarding the EWS value. The customer's choice of the price he is willing to pay depends on the value expected to be derived from use and the total cost including the cost of waiting. As to the companies, the EWS pricing strategy includes more uncertainty and complexity. On the one hand, it is necessary to comprehensively consider the consumers' expectations of EWS value under the effect of EWS response time and price. On the other hand, it is also necessary to consider the consumers' EWS expectations under the different stages of market development. At present, adopting different pricing strategies

for EWS with different response times to meet consumers' expectations and enable companies to obtain optimal revenue is still ambiguous.

Therefore, further research on EWS pricing strategies with the consideration of response time for time-sensitive consumers is interesting, but the following two challenging issues need to be addressed:

- (1) How to determine consumers' expectations of the EWS value with the combined effect of response time and price.
- (2) The impact of EWS response time on the supply chain pricing strategy under different stages of product life cycle.

The possible contributions are mainly:

- (1) Unlike the product operation and maintenance services, which considers the actual cost incurred and adopts a cost-plus approach to make the pricing decision, the pricing of EWS consider the potential costs. From the perspective of time-sensitive consumers, comprehensively considers the response time and its corresponding price, a consumer utility function is constructed to carve the expected cost of EWS. This approach expands the traditional understanding of EWS as subsidiary services bundled with products, and proposes the consumer utility function from the perspective of the expected value of EWS, to better distinguish the response time characteristics of EWS and reflect the consumer decision-making process.
- (2) To understand the market characteristics of the EWS product life cycle, focusing on the growth and maturity periods, two scenarios with identical and differentiated response time are considered, and the EWS pricing strategy in multiple cycles is developed. This approach subdivides the dynamic development characteristics of the product and service market, and conducts intensive research on EWS strategies under different market development stages, specifically where different EWS pricing strategies are adopted for new product-service launch period and popular product-service promotion period.
- (3) Under the two scenarios, from the company's perspective, the demand functions and profit functions are developed based on the consumer utility. Considering of the impact of EWS response time, pricing, cost, etc. comprehensively, the EWS pricing strategy is proposed. This approach further quantifies the internal impact mechanism between response time and pricing in multiple scenarios from the perspective of time sensitive consumer, which is more in line with the companies' practical difficulties in making business decisions under complex market environments.

Therefore, this study mainly focuses on two objectives: firstly, construct a consumer utility function by comprehensively considering the EWS response time and price; secondly, develop EWS pricing strategies with differentiated response time under multiple cycles. This paper is organized as follows: [Section 2](#) reviews the literature on response time and supply chain management, [Section 3](#) describes the problem and gives the assumption of the model, [Section 4](#) constructs the functions and the model under different scenarios, [Section 5](#) analyzes the pricing strategies for each scenario, [Section 6](#) exams the impacts of various factors and [Section 7](#) draws conclusion and shows the future work.

2. Literature review

Pricing of product-service with response time is an important and changeling branch of the EWS supply chain strategy that has developed rapidly in the recent years. There are mainly three categories of research related to this area, namely the pricing strategies of EWS supply chain, the product-service pricing issues considering response time, and the strategies of supply chain management with time considerations. Relevant research is reviewed from those perspectives.

2.1. The pricing strategies of EWS supply chain

The research basis of the study is the EWS pricing strategy, therefore, it is necessary to first review the existing work in this field. The studies on supply chain strategies for EWS initially focus on the sales channel, i. e., the optimal EWS provider decisions. The research generally considered a model, consisting a retailer who sale the EWS, and a manufacturer or supplier who carry out the EWS. Desai & Padmanabhan [1] based on the direct, non-direct, and dual-channel sales of EWS, considering the influence of double marginalization and complementary goods effect, proposed the optimal design of EWS channel strategy. Zhang et al. [15] investigated the optimal EWS provision with a platform supply chain, found that the agent, who takes the ownership over the product, acts more responsively in providing the EWS across the two online channel modes. Further, some scholars conducted research on pricing strategies for EWS under different channels. Wang et al. [6] proposed four kinds of decision-making models and aims to study decisions of the electronic commerce supply chain, including EWS price, sales price, and service level of e-platform. For electronic commerce supply chain enterprises, whether to dominate the system or to provide EWS, it is conducive to the increase of profits. Zhang et al. [16] constructed a manufacturer-leading supply chain system considering the EWS to study the influence of service cost on the choice of the EWS provider, analyzed retail pricing, EWS pricing, EWS quality, the manufacturer's profit, the retail's profit and the total system profit. The result showed that both the manufacturer and the retailer had to balance the ratio of service cost. Zhang et al. [17] propose four models based on two assessments and two supply chain structures, to investigate the pricing strategies of product and warranty sales. The study compared the optimal prices of the two supply chain structures under unbiased assessments.

In the pricing strategy of EWS supply chain, the service duration and purchasing point are also important influence factors, which affect the cost and demand of EWS, and need to be considered in the design of supply chain contracts. Chang & Lin [18] studied the optimal repair strategy and the optimal EWS duration during the product life cycle from the perspective of the seller in a two-echelon supply chain consisting of a manufacturer and a retailer; Lam & Lam [19] found that there existed a decision of the optimal EWS duration when consumers choose whether to renew the contract after the end of the basic warranty period; Tong et.al [20] investigated the EWS duration problem in two scenarios: purchasing EWS at the same time as purchasing the product and purchasing EWS after the end of the basic warranty period. Aksezer [21] analyzed the failure behavior of different classes of cell phone products and their related costs through a chain of consumer electronics retailer operating in Türkiye. Within different EWS duration, the costs for coverage of the third, fourth, and fifth years were determined.

The above literature mainly focused on the EWS channel, cost, demand, duration etc. to study the EWS supply chain pricing strategy. The EWS was regarded as a part of the products marketing policy, and the objective of the EWS providers was to maximize their profits. These studies, from the perspective of maximizing supply chain profits, reveal the influencing factors of EWS pricing decisions, and provide a research basis. However, there is less research on the EWS strategy that considers maximizing both companies' profits and consumer utility. There are a few work on developing the EWS pricing strategy from the perspective of consumer, such as consider the impact of the response time on the market for EWS.

2.2. The product-service pricing issues considering response time

Response time is an important consideration factor, and understanding its impact mechanism on the EWS pricing strategy is critical. Current research on this area are mainly focus on the relationship and the corresponding strategies of the response time and product-service pricing. Zhang et al. [22] considered the impact of customer choice behavior, investigated how a monopoly service firm decides its service

product's response time and price under two product design strategies. The results indicated that the service firm should adopt a segmented pricing strategy based on the customer perceived values and time-sensitive degrees. Emin & Ramazan [23] demonstrated the relative importance of the response time and discount amount according to the criticality level of failures. It focused on gender differences and determine whether the response time or discount amount is more important for male and female customers in high or low-criticality situations. Mo et al. [24] considered two different response time, namely 24-hour and 48-hour, based on which constructed a price discrimination strategy. Cao et al. [25] studied centralized and decentralized decision making in a closed-loop supply chain, considering the impact of response time, developed the optimal pricing strategies. Afèche et al. [26] studied revenue-maximizing tariffs that depend on realized lead times for a provider serving multiple time-sensitive customer types. Found that under price and capacity optimization, lead-time-dependent pricing yields higher profits with less capacity compared to flat-rate pricing. Afèche et al. [27] designed price/lead-time menus and the corresponding scheduling policy for a profit-maximizing service provider serving customers with private information on their preferences. Wang et al. [28] considered the impact of consumer time preferences, and evaluated two scenarios of commission rates charged by the e-commerce platform, to study the optimal pricing of paid members and information acquisition strategies. Xu et al. [29] proposed a multi-level pricing scheme to meet the transport demand for time-sensitive goods. A dynamic slot-inventory control model considering the choice behavior of goods owners was established to maximize the company's revenue.

The above studies focus on the effects of response time and response speed on price discrimination strategy, product-service pricing strategy, membership fee strategy, etc. They mainly studied the intrinsic relationship between response time and product-service pricing. These studies consider the pricing strategies under different consumer demands for response time, and verify the relationship between response time and pricing decisions. But less attention has been paid to the research of the specific pricing strategies which can be directly used by the companies in real business. There is even less literature on the pricing strategies of EWS under the influence of response time and at different stages of the market.

2.3. The strategies of supply chain management with time considerations

Generally, companies pay more attention to the pricing strategy of EWS supply chain under different market stages, which is also the purpose of this study. This field involves research on supply chain management strategies with multiple time factors. There are some research focusing on service provisioning methods and management strategies under the influence of time. Qin et al. [30] studied the problem of inventory allocation optimization, by optimally trading off the safety stock with the service response time, so as to generate recommended inventory strategies on a daily basis. Zha et al. [31] developed a two-echelon supply chain decision model to analyze the effects of product quality, pricing, and inventory management in the context of extended warranty services. The results indicated significant differences in optimal decisions between centralized and decentralized supply chains, especially concerning pricing and inventory control. Lin et al. [32] proposed a dynamic pricing mechanism considering the factors of user feedback, service duration and service quality level, in order to enable the service provider to determine the optimal supply chain strategies. Wang & Zhou [33] designed a "one-to-many" supply chain system which composed of one supplier and N retailers, considering the demand is sensitive to price and time, the reasonable response time of centralized and decentralized supply chain were determined respectively. Feldman et al. [34] established a queuing model where the service providers and rational consumers are heterogeneous in their demands for service duration, and proposed that the time limit is a useful lever that works well when combined with the price mechanism.

Guo et al. [35] implemented a Stakelberg Game model, consisting of an overseas warehouse with online and offline distribution, and a cross-border e-commerce platform with information on market demand, to study the supply chain strategy of overseas warehouse operation mode based on delivery time and information sharing. Song et al. [36] proposed a joint contract to coordinate the time-varying supply chain of risk-averse manufacturers and retailers. The joint contract used price reduction subsidies and revenue-sharing strategies to enable manufacturers and retailers to share risks and achieve overall coordination of the supply chain. Rashid et al. [37] dealt with the retailer's location problem, when inventory costs for retailers and response time costs for suppliers have been considered. Bronzo et al. [38] analyzed the effects of big data analytics capabilities (BDACs) on companies' reaction time, and the effects of companies' reaction time on supply chain resilience. This study found that BDACs reduce reaction time, which, in turn, improves supply chain resilience.

The above studies mainly focused on supply chain management strategies, such as inventory management, service quality level, service providers, pricing mechanism, facility location, etc., considering the response time, service duration, delivery time, time value, etc., and developed the strategies to maximize the companies' revenue. These studies address a specific market development stage from the perspective of companies' business, and reveal a supply chain management strategy that considers multiple time factors under static market characteristics. There hardly exists research from the perspective of consumers' demand characteristics in different market development stages, considering the impact of consumers' time sensitivity, the expected value of EWS, etc. on supply chain management strategies.

All those studies show that response time has become a key factor to consider when pricing product-service in both business practice and academic research. EWS is a typical product-service approach that extends the product life cycle and can increase consumer utility. However, there are fewer studies on how response time simultaneously affects pricing and satisfies consumer utility. Therefore, this paper takes the consumer's time-sensitive response time as an important factor affecting the pricing of product-service, and applies Stakelberg Game theory to explore the pricing strategy of EWS supply chain, so as to enable consumers to obtain a better product-service utility while companies obtain the optimal revenue.

3. Problem description

Consider a product-service supply chain comprising a manufacturer and two retailers (Self-owned, Franchised), the manufacturer works as the leader in the Stakelberg Game, while the two retailers are followers. The decision-making sequence is as follows: firstly, the manufacturer determines the basic wholesale price for the parts and support services needed for EWS based on the general industry response time, as well as the admission fee and variable rate for the franchise retailer; Then, self-owned and franchised retailers set the retail prices and response time for EWS based on consumer demand and wholesale prices respectively.

The manufacturer provides spare parts and support services to the two retailers. Both retailers purchase the spare parts and support services from the manufacturer to fulfill the EWS performance. The consumers are time-sensitive for the response of the EWS, they make the EWS purchasing decisions to maximize their utilities, which are composed of the EWS prices and response time. The members of the supply chain, as rational economic agents, are driven by the objective of maximizing their own profits when making decisions.

In practice, retailers can set the EWS response time identical according to the general industry performance. While they can also provide various EWS response time ($t_1 < t_2$ or $t_1 > t_2$). The former mainly concerns the EWS market just launched, in which all retailers are required to provide services with the same standard in order to gain consumers' recognition and thus expand the market. The latter considers the mature EWS market, in which the retailers are allowed to

provide EWS with different service levels to enhance the consumers' experience and maximize the revenue. At the mature stage, the franchised retailer can adopt a follow-the-leader strategy, i.e., treating the self-owned retailers as a benchmark ($t_1 < t_2$), or they can adopt an aggressive strategy, providing the EWS with a shorter response time than that of the self-owned retailer ($t_1 > t_2$).

Therefore, two scenarios are discussed. The first scenario is considering identical response time (IRT). The manufacturer provide EWS with wholesale price w to two retailers. The self-owned retailer r_1 /franchised retailer r_2 offer no difference EWS response time t_1/t_2 ($t_1 = t_2 = t_0$), and price p_1/p_2 respectively. The franchised retailer pay the fixed franchise fee k to the manufacturer. The scenario IRT is shown in Fig. 1(a). In the second scenario with different response time(DRT), the self-owned retailer r_1 offers EWS response time t_1 , and the franchised retailer r_2 offers EWS response time t_2 ($t_1 < t_2$ or $t_1 > t_2$). The scenario DRT is shown in Fig. 1(b). The solid arrow indicates the decision-making relationship between the game subjects, while the dashed arrow indicates the payment relationship.

Notations are shown in Table 1 below.

4. Function construction

In this section, the formulas for each party are constructed.

4.1. Utility function

Since the EWS response time works as a crucial indicator of the service level, the logarithmic function is used to describe the relationship between service level and service utility [39]. Without loss of generality, the EWS consumer utility function is constructed, considering both the response time and the pricing. Two scenarios are discussed.

In the first scenario, both self-owned and franchised retailers provide identical response time of EWS. The consumer utility functions are as follows:

$$U_1 = v - \alpha p_1 + \beta \ln \frac{1}{t}, U_2 = \theta v - \alpha p_2 + \beta \ln \frac{1}{t} \quad (1)$$

In the second scenario, the two retailers provide different response time of EWS. Assuming Δt represents the difference between the two response time, the consumer utility functions are as follows:

$$U_1 = v - \alpha p_1, U_2 = \theta v - \alpha p_2 + \beta \ln \frac{1}{\Delta t} \quad (2)$$

When making decision of purchasing EWS, the time-sensitive consumers compare the utility from the self-owned retailer and franchised retailer with zero. Therefore, three cases are discussed.

Case 1: $u_1 = u_2$. The utilities from both retailers are identical, the consumer will purchase EWS from either retailer. In practice, the combination strategy of EWS response time and price brings equal utility to consumers. For example, the consumer utility under the combination strategy of shorter response time and higher price is equal to that of longer response time and lower price.

Case 2: $u_1 < u_2$. The utility from the franchised retailer is greater than from the self-owned retailer, then the consumer will purchase EWS from the franchised retailer. In practice, the combination strategy of EWS response time and price provided by self-owned and franchised retailer has differences in utility for consumers.

Case 3: $u_1 > u_2$. The utility from the self-owned retailer is greater than from the franchised retailer, then the consumer will purchase EWS from the self-owned retailer. In practice, this case is similar to Case 2.

Considering the three extreme situations, set the consumer utility equal to zero ($u_1 = 0$, $u_2 = 0$, and $u_1 - u_2 = 0$), then the consumer valuations of EWS can be obtained. The valuations with identical response time and different response time are as follows:

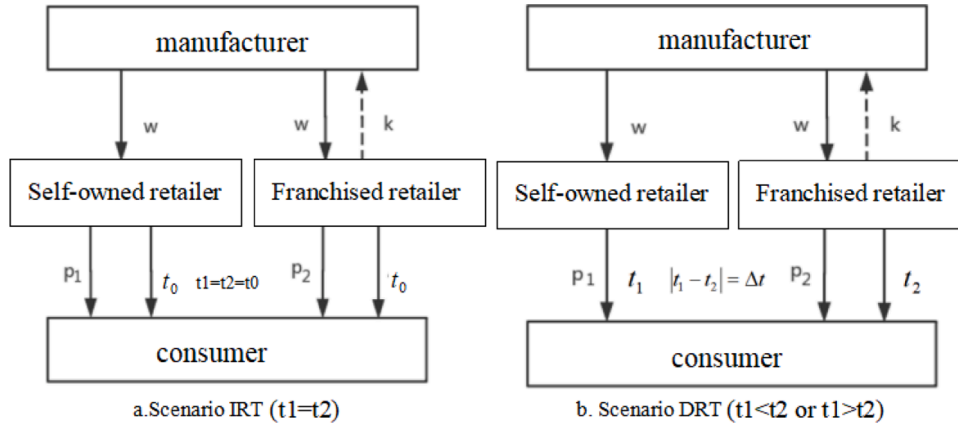


Fig. 1. The models of the supply chain with EWS response time.

Table 1

Notations.

Symbol	Description	Symbol	Description
m	Manufacturer	α	consumer price sensitivity coefficient for EWS
r_i	retailer i , $i = 1$ self-owned, $i = 2$ franchised	β	consumer time-sensitive coefficient for EWS
w	wholesale price of EWS	Δt	response time difference of EWS
t_i	response time of EWS, $i = 1, 2$	t_0	Identical response time of EWS
p_i	retail price of EWS, $i = 1, 2$	η	cost rate of EWS
c	cost of EWS	U_i	consumers utility of EWS, $i = 1, 2$
k	a fixed franchise fee	D_i	demand of EWS, $i = 1, 2$
λ	a variable franchise rate (variable franchise fee $\lambda p_2 D_2$)	Π_m	profit of manufacturer
v	consumer valuation of EWS	Π_{ri}	profit of retailer, $i = 1, 2$
θ	substitute ratio of EWS		

$$v_1^+ = ap_1 - \beta \ln \frac{1}{t}, v_2^+ = \frac{ap_2 - \beta \ln \frac{1}{t}}{\theta}, v_3^+ = \frac{\alpha(p_1 - p_2)}{1 - \theta} \quad (3)$$

$$v_1^+ = ap_1, v_2^+ = \frac{ap_2 - \beta \ln \frac{1}{\Delta t}}{\theta}, v_3^+ = \frac{\alpha(p_1 - p_2) + \beta \ln \frac{1}{\Delta t}}{1 - \theta} \quad (4)$$

4.2. Demand function

The demand for EWS is related to product demand as well as the characteristics of the service, therefore, only consumers who have purchased a product will probably purchase EWS. The response time has an important impact on purchasing willingness of time-sensitive consumers, and they make decisions based on the consumer valuations of EWS. Considering different combinations of the consumer valuations of EWS, the relationship between two retailers' prices are as follows.

Case ①: When $v_1 \geq v_2$ and $v_3 \leq 1$, the consumer's valuation of the self-owned retailer is greater, meanwhile, the retailers' price of the EWS is set to satisfy the consumer's valuation expected range $[0, 1]$. So that the consumer's utilities of EWS provided by both retailers are greater than zero, and the consumer makes decision based on maximization of the utility. The consumer has the option of purchasing EWS from either self-owned retailer or franchised retailer, and the relationship between the EWS prices of the two scenarios (IRT and DRT) are shown as follows:

$$p_1 - \frac{1 - \theta}{\alpha} \leq p_2 \leq \theta p_1 + \frac{\beta \ln \frac{1}{t}(1 - \theta)}{\alpha} \quad (5)$$

$$p_1 - \frac{1 - \theta - \beta \ln \frac{1}{\Delta t}}{\alpha} \leq p_2 \leq \theta p_1 + \frac{\beta \ln \frac{1}{\Delta t}}{\alpha} \quad (6)$$

Case ②: When $v_1^+ \geq v_2^+$ and $v_3^+ > 1$, the consumer's valuation of the self-owned retailer is greater, however, the retailers' price of the EWS is set beyond the constraint of the consumer's valuation expected range $[0, 1]$. So that the consumer's utilities of EWS provided by both retailers maybe less than zero, and the consumer makes decision based on minimizing utility loss. The consumer will purchase EWS from the franchised retailer, and the relationship between the EWS prices of the two scenarios (IRT and DRT) are shown as follows:

$$p_2 \leq p_1 - \frac{1 - \theta}{\alpha} \quad (7)$$

$$p_2 \leq p_1 - \frac{1 - \theta - \beta \ln \frac{1}{\Delta t}}{\alpha} \quad (8)$$

Case ③: When $v_1^+ \leq v_2^+$, the consumer's valuation of the franchised retailer is greater, whether the retailers' price of the EWS is set to satisfy the consumer's valuation expected range $[0, 1]$ or not. The consumer will purchase EWS from the self-owned retailer, and the relationship between the EWS prices of the two scenarios (IRT and DRT) are shown as follows:

$$p_2 \geq \theta p_1 + \frac{\beta \ln \frac{1}{t}(1 - \theta)}{\alpha} \quad (9)$$

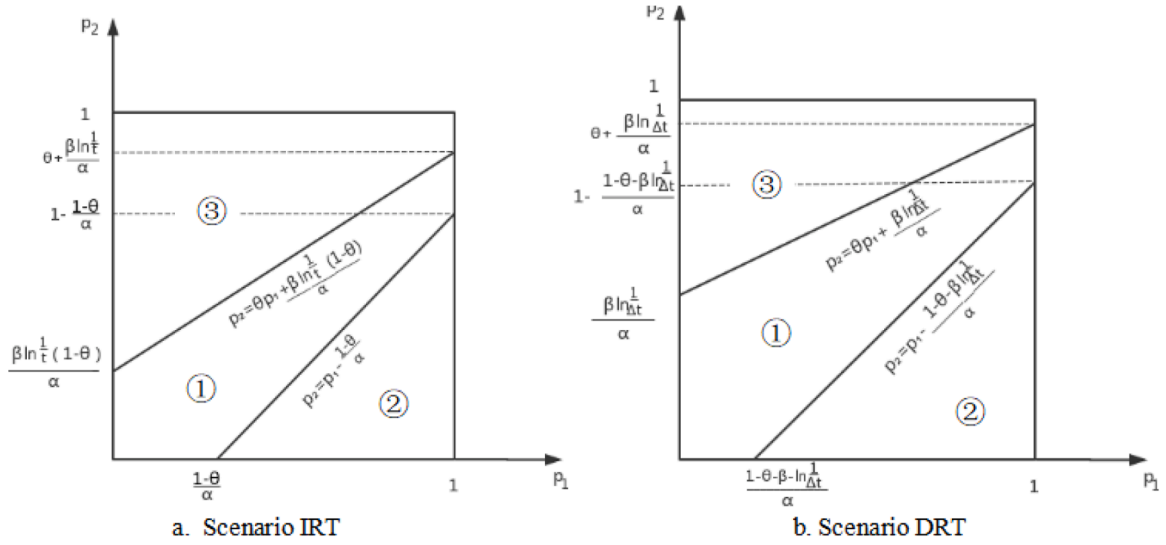
$$p_2 \geq \theta p_1 + \frac{\beta \ln \frac{1}{\Delta t}}{\alpha} \quad (10)$$

The relationships between p_1 and p_2 in Eqs. (5)-(10) are shown in Fig. 2 below.

In Fig. 2, the region ①②③ respectively display the range of price intervals based on the EWS response time. It can be intuitively seen that in the region ③, the EWS price of franchise retailer is higher, so the consumer utility by self-owned retailer is greater. In region ②, the EWS price of self-owned retailer is higher, then the consumer utility by franchise retailer is greater. In region ①, the EWS price of two retailers is in between the region ② and ③, and the consumer utility by self-owned retailer is either greater or less than that of franchise retailer.

The region ① represents Case ①. The consumer will choose to purchase EWS from either the self-owned or the franchised retailer, then the demand functions for the EWS under the two scenarios (IRT and DRT) are as follows:

$$D_1 = 1 - \frac{\alpha(p_1 - p_2)}{1 - \theta}, D_2 = \frac{\alpha(p_1 - p_2)}{1 - \theta} - \frac{ap_2 - \beta \ln \frac{1}{t}}{\theta} \quad (11)$$

Fig. 2. Relationship between p_1 and p_2 .

$$D_1 = 1 - \frac{\alpha(p_1 - p_2) + \beta \ln \frac{1}{\Delta t}}{1 - \theta}, D_2 = \frac{\alpha(p_1 - p_2) + \beta \ln \frac{1}{\Delta t}}{1 - \theta} - \frac{\alpha p_2 - \beta \ln \frac{1}{\Delta t}}{\theta} \quad (12)$$

The region ② and region ③ represent Case ② and Case ③ respectively. In region ②, the consumer purchases EWS from franchised retailer. The demand function for EWS under the two scenarios are shown below:

$$D_1 = 1 - \frac{\alpha p_1 - \beta \ln \frac{1}{\Delta t}}{\theta}, D_2 = 1 - \alpha p_2 + 2\beta \ln \frac{1}{\Delta t} \quad (13)$$

Similarly, in region ③, the consumer purchases EWS from self-owned retailer. The demand function are shown below:

$$D_1 = 1 - \frac{\alpha p_1}{\theta}, D_2 = 1 - \alpha p_2 + \beta \ln \frac{1}{t} \quad (14)$$

The consumer's purchasing decision for EWS is clear in region ② and region ③. However, in region ①, the consumer can choose either the self-owned or the franchised retailer. To further analyze retailer's decision in a competitive supply chain, we focus on region ①, discussing the EWS strategies under two scenarios (IRT and DRT).

5. Strategy analysis

5.1. Scenario IRT

In this scenario, as the market for EWS is expanding, all retailers are required to adopt the same service standards. The self-owned retailer and franchised retailer implement the identical EWS strategy to the consumers. Based on the demand function in Eq. (11), the total demand function for EWS is constructed as:

$$D = D_1 + D_2 = 1 - \alpha p + \beta \ln \frac{1}{t}$$

Meanwhile, the EWS cost formula is $c = \frac{\eta}{2t^2}$ [40]. To motivate the franchised retailer, the manufacturer only charges a fixed franchise fee k . Then the profit functions of the manufacturer and the retailers are shown below.

$$\Pi_m = wD + F = w \left(1 - \alpha p + \beta \ln \frac{1}{t} \right) + k \quad (15)$$

$$\Pi_r = D(p - w - c) - F = \left(1 - \alpha p + \beta \ln \frac{1}{t} \right) \left(p - w - \frac{\eta}{2t^2} \right) - k \quad (16)$$

Proposition 1: The optimal retailer EWS price p^* is negatively related to the response time t . Similarly, the cost of the EWS is negatively related to the response time t .

Proof: The EWS price can be determined by the *backward induction* method. First, calculate the retailer profit Π_r in Eq. (16) for second partial derivative with respect to the EWS price p . As $\frac{\partial^2 \Pi_r}{\partial p^2} = -2\alpha < 0$, there is an optimal EWS price that maximizes the retailer profit. calculate the manufacturer profit Π_m in Eq. (15) for second partial derivative with respect to wholesale price w . As $\frac{\partial^2 \Pi_m}{\partial w^2} = -\frac{\alpha}{2} < 0$, there is an optimal EWS price that maximizes the manufacturer profit. Second, let the partial derivative of Π_m with respect to w be zero, the optimal wholesale price of EWS is:

$$w^* = \frac{-\alpha\eta + 2t^2 \left(a + \beta \ln \frac{1}{t} \right)}{4\alpha t^2} \quad (17)$$

Then, substituting w^* into Eq. (16), the optimal retailer EWS price p^* is:

$$p^* = \frac{\alpha\eta + 6t^2 \left(1 + \beta \ln \frac{1}{t} \right)}{8\alpha t^2} \quad (18)$$

Finally, calculate the partial derivative of p^* and c with respect to the response time t .

$$\frac{\partial p^*}{\partial t} = -\frac{\eta}{4t^2} - \frac{3\beta}{4\alpha t} < 0; \frac{\partial c}{\partial t} = -\frac{\eta}{t^3} < 0 \quad (19)$$

In other words, both the optimal EWS price p^* and the cost c are monotonically decreasing functions of the response time t . Q.E.D.

Proposition 1 indicates that when a certain EWS newly enters the consumer market, companies tend to cooperate, and set identical EWS response time in order to expand market share. This situation is an approximate theoretical state, where the given response time directly affects the EWS cost and price.

Proposition 2: For a given EWS response time t , the retailer can always optimize the manufacturer and the retailer profits by pricing the EWS appropriately.

Proof: First, take the partial derivatives of Eq. (16) with respect to the EWS price p and the response time t .

$$\frac{\partial \Pi_r}{\partial p} = 1 - 2\alpha p + w\alpha + \frac{\alpha\eta}{2t^2} + \beta \ln \frac{1}{t}$$

$$\frac{\partial \Pi_r}{\partial t} = -\frac{\beta}{t} \left(p - w - \frac{\eta}{2t^2} \right) + \frac{\eta}{t^3} \left(1 - \alpha p + \beta \ln \frac{1}{t} \right)$$

Furthermore, calculate the second partial derivatives of the retailer profit Π_r with respect to p and t .

$$\frac{\partial \Pi_r^2}{\partial p^2} = -2\alpha$$

$$\frac{\partial \Pi_r^2}{\partial t^2} = \frac{\beta}{t^2} (p - w) - \frac{3\eta}{t^4} \left(1 - \alpha p + \beta \ln \frac{1}{t} \right) - \frac{5\beta\eta}{2t^4}$$

Calculate the second mixed derivative of the retailer profit Π_r with respect to p and t .

$$\frac{\partial \Pi_r^2}{\partial p \partial t} = \frac{\partial \Pi_r^2}{\partial t \partial p} = -\frac{\alpha\eta}{t^3} - \frac{\beta}{t}$$

Construct the Hessian matrix, the first-order principal minor determinant $D_1 = -2\alpha < 0$, the second-order principal minor determinant D_2 is:

$$D_2 = \begin{pmatrix} \frac{\partial \Pi_r^2}{\partial p^2} & \frac{\partial \Pi_r^2}{\partial p \partial t} \\ \frac{\partial \Pi_r^2}{\partial t \partial p} & \frac{\partial \Pi_r^2}{\partial t^2} \end{pmatrix} = \begin{pmatrix} -2\alpha & -\frac{\alpha\eta}{t^3} - \frac{\beta}{t} \\ -\frac{\alpha\eta}{t^3} - \frac{\beta}{t} & \frac{\beta}{t^2} (p - w) - \frac{3\eta}{t^4} \left(1 - \alpha p + \beta \ln \frac{1}{t} \right) - \frac{5\beta\eta}{2t^4} \end{pmatrix}$$

$$= -2\alpha \left[\frac{\beta}{t^2} (p - w) - \frac{3\eta}{t^4} \left(1 - \alpha p + \beta \ln \frac{1}{t} \right) - \frac{5\beta\eta}{2t^4} \right] - \left(-\frac{\alpha\eta}{t^3} - \frac{\beta}{t} \right)^2 \quad (20)$$

$$p_1^* = \frac{-\alpha\eta(\theta - 1) + \Delta t^2 \left[\theta + \beta \ln \frac{1}{\Delta t} \right] \{4\lambda + \theta[2 + \lambda(\lambda - 4)]\} + 2\Delta t^2 \left(\theta - \beta \ln \frac{1}{\Delta t} - 2 \right)}{8\alpha\Delta t^2(\theta - 1)} \quad (26)$$

In Eq. (20), in order to make the Hesse matrix negative definite, D_2 should be positive.

$$-2\alpha \left[\frac{\beta}{t^2} (p - w) - \frac{3\eta}{t^4} \left(1 - \alpha p + \beta \ln \frac{1}{t} \right) - \frac{5\beta\eta}{2t^4} \right] - \left(-\frac{\alpha\eta}{t^3} - \frac{\beta}{t} \right)^2 > 0 \quad (21)$$

then

$$p < \frac{\alpha t^2 \left[2w\beta + 6\eta \left(1 + \beta \ln \frac{1}{t} \right) - 2\eta\beta \right] + \beta t^4 (5\alpha\eta - \beta) - \alpha^2 \eta^2}{2\alpha t^2 (\beta t^2 + 3\alpha\eta)} \quad (22)$$

Therefore, with a given response time t , the retailer can always set the proper EWS price to satisfy the constraint i.e. Eq. (22), and maximize the profits for both the manufacturer and the retailer. Q.E.D.

Proposition 2 indicates that with identical EWS response time, companies can design appropriate pricing strategies based on the relationship between EWS response time and price in Proposition 1 to achieve maximum profits, and promote the continuous growth of the EWS market.

5.2. Scenario DRT

In this scenario, as the market for EWS is mature, the retailers can offer EWS with differentiated service levels, while the self-owned and the franchised retailers each developing their own EWS strategies. Based on the demand function in Eq. (12), the EWS cost formula is $c = \frac{\eta}{2\Delta t^2}$

[40]. To maximize the profit, the manufacturer charges a variable franchise fee based on sales of EWS, in addition to the fixed franchise fee k . Then the profit functions of the manufacturer and the retailers are shown below.

$$\text{Max}_{w^*} \Pi_m^* = w \left[1 - \frac{\alpha(p_1 - p_2) + \beta \ln \frac{1}{\Delta t}}{1 - \theta} \right] + (w + \lambda p_2) \left[\frac{\alpha(p_1 - p_2) + \beta \ln \frac{1}{\Delta t}}{1 - \theta} - \frac{\alpha p_2 - \beta \ln \frac{1}{\Delta t}}{\theta} \right] + k \quad (23)$$

$$\text{Max}_{p_1^*, p_2^*} \Pi_{r1}^* = (p_1 - w) \left[1 - \frac{\alpha(p_1 - p_2)}{1 - \theta} \right] \quad (24)$$

$$\text{Max}_{p_1^*, p_2^*} \Pi_{r2}^* = \left[(1 - \lambda)p_2 - w - \frac{\eta}{2\Delta t^2} \right] \left[\frac{\alpha(p_1 - p_2)}{1 - \theta} - \frac{\alpha p_2 - \beta \ln \frac{1}{\Delta t}}{\theta} \right] - k \quad (25)$$

Proposition 3: The two retailers optimal EWS prices are negatively related with the price sensitivity coefficient, and positively related with the response time-sensitive coefficient.

Proof: By the *backward induction* method, the optimal EWS prices for both retailers are as follow:

$$p_2^* = \frac{\alpha\eta(\theta - 1) + \Delta t^2 \{ -6 + 4\lambda + \theta[6 + \lambda(\lambda - 4)] \} \left(\theta + \beta \ln \frac{1}{\Delta t} \right)}{4\alpha\Delta t^2(\theta - 1)(\lambda - 2)} \quad (27)$$

Calculate the first partial derivatives of the optimal EWS prices p_1^* and p_2^* with respect to α and β respectively.

$$\frac{\partial p_1^*}{\partial \alpha} = \frac{\left(\theta + \beta \ln \frac{1}{\Delta t} \right) \{4\lambda + \theta[2 + \lambda(\lambda - 4)]\} + 2 \left(\theta - \beta \ln \frac{1}{\Delta t} - 2 \right)}{8\alpha^2(1 - \theta)} \quad (28)$$

$$\frac{\partial p_2^*}{\partial \alpha} = \frac{\left(\theta + \beta \ln \frac{1}{\Delta t} \right) \{ -6 + 4\lambda + \theta[6 + \lambda(\lambda - 4)] \}}{4\alpha^2(\theta - 1)(\lambda - 2)} \quad (29)$$

$$\frac{\partial p_1^*}{\partial \beta} = \frac{\ln \frac{1}{\Delta t} \{ -2 + 4\lambda + \theta[2 + \lambda(\lambda - 4)] \}}{8\alpha(\theta - 1)} \quad (30)$$

$$\frac{\partial p_2^*}{\partial \beta} = \frac{\ln \frac{1}{\Delta t} \{ -6 + 4\lambda + \theta[6 + \lambda(\lambda - 4)] \}}{4\alpha(\theta - 1)(\lambda - 2)} \quad (31)$$

Observing Eq.(26), p_1^* should be greater than zero, as $\theta < 1$, therefore

$$\begin{aligned}
& -\alpha\eta(\theta-1) + \Delta t^2 \left[\theta + \beta \ln \left(\frac{1}{\Delta t} \right) \right] \{4\lambda + \theta[2 + \lambda(\lambda-4)]\} \\
& + 2\Delta t^2 \left[\theta - \beta \ln \left(\frac{1}{\Delta t} \right) - 2 \right] \\
& < 0
\end{aligned}$$

Since $-\alpha\eta(\theta-1) > 0$, then

$$\left(\theta + \beta \ln \frac{1}{\Delta t} \right) \left\{ 4\lambda + \theta[2 + \lambda(\lambda-4)] + 2 \left(\theta - \beta \ln \frac{1}{\Delta t} - 2 \right) \right\} < 0$$

in that case, $\frac{\partial p_1^*}{\partial \alpha} < 0$.

Similarly in Eq.(27), p_2^* should also be greater than zero, both θ and $\lambda < 1$, therefore

$$\{ -6 + 4\lambda + \theta[6 + \lambda(\lambda-4)] \} \left(\theta + \beta \ln \frac{1}{\Delta t} \right) < 0$$

in that case, $\frac{\partial p_2^*}{\partial \alpha} < 0$.

Likewise, it can be proved that Eq. (30) and Eq. (31) are both greater than zero, i.e. $\frac{\partial p_1^*}{\partial \beta} > 0$ and $\frac{\partial p_2^*}{\partial \beta} > 0$.

Hence, the optimal EWS prices p_1^* and p_2^* are decreasing function of the price sensitivity coefficient α , and increasing function of the response time-sensitive coefficient β . Q.E.D.

Proposition 3 indicates that as the EWS market develops to a mature stage, companies understand the consumer demands better and engage in competition. Based on the pricing strategy in Proposition 2, companies need to consider consumer price sensitivity and response time sensitivity, and set a more complex combination pricing strategy.

Proposition 4: When $t_1 < t_2$, the optimal EWS price of the self-owned retailer p_1^* is positively related to the differential response time Δt . The optimal EWS price of the franchised retailer p_2^* is negatively related to the differential response time Δt . When $t_1 > t_2$, p_1^* is negatively related to Δt , and p_2^* is positively related to Δt .

Proof: Take the first partial derivatives of the optimal EWS prices p_1^* and p_2^* with respect to Δt in Eq. (26) (27):

$$\frac{\partial p_1^*}{\partial \Delta t} = \frac{2\alpha\eta(\theta-1) - \Delta t\beta \ln \frac{1}{\Delta t} \{ -2 + 4\lambda + \theta[2 + \lambda(\lambda-4)] \}}{8\alpha\Delta t^3(\theta-1)} \quad (32)$$

$$\frac{\partial p_2^*}{\partial \Delta t} = \frac{2\alpha\eta(\theta-1) + \Delta t\beta \ln \frac{1}{\Delta t} \{ -6 + 4\lambda + \theta[6 + \lambda(\lambda-4)] \}}{4\alpha\Delta t^3(\theta-1)(\lambda-2)} \quad (33)$$

Based on the proof of Proposition 3, both the numerators in Eq. (32) and Eq. (33) are less than zero, therefore, $\frac{\partial p_1^*}{\partial \Delta t} > 0$ and $\frac{\partial p_2^*}{\partial \Delta t} < 0$.

Δt is defined as $|t_1 - t_2|$, consisting two kinds of situation, $t_1 < t_2$ and $t_1 > t_2$. When $t_1 < t_2$, the optimal EWS prices p_1^* is greater than p_2^* , and the more difference of response times between the two retailers, the higher the price p_1^* , i.e., p_1^* is an increasing function of Δt . Similarly, p_2^* is a decreasing function of Δt . when $t_1 > t_2$, p_1^* is less than p_2^* , and the more difference of response times between the two retailers, the lower the price p_1^* , i.e., p_1^* is a decreasing function of Δt , and p_2^* is an increasing function of Δt . Q.E.D..

Proposition 4 indicates that in the competition of the EWS market, based on the EWS combination pricing strategy in Proposition 3, companies can design their own optimal pricing strategy and obtain a price competitive advantage by adjusting the difference of response time with their competitors.

6. Sensitivity analysis

Based on the verification of the previous four propositions, this section focus on observing the impacts on the EWS strategies under the combination of response time and price through two parameters: consumer price sensitivity coefficient for EWS α and consumer time-sensitive coefficient for EWS β . The parameters such as cost rate of

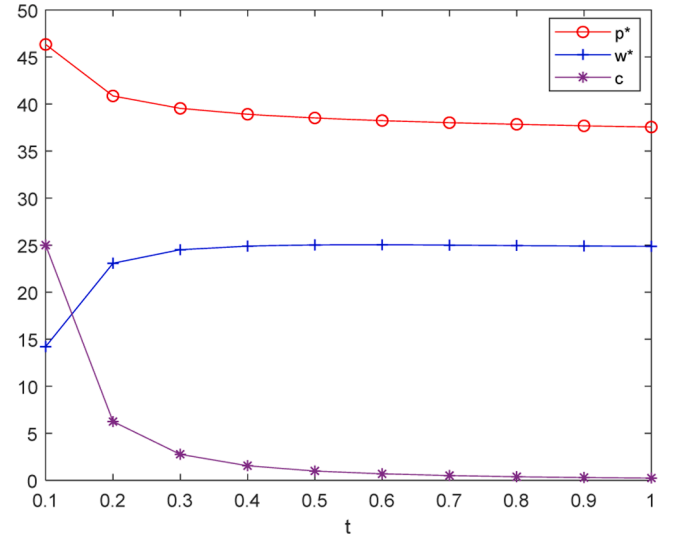


Fig. 3. The impacts of t on p^* , w^* and c .

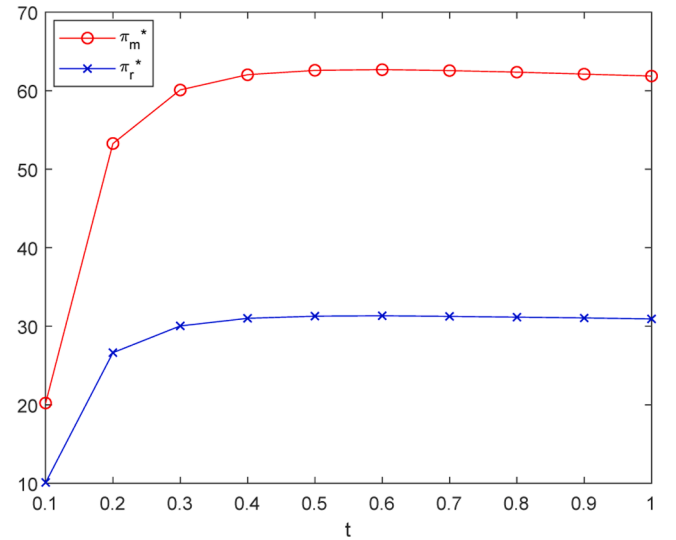


Fig. 4. The impacts of t on Π_m^* and Π_r^* .

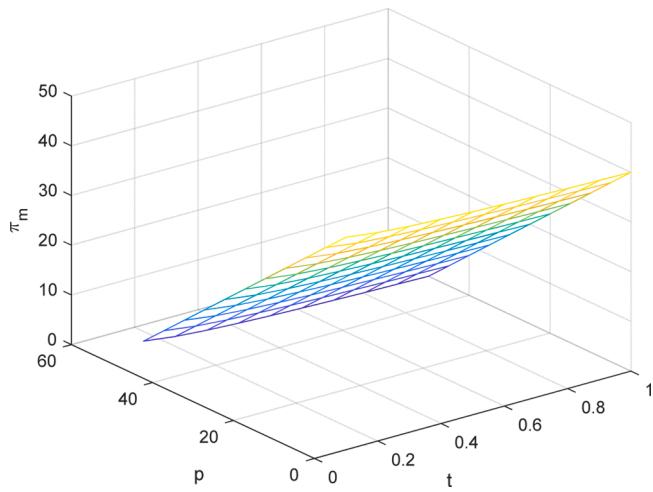
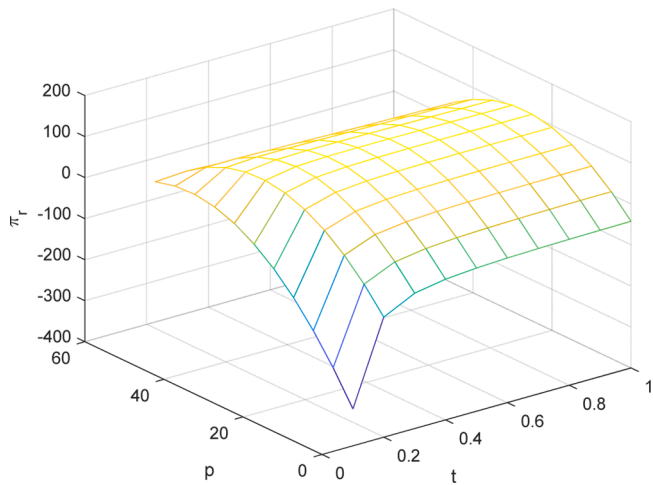
EWS η , variable franchise rate λ , and substitute ratio of EWS θ are mainly used to support the acquisition of numerical calculation results. The changes in these parameters do not affect the conclusions, so the detailed analysis is omitted. According to the reference [40], without lossing of generality, set the parameters as follows: $\alpha = 0.2$, $\beta = 0.3$, $\eta = 0.1$, $\lambda = 0.2$, $\theta = 0.4$. Among them, α and β are initial values selected. In sensitivity analysis, different combinations of these two parameters are carried out. As to η , λ and θ , the selection of the values are according to theoretical literature review, as well as empirical business practices.

Hence, the sensitivity analysis is conducted to exam the impacts of the price and response time on EWS supply chain strategies in scenario IRT and scenario DRT.

6.1. Sensitivity analysis in scenario IRT

6.1.1. The impacts of response time on EWS strategy

Calculate the EWS prices, costs and profits with various time. In Fig. 3, both the EWS price p^* and cost c increase with decreasing of the response time t , and the EWS price w^* decreases with decreasing of the response time t . There exists a threshold value of the response time t . When $t < 0.2$, the EWS costs increase rapidly as the response time

Fig. 5. The impacts of p and t on Π_m .Fig. 6. The impacts of p and t on Π_r .

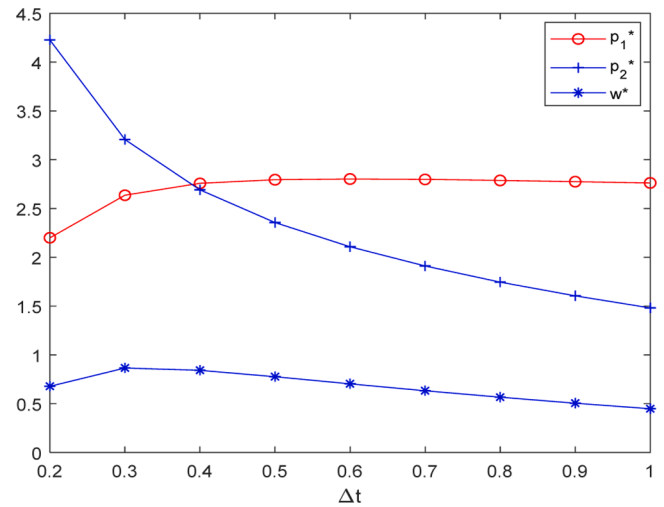
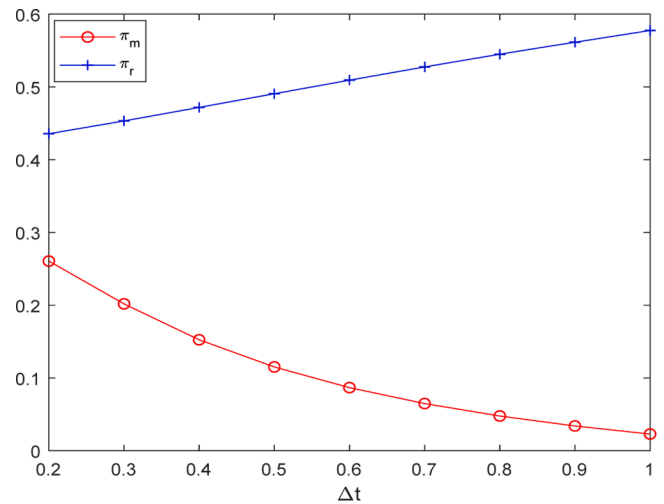
decreases, the EWS prices also increase, but is slower comparing with the increasing of the costs. It is consequent with Proposition 1, i.e. the optimal retailer EWS price p_2^* is negatively related to the response time t , and the cost of the EWS c is negatively related to the response time t .

In Fig. 4, the profits (Π_m^* and Π_r^*) of all supply chain members increase rapidly as the response time t increase (when $t < 0.2$), but the increasing speed slows down (when $t > 0.2$). The profit of the manufacturer is always greater than the profit of the two retailers.

With a given response time, the manufacturer may make the decision of increasing the wholesale price to maximize its profit. According to the manufacturer's decision, the retailers will adopt the strategies of decreasing the EWS prices and increasing the response time to win the market and maximize their profits.

6.1.2. The impacts of ews response time and prices on profits

Calculate the profits of supply chain members with various of the EWS response time and prices. In Fig. 5, the profit of the manufacturer Π_m increases with the EWS response time t increases, and decreases with the EWS price p increases. When t is larger and p is smaller, the manufacturer earns more profit as well as the EWS demands increase. In Fig. 6, the profits of the retailers Π_r increase at the beginning, and then decrease as p increases. There exists an threshold value of EWS response time that maximizes the profits of the retailers under the simultaneous effect of p and t . It is consequent with Proposition 2, i.e. for a given EWS response time t , the retailer can always optimize the manufacturer and

Fig. 7. The impacts of p and t on Π_m .Fig. 8. The impacts of Δt on Π_m^* and Π_r^* .

the retailer profits by pricing the EWS appropriately.

This suggests that when the EWS response time decrease, the EWS cost increases quicker than the EWS price, resulting in a decrease of the retailers' profit. Therefore, the retailers need to choose an appropriate response time within the threshold value.

6.2. Sensitivity analysis in scenario DRT

6.2.1. The impacts of response time differentiation on EWS strategy

Without loss of generality, take the case $t_1 < t_2$ as an example. Calculate the EWS prices and profits with various response time differentiation, shown in Fig. 7 and Fig. 8. The optimal EWS price of the self-owned retailer p_1^* decreases as the response time differentiation Δt increases, while the optimal EWS price of the franchised retailer p_2^* increases as Δt increases. As Δt increases, the curve represents the optimal EWS wholesale price w^* , initially rises and then declines. The curve of the manufacturer's profit rises with Δt increases, while the curve of the retailers' profit decline. The impacts of Δt for the case $t_1 > t_2$ is inverse. It is consequent with Proposition 4, i.e. when $t_1 < t_2$, the optimal EWS price of the self-owned retailer p_1^* is positively related to the differential response time Δt . The optimal EWS price of the franchised retailer p_2^* is negatively related to the differential response time Δt .

This suggests that an increase in the EWS differentiated response

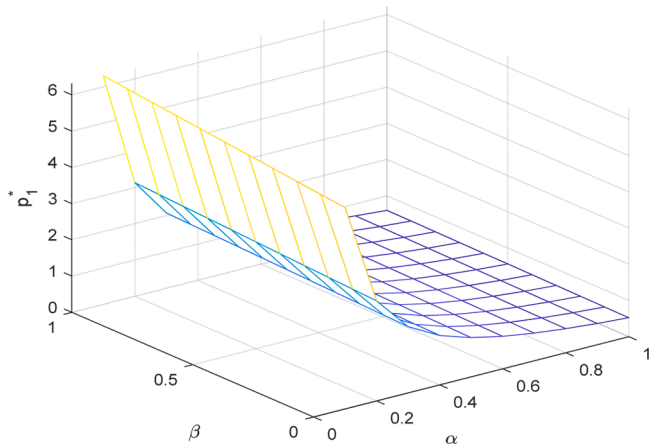


Fig. 9. The impacts of α and β on p_1^* .

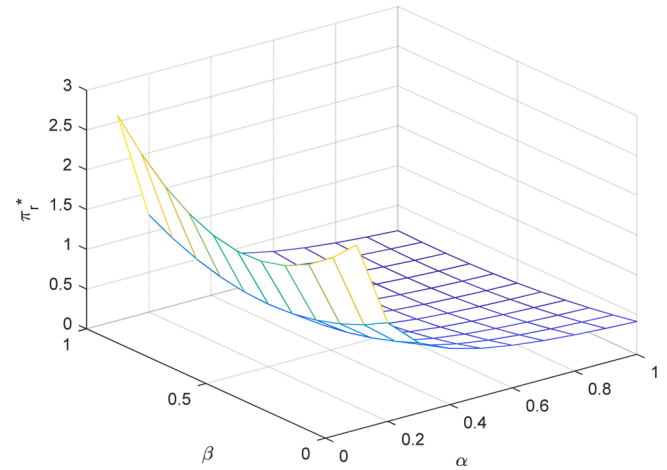


Fig. 12. The impacts of α and β on Π_{r*} .

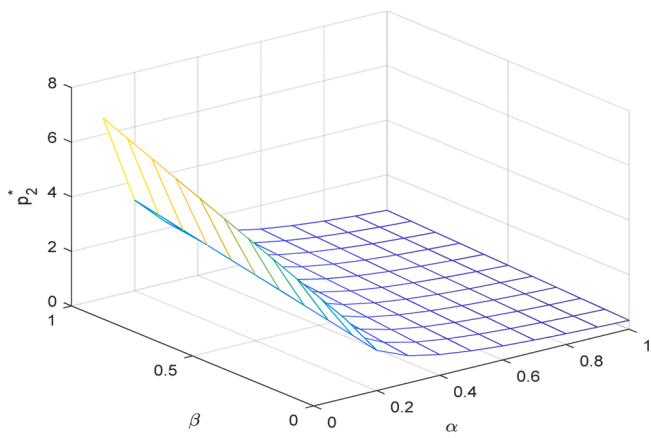


Fig. 10. The impacts of α and β on p_2^* .

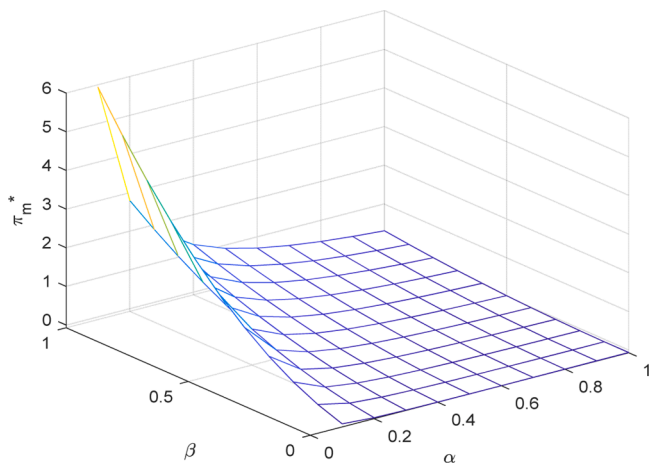


Fig. 11. The impacts of α and β on Π_{m*} .

time is beneficial to the manufacturer, the manufacturer's profit increases as the differentiation increases. The segment of the profit increasing may come from the self-owned retailer. In order to increase EWS profits, the franchised retailer need to enhance the EWS responsiveness, i.e., reduce the response time differentiation with the self-owned retailer.

6.2.2. The impacts of response time and price sensitivities on EWS strategies

Calculate the EWS prices with various sensitivity coefficients of response time and price, shown in Fig. 9 and Fig. 10. The optimal EWS prices (p_1^* , p_2^*) of both retailers are negatively related to the price sensitivity coefficient α , while positively related to the time-sensitive coefficient β . The franchise retailer's optimal EWS price p_2^* is more sensitive to changes in β , comparing with the price p_1^* . Both retailers' optimal EWS prices (p_1^* , p_2^*) are more sensitive in the range of smaller α . It is consequent with Proposition 3, i.e. the two retailers optimal EWS prices are negatively related with the price sensitivity coefficient, and positively related with the response time-sensitive coefficient.

Calculate the EWS profits with various sensitivity coefficients of response time and price, shown in Fig. 11 and Fig. 12. The profits of manufacturer Π_{m*} and the retailers Π_{r*} are negatively related to the price sensitivity coefficient α . The profit of manufacturer is positively related to the time-sensitive coefficient β , while the profit of the retailers Π_{r*} decreases initially and then increases with β increases. The profit of the retailers Π_{r*} is more sensitive with β in the range of smaller α , comparing with the manufacturer profit Π_{m*} .

This suggests that both the self-owned retailer and the franchised retailer prefer the consumer market where EWS price sensitivity is low and response time-sensitive is high. The retailers can set higher EWS prices by improving EWS responsiveness in order to obtain their optimal profits.

Choosing a market with lower EWS price sensitivity and higher response time-sensitive is more profitable for the manufacturer. Therefore, the manufacturer can adopt lower wholesale price or variable franchise fee to motivate the franchised retailer to shorten the response time, in order to achieve optimal supply chain profit.

7. Conclusion

To address the first challenge, comprehensively considers the response time and its corresponding price, a consumer utility function is constructed. The main conclusions and insights are as follows:

- (1) The consumer utility function considering the EWS response time is highly correlated with IRT and DRT scenarios, as well as self-owned and franchised retailers channels. Through cross comparison, the consumer utility function can be quantitatively described. Companies have insights into the consumer market based on the consumer utility function and develop corresponding market strategies.
- (2) The boundary value of the consumer utility function considering the EWS response time corresponds to the relationship between response time and pricing. By analyzing the quantified consumer

utility function and calculating its threshold, the demand function and profit function under IRT and DRT, as well as the two EWS providers, can be characterized. Companies can predict market demand and develop corresponding supply chain strategies based on consumer utility functions.

Based on the consumer utility, the EWS pricing strategies under two scenarios of IRT and DRT are studied specifically to address the second challenge. The main conclusions and insights are as follows:

- (1) Under IRT scenario, the retailers' optimal EWS prices are negatively related to the response time, and EWS costs are also negatively related to the response time. This suggests that during the growth period of EWS market, the self-owned and franchised retailers should adopt consistent EWS pricing strategies due to the identical response time. To expand the market for time-sensitive consumers, the retailers should consider the EWS pricing strategies with trade-off between shorter response time and higher price.
- (2) Under DRT scenario, when EWS response time changes, the change rate of the EWS cost is not consistent with the EWS price. As there exists a response time threshold, the self-owned and franchised retailers can set their own EWS prices to optimize profits. This suggests that during the mature period of the EWS market, the retailers can develop their EWS pricing strategies accurately and quantitatively based on the response time threshold and the wholesale price given by the manufacturer.
- (3) Under DRT scenario, the retailers' optimal EWS prices have a negative relationship with the price sensitivity coefficient of the consumers, and a positive relationship with the time sensitivity coefficient of the consumers. The increase in differentiated response times is beneficial to the retailers. This suggests that in the mature period of EWS market, the manufacturer and the self-owned retailer can significantly reduce EWS response time with a limited increase in the prices. By implementing such strategies to enhance consumer utility, they can continually consolidate the time-sensitive consumer market. Meanwhile, the franchised retailer need to follow the self-owned retailer and develop the EWS price strategy to narrow the gap of the response time.

This paper considers consumer utility under the joint effect of EWS response time and price, focusing on the impact of response time on EWS pricing strategies. However, besides the response time, the EWS pricing is also affected by factors such as consumer perceived risk, expected revenue, etc., which may all be components of consumer utility. With the continuous development of the future digital consumer market, factors such as consumers' preferences for online and offline channels, loyalty to product and service brands, and trust in supply chains through digital technologies such as blockchain will also affect consumer utility. Therefore, studying the EWS pricing strategy under the multidimensional aspects of consumer sensitivity of time, risk, revenue, brand and technology is a potential research field.

CRedit authorship contribution statement

Xingjian Zhou: Formal analysis, Writing – review & editing. **Yan Feng:** Formal analysis, Writing – review & editing. **Hongming Chen:** Resources. **Lihua Cai:** Writing – original draft. **Vladimir Bashkarev:** Resources.

Declaration of competing interest

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Data availability

Data will be made available on request.

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