Credit Payment Decision-Making in E-commerce Platforms Considering Consumer Utility (Postprint)

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Abstract

Consider a supply chain comprising two manufacturers producing products of different qualities and an e-commerce platform. Based on consumer surplus theory, this study investigates the credit payment service decision-making problem of e-commerce platforms. By establishing an e-commerce platform profit model grounded in consumer utility from selecting different payment methods for product purchases, we further analyze and derive the platform' s optimal credit payment service decisions. The research demonstrates that when consumers exhibit relatively high acceptance of average-quality products and credit payment services impose a relatively large negative effect on consumers, introducing credit payment can enhance platform profits and increase consumer surplus. Conversely, when consumers show relatively low acceptance of average-quality products and the negative effect of credit payment services is relatively small, launching credit payment services with an extended deferred payment period can improve platform profits and increase consumer surplus; otherwise, substantial capital costs will be incurred, damaging platform interests. E-commerce platforms can enhance their profitability by developing rational credit payment strategies.

Full Text

Preamble

Research on Credit Payment Service Decision-Making of E-commerce Platforms Considering Consumer Utility

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Abstract: This paper investigates the credit payment service strategy of an e-commerce platform in a supply chain consisting of two competitive manufacturers and one e-commerce platform. Based on consumer surplus theory and consumer utility under different payment choices, we develop a revenue model for the e-commerce platform and analyze its credit payment service decisions. The results show that when consumers have a high acceptance of average-quality products and the service creates a large negative effect on consumers, launching credit payment can improve platform revenue and increase consumer surplus. When consumer acceptance of average-quality products is low and the negative effect of the service is small, the platform can increase revenue and consumer surplus by launching the service with a longer delayed payment period; otherwise, substantial capital costs will damage platform profits. E-commerce platforms can enhance revenue by formulating appropriate credit payment strategies.

Keywords: consumer utility; delayed payment; platform revenue; consumer surplus

0 Introduction

With the rapid development of e-commerce and the diversification of values among new-generation consumers, internet users' consumption habits have changed, shifting from conservative consumption patterns to 超前消费 (consumption ahead of income). According to data from the China E-commerce Research Center, China' s e-commerce transaction volume reached 28.66 trillion yuan in 2017, a year-on-year increase of 24.77%. In this context, an increasing number of e-commerce platforms have begun offering credit payment services such as delayed payment and installment plans. These services are typically embodied as financial products, including "JD Baitiao" launched by JD.com, "Vipshop Flower" by Vipshop, and "Suning Willful Pay" by Suning, which allow consumers to purchase first and pay later. During the payment deferral period, consumers can invest the corresponding funds to obtain returns. Compared with consumer credit offered by traditional commercial banks, e-commerce platforms can conduct comprehensive analysis of users based on platform transaction data, enabling more accurate credit evaluation of consumers and improving the efficiency of credit payment services. The launch of credit payment services by e-commerce platforms has become a trend. According to data, the scale of China' s internet consumer credit lending reached 4.4 trillion yuan in 2017, representing a growth of 904.0% (iResearch Inc).

E-commerce platforms' launch of credit payment services can influence consumers' purchase intentions and payment willingness, enhance their motivation to purchase products, thereby increasing platform sales volume and improving customer stickiness. However, such services also create certain negative effects on consumers' online shopping experience, and platforms incur substantial upfront investment costs, service costs, and interest losses due to delayed receipt of payments (i.e., capital costs). Therefore, the impact of credit payment services on e-commerce platforms and consumers is worth studying, and determining when to launch credit payment services and the appropriate level of investment in such services are important decision-making issues for e-commerce platforms.

Current research on credit payment primarily focuses on two aspects. First, empirical methods are used to analyze the impact of credit payment services on consumer purchasing behavior or enterprises. Li Aimei et al. [3] analyzed factors affecting consumers' payment willingness based on mental accounting theory (such as the negative utility generated by payment hassle, payment timing, and separation of payment from consumption), concluding that payment methods affect consumer purchasing behavior and that payment method design has become increasingly important in business decision-making. Zhang Kui et al. [4,5] empirically studied the impact of consumer credit on consumption from a macro perspective. Li Guangzi et al. [6] analyzed the impact of consumer credit on consumption behavior from a micro perspective using credit limits. Second, mathematical models are established to study optimal decision-making problems of supply chain members under credit payment strategies and the impact of credit payment on supply chains. Among these, numerous studies have examined suppliers offering deferred payment strategies to retailers, such as Chung et al. [7], who considered a scenario where suppliers provide a fixed credit period to retailers but require order quantities to meet certain thresholds; otherwise, immediate payment is required, and studied retailers' optimal economic order quantity problems. Chen et al. [8] studied retailers'optimal ordering decisions under different payment schemes based on mental accounting theory. Ma Zhonghua et al. [9] studied supply chain coordination considering retailers' default risk under delayed payment. In addition, the phenomenon of retailers allowing consumers to delay payment to increase sales has gradually attracted attention from scholars both domestically and internationally. Feng et al. [10] established an inventory model for retailers' cost minimization based on Huang' s [11] two-level trade credit assumption, studying retailers' inventory cycle and payment timing issues. Chung et al. [12] extended the model to perishable products, Maihami et al. [13] further considered non-instantaneous deterioration, Thangam [14] studied price discounts and inventory issues under advance payment schemes and two-level deferred payment schemes, Zhu Junpei et al. [15] studied dynamic supply chain network equilibrium under two-level credit payment, and Yang Li [16] analyzed the impact of JD Baitiao on platform revenue using cost-benefit theory, taking JD Finance as an example. Research shows that while JD Baitiao can stimulate consumption, platform profits cannot be significantly improved solely through consumption stimulation, as other factors also matter.

The above studies rarely analyze e-commerce platforms' launch of credit payment services based on consumer valuation and internet shopping scenarios to examine their impact on consumer behavior and supply chain optimal decision-making. Currently, numerous studies have addressed consumers' strategic consumption behavior when facing different products. For example, Bi Gongbing et al. [17] studied dynamic pricing problems considering consumers' strategic behavior when a single retailer sells two substitutable products simultaneously.

Zeng Heqi et al. [18] studied intertemporal pricing of two substitutable products considering the coexistence of myopic and strategic consumers. Luo [19] and Wei Caimin et al. [20] studied the impact of consumers' acceptance of general brands and different power structures on retailers' operational decisions and supply chain members' profits based on consumer brand preference. Chen Zhangyue et al. [21] established a closed-loop supply chain model consisting of a supplier and a remanufacturer based on consumers' strategic choices, studying the impact of consumers' strategic degree and remanufactured product quality on supply chain members' profits and consumer surplus. These studies only consider consumers' strategic choices based on product preferences and do not involve the impact of payment methods on consumer purchasing decisions. This paper considers the existence of two products with different quality levels in the market, analyzes consumers' strategic choices under different payment methods after e-commerce platforms launch credit payment services based on consumer surplus theory, and examines the impact of credit payment services on supply chains and their members' benefits by comparing scenarios with and without the service.

1 Problem Description and Symbol Notation

This paper considers a supply chain consisting of two competitive manufacturers and one e-commerce platform, studying the optimal decision-making problems of the supply chain before and after the platform launches credit payment services, and comparing and discussing the impact of credit payment services on platform profits and consumer surplus.

Consumers' product value estimates are heterogeneous and follow a uniform distribution on [0,1]. The two manufacturers produce two substitutable products with different quality levels, which the e-commerce platform sells simultaneously for consumer choice. Manufacturer 1 produces Product 1 with relatively high quality, while Manufacturer 2 produces Product 2 with average quality. The products' prices are p_1 and p_2 ($p_1 > p_2$). Consumers have different valuations for the two products: higher valuation for the higher-quality product and lower valuation for the average-quality product, denoted as v and δv, respectively, where δ represents consumers' acceptance degree of the average-quality product.

When the e-commerce platform launches a credit payment service to attract consumers and increase platform sales—allowing consumers to delay payment for products purchased on the platform—consumers have two payment options: immediate payment and delayed payment. If consumers use the credit payment service, they can enjoy the benefit of paying after an interest-free period t. During this period, consumers can invest the funds in other channels to obtain additional interest or returns, so the actual price paid by consumers under this payment method is $p(1-\theta t)$, where θ is the consumer' s corresponding investment return rate. However, using this service incurs various inconvenience costs for consumers, such as cumbersome service activation processes, limited usage scenarios, and the risk of additional fees due to overdue payments. Literature

(Li Aimei, Hao Mei, Li Li, et al., 2012) also indicates that post-consumption payment generates more negative effects for customers.

Additionally, we assume that in the supply chain, the two manufacturers are leaders, and the e-commerce platform purchases products from manufacturers to sell to customers. The structural model is shown in Figure 1 [Figure 1: see original paper].

The symbol notation in this paper is as follows: To distinguish parameters in the two market scenarios, we use superscript N to denote the market without credit payment service and superscript D to denote the market with credit payment service; subscript e denotes the retailer (e-commerce platform), subscript m denotes the manufacturer; subscript I represents payment through credit payment service, and subscript D represents direct payment.

- v: Consumer' s value estimate for the product, following a uniform distribution on [0,1]
- c_i: Manufacturer' s unit production cost, $i = 1, 2$
- w_i: Manufacturer' s unit wholesale price, $i = 1, 2$
- p_i: Unit product retail price ($0 \leq p_i \leq 1$, $i = 1, 2$)
- δ: Consumer acceptance degree of the lower-quality brand, $\delta \in (0, 1)$
- α: Negative effect of credit payment service on consumers, $\alpha \in (0, 1)$
- θ: Consumer' s investment return rate, $\theta \in (0, 1)$
- β: E-commerce platform' s capital cost rate, $\beta \in (0, 1)$
- D_{ji}: Consumer demand for product i through payment method j, $i, j = 1, 2$
- π: Enterprise profit
- cs: Total consumer surplus
- sw: Social welfare

Consumers make strategic choices based on their consumer surplus when making product purchase decisions:

i. Direct payment to purchase Product 1: $U_{11} = v - p_1$

ii. Direct payment to purchase Product 2: $U_{22} = \delta v - p_2$

iii. Delayed payment to purchase Product 1: $U_{31} = v - p_1 - \alpha - \theta t$

iv. Delayed payment to purchase Product 2: $U_{42} = \delta v - p_2 - \alpha - \theta t$

[Figure 1: see original paper] E-commerce platform launches credit payment service model

2 Platform Without Credit Payment Service (N)

This section analyzes the e-commerce platform' s pricing decisions and supply chain members' benefits in a market where the platform has not launched credit payment services. When analyzing market demand, we only consider scenarios where demand exists for both products simultaneously.

In a market without credit payment services, consumers must pay for products immediately upon purchase. As described in Section 1, consumers have only two strategic choices (i, ii): when $v-p_1>\delta v-p_2$ and $v-p_1>0$, consumers will purchase Product 1; when $\delta v-p_2>v-p_1$ and $\delta v-p_2>0$, consumers will purchase Product 2. Therefore, consumers' product choices involve three critical states: when $v-p_1>0$, consumers will purchase Product 1; when $\delta v-p_2>0$, consumers will purchase Product 2; when $v-p_1<0$ and $\delta v-p_2<0$, consumers will not purchase any product.

The demand functions for the two products are as follows:

$D_{11}^N(p_1,p_2)=1-\frac{p_1-p_2}{1-\delta}$

$D_{22}^N(p_1,p_2)=\frac{p_1-p_2}{1-\delta}-\frac{p_2}{\delta}$

The e-commerce platform' s profit function is:

$\pi_e^N(p_1,p_2)=(p_1-w_1)D_{11}^N(p_1,p_2)+(p_2-w_2)D_{22}^N(p_1,p_2)$

The manufacturers' profit functions are:

$\pi_{m1}^N(w_1)=(w_1-c_1)D_{11}^N(p_1,p_2)$

$\pi_{m2}^N(w_2)=(w_2-c_2)D_{22}^N(p_1,p_2)$

The e-commerce platform and the two manufacturers make optimal decisions to maximize their profits based on equations (1) and (2), leading to the following theorem.

Theorem 1 When the e-commerce platform does not launch credit payment services, the retail prices of the two products with different quality levels are:

$p_1^N=\frac{2c_1+5c_2+2\delta-2}{8\delta-8}$

$p_2^N=\frac{c_1+6c_2\delta+2\delta-2}{8\delta-8}$

Proof: The e-commerce platform maximizes profit by taking first-order and second-order partial derivatives of the profit function (3). The Hesse matrix for the platform' s profit function with respect to p_1 and p_2 is:

$$H=\begin{bmatrix}-2 & 2\delta\\ 2\delta & -2\delta\end{bmatrix}$$

Through calculation, we can determine that H is negative definite, so the platform' s profit function is concave with respect to p_1 and p_2, thus a unique maximum exists. Setting the first-order derivatives to zero yields $p_1=\frac{w_1+w_2+1}{2}$ and $p_2=\frac{w_1+w_2}{2\delta}$. Substituting these into equations (4) and (5), taking first-order derivatives with respect to w_1 and w_2 and setting them to zero, we obtain the optimal wholesale price decisions. Finally, substituting these back into the retail price expressions yields the optimal retail price decisions.

Based on Theorem 1, the consumer surplus and social welfare when the e-commerce platform does not launch credit payment services are:

$cs^N = \int_{v_1}^{1}(v - p_1^N)dv + \int_{v_2}^{v_1}(\delta v - p_2^N)dv$

$sw^N = \pi_e^N + \pi_{m1}^N + \pi_{m2}^N + cs^N$

Corollary 1 As consumers' acceptance of average-quality products increases, the price of higher-quality products decreases, while the price of average-quality products increases.

Proof: From Theorem 1, we have $\frac{\partial p_1^N}{\partial \delta} < 0$ and $\frac{\partial p_2^N}{\partial \delta} > 0$. Therefore, Corollary 1 is proved. When the e-commerce platform does not launch credit payment services, higher consumer acceptance of average-quality products leads to higher valuation of these products and greater demand, resulting in higher prices, while the opposite holds for higher-quality products.

3 Platform With Credit Payment Service (D)

When the e-commerce platform launches credit payment services, consumers have four strategic choices when facing products of different quality levels and payment methods. Consumers make purchase and payment decisions based on consumer surplus, and the e-commerce platform sets product prices to maximize revenue.

The conditions for consumers to choose immediate payment to purchase Product 1 (I1) are: $\{v - p_1 \geq \max\{\delta v - p_2, v - p_1 - \alpha - \theta t, \delta v - p_2 - \alpha - \theta t\}, v - p_1 \geq 0\}$.

The conditions for consumers to choose immediate payment to purchase Product 2 (I2) are: $\{\delta v - p_2 \geq \max\{v - p_1, v - p_1 - \alpha - \theta t, \delta v - p_2 - \alpha - \theta t\}, \delta v - p_2 \geq 0\}$.

The conditions for consumers to use credit payment service for delayed purchase of Product 1 (D1) are: $\{v - p_1 - \alpha - \theta t \geq \max\{v - p_1, \delta v - p_2, \delta v - p_2 - \alpha - \theta t\}, v - p_1 - \alpha - \theta t \geq 0\}$.

The conditions for consumers to use credit payment service for delayed purchase of Product 2 (D2) are: $\{\delta v - p_2 - \alpha - \theta t \geq \max\{v - p_1, \delta v - p_2, v - p_1 - \alpha - \theta t\}, \delta v - p_2 - \alpha - \theta t \geq 0\}$.

Consumers have different valuations for purchasing different products under different payment methods, and these valuations determine their purchase choice sequence. Consumers with high valuations will not choose to purchase Product 2 through delayed payment, while consumers with low valuations will not choose to purchase Product 1 through immediate payment. However, the choice sequence for consumers with valuations between these extremes—between immediate payment for Product 2 and delayed payment for Product 1—depends on the relationship between δ and α.

3.1 Scenario 1

In this scenario, consumers' valuation for immediate payment purchase of Product 2 is greater than that for delayed payment purchase of Product 1. Consumers' product purchase sequence decision is: immediate payment purchase of Product 1, immediate payment purchase of Product 2, delayed payment purchase of Product 1, delayed payment purchase of Product 2. The e-commerce platform determines product prices based on consumer valuations and product choices. In this case, we have $p_1 > p_2 > p_1 - \alpha - \theta t > p_2 - \alpha - \theta t$. Consumers generate four critical states when making the above product purchase decisions, respectively $v_1 = \frac{p_1 - p_2}{1-\delta}$, $v_2 = \frac{p_2 - (p_1 - \alpha - \theta t)}{\delta - (1 - \alpha - \theta t)}$, $v_3 = \frac{(p_1 - \alpha - \theta t) - (p_2 - \alpha - \theta t)}{1-\delta}$, and $v_4 = \frac{p_2 - \alpha - \theta t}{\delta}$. At this time, the product demand functions are as follows:

Consumer immediate payment demand function for Product 1: $D_{11}^D(p_1, p_2) = 1 - \frac{p_1 - p_2}{1-\delta}$

Consumer immediate payment demand function for Product 2: $D_{22}^D(p_1, p_2) = \frac{p_1 - p_2}{1-\delta} - \frac{p_2 - (p_1 - \alpha - \theta t)}{\delta - (1 - \alpha - \theta t)}$

Consumer delayed payment demand function for Product 1 using credit payment service: $D_{31}^D(p_1, p_2) = \frac{p_2 - (p_1 - \alpha - \theta t)}{\delta - (1 - \alpha - \theta t)} - \frac{(p_1 - \alpha - \theta t) - (p_2 - \alpha - \theta t)}{1-\delta}$

Consumer delayed payment demand function for Product 2 using credit payment service: $D_{42}^D(p_1, p_2) = \frac{(p_1 - \alpha - \theta t) - (p_2 - \alpha - \theta t)}{1-\delta} - \frac{p_2 - \alpha - \theta t}{\delta}$

The e-commerce platform' s profit function is:

$\pi_e^D(p_1, p_2) = (p_1 - w_1)D_{11}^D + (p_2 - w_2)D_{22}^D + (p_1(1 - \theta t) - w_1)D_{31}^D + (p_2(1 - \theta t) - w_2)D_{42}^D$

The manufacturers' profit functions are:

$\pi_{m1}^D(w_1) = (w_1 - c_1)(D_{11}^D + D_{31}^D)$

$\pi_{m2}^D(w_2) = (w_2 - c_2)(D_{22}^D + D_{42}^D)$

First, substituting the market demand functions (11)-(14) into the e-commerce platform's profit function (15), we obtain the expression for product retail prices based on the profit maximization principle. Then, substituting these into equations (16)-(17) and taking first-order derivatives with respect to w_1 and w_2 and setting them to zero, we obtain the optimal wholesale price decisions. Finally, substituting these back into the retail price expressions yields the following theorem.

Theorem 2 When the e-commerce platform launches credit payment service and $1 - \delta - \alpha > 0$, the retail prices of the two products are:

$p_1^D = \frac{B - A\delta}{\delta(1-\delta)}$

$p_2^D = \frac{B - A}{1-\delta}$

where $A = \frac{2c_1 + c_2 + 2\delta - 2}{8\delta - 8}$ and $B = \frac{c_1 + 6c_2\delta + 2\delta - 2}{8\delta - 8}$.

Proof: Please see Appendix 1.

Based on Theorem 2, the optimal revenues of the e-commerce platform and manufacturers are:

$\pi_e^D = \frac{(\delta-\delta^2-\alpha+\alpha\delta-\alpha^2)(c_1-c_2)^2}{4(1-\delta)(\delta-\alpha-\delta^2+\alpha\delta)}$

$\pi_{m1}^D = \frac{(c_2-c_1+2\delta-2)^2}{16(1-\delta)}$

$\pi_{m2}^D = \frac{(c_1-c_2+2\delta-2\delta^2)^2}{16\delta(1-\delta)}$

The consumer surplus and social welfare in this case are:

$cs^D = \int_{v_1}^{1}(v-p_1^D)dv + \int_{v_2}^{v_1}(\delta v-p_2^D)dv + \int_{v_3}^{v_2}(v-p_1^D-\alpha-\theta t)dv + \int_{v_4}^{v_3}(\delta v-p_2^D-\alpha-\theta t)dv$

$sw^D = \pi_e^D + \pi_{m1}^D + \pi_{m2}^D + cs^D$

Corollary 2 When the negative effect of credit payment service is large (e.g., $\alpha > \frac{1-\delta}{2}$), the delayed payment period significantly influences consumers' purchase choices and demand, thereby affecting the e-commerce platform' s pricing decisions for products.

Proof: In Scenario 1, consumers have a relatively high satisfaction degree with average-quality products. Therefore, when the negative effect of credit payment service is large, as the delayed payment period increases, consumers' valuation for purchasing higher-quality products through delayed payment decreases, reducing demand for these products. Consequently, the platform raises prices to reduce costs and maintain profit margins, meaning both product prices increase compared to the scenario without credit payment service.

3.2 Scenario 2

In this scenario, consumers' valuation for delayed payment purchase of Product 1 is greater than that for immediate payment purchase of Product 2. Consumers' product purchase sequence decision is: immediate payment purchase of Product 1, delayed payment purchase of Product 1, immediate payment purchase of Product 2, delayed payment purchase of Product 2. Similar to the previous subsection, the e-commerce platform determines product prices based on consumer valuations and product choices. In this case, we have $p_1 > p_1-\alpha-\theta t > p_2 > p_2-\alpha-\theta t$. Consumers generate four critical states when making the above product purchase decisions, respectively $v_1 = \frac{p_1-(p_1-\alpha-\theta t)}{\alpha+\theta t}$, $v_2 = \frac{(p_1-\alpha-\theta t)-p_2}{1-\delta-\alpha-\theta t}$, $v_3 = \frac{p_2-(p_2-\alpha-\theta t)}{\alpha+\theta t}$, and $v_4 = \frac{p_2-\alpha-\theta t}{\delta}$. At this time, the product demand functions are as follows:

Consumer immediate payment demand function for Product 1: $D_{11}^D(p_1,p_2) = 1 - \frac{p_1-(p_1-\alpha-\theta t)}{\alpha+\theta t}$

Consumer delayed payment demand function for Product 1 using credit payment service: $D_{31}^D(p_1,p_2) = \frac{p_1-(p_1-\alpha-\theta t)}{\alpha+\theta t} - \frac{(p_1-\alpha-\theta t)-p_2}{1-\delta-\alpha-\theta t}$

Consumer immediate payment demand function for Product 2: $D_{22}^D(p_1,p_2) = \frac{(p_1-\alpha-\theta t)-p_2}{1-\delta-\alpha-\theta t} - \frac{p_2-(p_2-\alpha-\theta t)}{\alpha+\theta t}$

Consumer delayed payment demand function for Product 2 using credit payment service: $D_{42}^D(p_1,p_2) = \frac{p_2-(p_2-\alpha-\theta t)}{\alpha+\theta t} - \frac{p_2-\alpha-\theta t}{\delta}$

The e-commerce platform’ s profit function is:

$\pi_e^D(p_1,p_2) = (p_1-w_1)D_{11}^D + (p_1(1-\theta t)-w_1)D_{31}^D + (p_2-w_2)D_{22}^D + (p_2(1-\theta t)-w_2)D_{42}^D$

The manufacturers’ profit functions are:

$\pi_{m1}^D(w_1) = (w_1-c_1)(D_{11}^D + D_{31}^D)$

$\pi_{m2}^D(w_2) = (w_2-c_2)(D_{22}^D + D_{42}^D)$

Similar to the previous subsection, from equations (23)-(26) we obtain the product demand functions. Based on the profit functions, we can derive the optimal price decisions for products, as shown in Theorem 3.

Theorem 3 When the e-commerce platform launches credit payment service and $1-\delta-\alpha<0$, the retail prices of the two products are:

$p_1^D = \frac{C-D\delta}{\delta(1-\delta)}$

$p_2^D = \frac{C-D}{1-\delta}$

where $C = \frac{2c_1+c_2+2\delta-2}{8\delta-8}$ and $D = \frac{c_1+6c_2\delta+2\delta-2}{8\delta-8}$.

Proof: Please see Appendix 2.

Based on Theorem 3, the optimal revenues of the e-commerce platform and manufacturers in this case are:

$\pi_e^D = \frac{(\delta-\delta^2-\alpha+\alpha\delta-\alpha^2)(c_1-c_2)^2}{4(1-\delta)(\delta-\alpha-\delta^2+\alpha\delta)}$

$\pi_{m1}^D = \frac{(c_2-c_1+2\delta-2)^2}{16(1-\delta)}$

$\pi_{m2}^D = \frac{(c_1-c_2+2\delta-2\delta^2)^2}{16\delta(1-\delta)}$

The consumer surplus and social welfare in this case are:

$cs^D = \int_{v_1}^1 (v-p_1^D)dv + \int_{v_2}^{v_1}(v-p_1^D-\alpha-\theta t)dv + \int_{v_3}^{v_2}(\delta v-p_2^D)dv + \int_{v_4}^{v_3}(\delta v-p_2^D-\alpha-\theta t)dv$

$sw^D = \pi_e^D + \pi_{m1}^D + \pi_{m2}^D + cs^D$

Corollary 3 When the negative effect of credit payment service is small (e.g., $\alpha < \frac{1-\delta}{2}$), we have $\frac{\partial p_1^D}{\partial t} > 0$ and $\frac{\partial p_2^D}{\partial t} < 0$, while π_e^D is not monotonic with respect to t.

Proof: When $1-\delta-\alpha<0$, taking partial derivatives of product prices with respect to the delayed payment period t yields $\frac{\partial p_1^D}{\partial t} > 0$ and $\frac{\partial p_2^D}{\partial t} < 0$. However, the platform’s revenue is not monotonic with respect to t and δ. When α is small, the impact of credit payment service is the same in Scenario 1 and Scenario 2.

When δ is small, as the delayed payment period increases, consumers' valuation for purchasing higher-quality products through delayed payment increases, leading to increased demand for these products, so product prices rise.

4 Impact of Credit Payment Service

Through the above analysis of models with and without credit payment service launched by the e-commerce platform, we have obtained optimal product pricing decisions and maximum platform profits. This section compares product prices, platform revenue, and consumer surplus between the two scenarios to explore the impact of credit payment service.

Proposition 1 (i) In Scenario 1, when α is large, we have $p_1^D > p_1^N$ and $p_2^D > p_2^N$. (ii) In Scenario 2, when α is small, we have $p_1^D < p_1^N$ and $p_2^D < p_2^N$.

Proof: (i) In Scenario 1, $p_1^D - p_1^N = \frac{1-\delta-2\alpha}{8(1-\delta)}$. When α is large (e.g., $\alpha > \frac{1-\delta}{2}$), and since $\frac{\partial(p_1^D - p_1^N)}{\partial\alpha} < 0$, we have $p_1^D > p_1^N$. Similarly, $p_2^D - p_2^N = \frac{\delta(1-\delta-2\alpha)}{8(1-\delta)}$, and when $\alpha > \frac{1-\delta}{2}$, we have $p_2^D > p_2^N$.

(ii) In Scenario 2, $p_1^D - p_1^N = \frac{2\alpha-(1-\delta)}{8(1-\delta)}$. When α is small (e.g., $\alpha < \frac{1-\delta}{2}$), we have $p_1^D < p_1^N$. Similarly, $p_2^D - p_2^N = \frac{\delta(2\alpha-(1-\delta))}{8(1-\delta)}$, and when $\alpha < \frac{1-\delta}{2}$, we have $p_2^D < p_2^N$. Proposition 1 is proved.

From Proposition 1, in Scenario 1, consumers have a relatively high acceptance of average-quality products, and the e-commerce platform' s launch of credit payment service cannot significantly stimulate consumers' purchase desire but instead generates substantial capital costs. Therefore, the platform raises product prices to reduce costs and maintain profit margins. In Scenario 2, the negative effect of credit payment service on consumers is small. When consumers face the choice between delayed payment for Product 1 and immediate payment for Product 2, they prefer the former. Therefore, for Product 2, the launch of credit payment service allows consumers to purchase higher-quality products through delayed payment, partially eroding Product 2' s market demand. To increase Product 2' s sales, the platform lowers its price to enhance market competitiveness. For Product 1, when the delayed payment period is short, the service' s attractiveness is limited, so to increase Product 1' s sales, the platform lowers its price. Moreover, when the delayed payment period is short, the gap between purchasing Product 1 through delayed payment and purchasing Product 2 through immediate payment is small, intensifying competition between the two products, and Product 1' s price will also decrease. When the delayed payment period is long, delayed payment becomes highly attractive to consumers, effectively stimulating their desire to purchase Product 1, and Product 1' s sales increase significantly, leading to higher prices. Additionally, a longer deferred payment period means the platform will incur greater capital costs, so to improve platform revenue, the platform will appropriately increase the product' s price, meaning that compared to the scenario without credit payment service, the product' s price increases.

Proposition 2 When α is small, there exists $t^* \in (0,1)$ such that when $t \in (0,t^*)$, $\pi_e^D < \pi_e^N$, and when $t \in (t^*,1)$, $\pi_e^D > \pi_e^N$. However, platform revenue is not monotonic with respect to δ and t.

Proof: When $1-\delta-\alpha < 0$, define: $\Delta\pi_e = \pi_e^D - \pi_e^N$. When α is small, the impact of credit payment service is the same in Scenario 1 and Scenario 2. When δ is small, as the delayed payment period increases, consumers' valuation for purchasing higher-quality products through delayed payment increases, leading to increased demand for these products, so product prices rise.

Based on the above analysis, the consumer surplus and social welfare in this case are:

$cs^D = \int_{v_1}^{1}(v-p_1^D)dv + \int_{v_2}^{v_1}(v-p_1^D-\alpha-\theta t)dv + \int_{v_3}^{v_2}(\delta v-p_2^D)dv + \int_{v_4}^{v_3}(\delta v-p_2^D-\alpha-\theta t)dv$

$sw^D = \pi_e^D + \pi_{m1}^D + \pi_{m2}^D + cs^D$

Corollary 3 When the negative effect of credit payment service is small, we have $\frac{\partial cs^D}{\partial t} > 0$, while π_e^D is not monotonic with respect to t.

Proof: When $1-\delta-\alpha < 0$, $\frac{\partial cs^D}{\partial t} = \frac{(1-\delta-2\alpha)(c_1-c_2)^2}{4(1-\delta)(\delta-\alpha-\delta^2+\alpha\delta)}$. When $\alpha < \frac{1-\delta}{2}$, $\frac{\partial cs^D}{\partial t} > 0$. When $\delta > \delta^*$, $\frac{\partial cs^D}{\partial \delta} < 0$, meaning at least one δ^* exists. Corollary 3 is proved. In this scenario, consumers have a relatively low acceptance of average-quality products, so when the negative effect of credit payment service is small, as the delayed payment period increases, consumers' valuation for purchasing higher-quality products through delayed payment increases, leading to increased demand for these products, so product prices rise.

5 Numerical Analysis

Based on the numerical examples in reference [23] and combined with the context of this paper, we set parameters $\theta = 0.5$, $\beta = 0.5$, $c_1 = 0.3$, $c_2 = 0.2$.

5.1 Impact of Credit Payment Service on Platform and Consumers

From Section 3, we know that this paper discusses two scenarios when establishing the model with credit payment service launched. This section compares and analyzes the scenario without credit payment service with these two scenarios to discuss the impact of credit payment service. Specific results are shown in Tables 1 and 2.

Table 1 Impact of credit payment service on platform revenue and consumer surplus $(1-\delta-\alpha > 0)$

As shown in Table 1, parameters δ are 0.6, 0.7, and 0.8, respectively, and the delayed payment period t ranges from 0.81 to 0.85. When fixing δ, as the delayed payment period increases, both platform profit and consumer surplus after launching credit payment service will be greater than those without the service, creating a win-win situation. When the delayed payment period remains unchanged, as α increases, both platform profit and consumer surplus show a downward trend but remain higher than the scenario without the service. Table 1 demonstrates that when the negative effect of credit payment service on consumers is large $(1-\delta-\alpha > 0)$ and the delayed payment period is also large, consumers prefer direct payment purchase of Product 2 over delayed payment purchase of Product 1. Due to the longer delay period, the service is highly attractive to consumers, and credit payment service serves as an effective means to stimulate consumer shopping, increasing platform sales and profits while satisfying different consumer needs and increasing consumer surplus.

Table 2 Impact of credit payment service on platform revenue and consumer surplus $(1-\delta-\alpha < 0)$

As shown in Table 2, parameters δ are 0.2, 0.3, and 0.4, respectively, and the delayed payment period t ranges from 0.75 to 0.95. Fixing parameter $\alpha = 0.2$, we observe that as t increases, the platform profit after launching credit payment service shows a trend of first decreasing and then increasing. For example, when $\delta = 0.2$, as t increases from 0.75 to 0.8, platform profit $\pi_e^D < \pi_e^N$ and shows a downward trend; when t increases from 0.85 to 0.95, we have $\pi_e^D > \pi_e^N$, and there exists $t^* \in (0.8, 0.85)$ such that $\pi_e^D = \pi_e^N$. Consumer surplus shows an upward trend and is greater than the scenario without credit payment service. The same trend exists when δ is 0.3 and 0.4. Table 2 shows that when the negative effect of credit payment service on consumers is small $(1-\delta-\alpha < 0)$, consumers prefer delayed payment purchase of Product 1 over direct payment purchase of Product 2. This service enables consumers to purchase higher-quality products and obtain additional investment returns, increasing consumer benefits. When the e-commerce platform launches consumer financial services and increases service investment, capital costs rise. Launching the service not only fails to improve platform revenue but also damages economic benefits. At this point, the average marginal cost exceeds the average marginal revenue. However, as investment in this factor continues to increase (i.e., the payment period extends), platform profit shows a substantial upward trend and exceeds the revenue without the service. At this time, the marginal revenue from launching the service exceeds the marginal cost, making credit payment service an effective means to increase platform sales and revenue.

5.2 Impact of Consumer Acceptance on Platform Revenue and Consumer Surplus

This section analyzes the impact of consumers' satisfaction degree with average-quality products on platform revenue and consumer surplus under different scenarios. Based on previously set parameters, we examine the impact of δ on the platform and consumers under Scenario 1 $(1-\delta-\alpha > 0)$ with $\alpha = 0.7$ and Scenario 2 $(1-\delta-\alpha < 0)$ with $\alpha = 0.2$.

Figure 2 [**Figure 2: see original paper**] and **Figure 3** [**Figure 3: see original paper**] show the impact of δ on the platform and consumers when $t = 0.95$. As shown in the figures, as δ increases, both platform profit π_e^N and consumer surplus cs^N without credit payment service increase. After launching credit payment service, platform profit π_e^D shows an upward trend, while consumer surplus cs^D shows a slow downward trend. In this case, δ affects the platform' s benefits both before and after launching credit payment service. When consumers' acceptance of average-quality products increases, demand for Product 2 increases, and platform sales also increase. After launching credit payment service, consumers prefer direct payment purchase of Product 2 over delayed payment purchase of Product 1. Therefore, for Product 2, whether purchased through direct or delayed payment, its demand will increase significantly, and consumer needs are well satisfied.

Figure 4 [**Figure 4: see original paper**] and **Figure 5** [**Figure 5: see original paper**] show the impact of δ on the platform and consumers when $t = 0.75$. As shown in the figures, as δ increases, both platform profit π_e^N and consumer surplus cs^N without credit payment service increase. After launching credit payment service, both platform profit π_e^D and consumer surplus cs^D show a downward trend. As shown in Figure 3, when δ increases from 0.45 to 0.46, we have $\pi_e^D > \pi_e^N$, and the trend is downward; when δ increases from 0.46 to 0.49, we have $\pi_e^D < \pi_e^N$, and there exists $\delta^* \in (0.45, 0.46)$ such that $\pi_e^D = \pi_e^N$. The results show that when the negative effect of credit payment service on consumers is large, as consumers' acceptance of average-quality products increases, consumer choices shift from prioritizing delayed payment purchase of Product 1 to direct payment purchase of Product 2. When δ is large, the credit payment service launched by the platform fails to effectively improve platform revenue but instead generates substantial capital costs, causing damage to the platform.

6 Conclusion

An increasing number of e-commerce platforms are launching credit payment services, hoping to stimulate consumers' purchase desire and achieve the goal of increasing platform sales and revenue. This paper studies the impact of credit payment services on e-commerce platform revenue and consumer surplus when the platform simultaneously sells two products of different quality levels. The research shows that consumers' acceptance of average-quality products and the negative effect of credit payment services on consumers play important roles in determining the market effectiveness of the service.

When consumers have a high acceptance of average-quality products, e-commerce platforms need to take measures to minimize the negative effect of the service on consumers—such as simplifying the service activation process, expanding service application scenarios, and extending credit periods—to increase the service' s attractiveness to consumers if they want to improve platform sales through credit consumption services. In this case, credit payment service not only brings good benefits to the platform but also satisfies different consumer needs, increases consumer surplus, and creates a win-win situation. When consumers have a low acceptance of average-quality products, the effectiveness of credit payment service is related to the delayed payment period and there exists a critical value. When the platform' s investment in the service is below the critical value, the service not only fails to improve platform revenue but also generates substantial capital costs that damage platform benefits. When the platform continues to increase investment in the service and exceeds the critical value, credit consumption service begins to generate positive effects. Platform profit shows a substantial upward trend and exceeds the revenue without the service. At this point, credit payment service becomes an effective means to increase platform sales and revenue.

This paper studies the impact of credit payment service period and the negative effect of credit payment on consumers on e-commerce platforms and consumers, providing suggestions and theoretical basis for e-commerce platforms to formulate reasonable marketing strategies. However, when analyzing the costs of launching credit payment services, this paper only considers the platform' s capital usage costs. Further research could introduce fixed costs or other variable costs of the platform. Additionally, in real life, consumers' purchase and payment decisions are also influenced by many factors, such as consumers' platform usage preferences, payment method habits, and disposable income. How these factors affect e-commerce decision-making also warrants further study.

Appendix 1: Proof of Theorem 2

Manufacturers, as leaders, first determine product wholesale prices w_1 and w_2, and the retailer (e-commerce platform), as a follower, then determines product retail prices p_1 and p_2. This theorem is proved using backward induction.

From equation (15), when $1-\delta-\alpha>0$, the e-commerce platform' s profit function is:

$$\pi_e^D(p_1,p_2) = (p_1-w_1)\left(1-\frac{p_1-p_2}{1-\delta}\right)+(p_2-w_2)\left(\frac{p_1-p_2}{1-\delta}-\frac{p_2-(p_1-\alpha-\theta t)}{\delta-(1-\alpha-\theta t)}\right)+(p_1(1-\theta t)-w_1)\left(\frac{p_2-(p_1-\alpha-\theta t)}{\delta-(1-\alpha-\theta t)}-\frac{(p_1-\alpha-\theta t)-(p_2-\alpha-\theta t)}{1-\delta}\right)+(p_2(1-\theta t)-w_2)\left(\frac{(p_1-\alpha-\theta t)-(p_2-\alpha-\theta t)}{1-\delta}-\frac{p_2-\alpha-\theta t}{\delta}\right)$$

subject to $0\le\frac{p_2-(p_1-\alpha-\theta t)}{\delta-(1-\alpha-\theta t)}\le\frac{(p_1-\alpha-\theta t)-(p_2-\alpha-\theta t)}{1-\delta}\le\frac{p_2-\alpha-\theta t}{\delta}\le 1$.

Taking first-order and second-order partial derivatives of the profit function with respect to p_1 and p_2, we obtain the Hesse matrix:

$$H=\begin{bmatrix}\frac{2(1-\theta t)}{1-\delta}-\frac{2}{\delta-(1-\alpha-\theta t)} & -\frac{2(1-\theta t)}{1-\delta}+\frac{2}{\delta-(1-\alpha-\theta t)}\\ -\frac{2(1-\theta t)}{1-\delta}+\frac{2}{\delta-(1-\alpha-\theta t)} & \frac{2(1-\theta t)}{1-\delta}-\frac{2}{\delta-(1-\alpha-\theta t)}-\frac{2\theta t}{\delta}\end{bmatrix}$$

To simplify calculations, we assume $\theta=\beta=1$. Through calculation, we find that the first-order principal minor of this Hesse matrix is less than 0, and the second-order principal minor is always greater than 0 when $t>\frac{1}{4}$, indicating that H is negative definite. Moreover, the constraints of this maximization problem are linear functions. For this convex programming problem, the Kuhn-Tucker conditions are necessary and sufficient for determining the optimal solution.

Introducing generalized Lagrange multipliers $\lambda_1, \lambda_2, \lambda_3, \lambda_4$, we rewrite the objective function as:

$$L(p_1, p_2, \lambda_1, \lambda_2, \lambda_3, \lambda_4) = \pi_e^D(p_1, p_2) + \lambda_1\left(1 - \frac{p_2-(p_1-\alpha-\theta t)}{\delta-(1-\alpha-\theta t)}\right) + \lambda_2\left(\frac{p_2-(p_1-\alpha-\theta t)}{\delta-(1-\alpha-\theta t)} - \frac{(p_1-\alpha-\theta t)-(p_2-\alpha-\theta t)}{1-\delta}\right) + \lambda_3\left(\frac{(p_1-\alpha-\theta t)-(p_2-\alpha-\theta t)}{1-\delta} - \frac{p_2-\alpha-\theta t}{\delta}\right) + \lambda_4\left(\frac{p_2-\alpha-\theta t}{\delta}\right)$$

The first-order principal minor of the Hesse matrix is less than 0, and the second-order principal minor is always greater than 0 when $t > \frac{1}{4}$, indicating that H is negative definite. The Lagrangian function and Kuhn-Tucker conditions for this function are:

$$\frac{\partial L}{\partial p_1} = 0,\ \frac{\partial L}{\partial p_2} = 0$$

$$\lambda_i \geq 0,\ \lambda_i g_i(p_1, p_2) = 0,\ i = 1, 2, 3, 4$$

where $g_i(p_1, p_2)$ are the constraint functions.

According to the Kuhn-Tucker conditions, we obtain $p_1 = \frac{B-A\delta}{\delta(1-\delta)}$ and $p_2 = \frac{B-A}{1-\delta}$. To simplify calculations, we assume $\theta = \beta = 1$, obtaining the retail price expressions. Substituting these into manufacturers' profit functions (16) and (17), we solve for the product wholesale prices that maximize manufacturers' profits, and finally substitute these back into the retail price expressions to obtain the optimal retail price decisions. Theorem 2 is proved.

Appendix 2: Proof of Theorem 3

Similar to Theorem 2, from equation (27), when $1 - \delta - \alpha < 0$, the e-commerce platform' s profit function is:

$$\pi_e^D(p_1, p_2) = (p_1 - w_1)\left(1 - \frac{p_1-(p_1-\alpha-\theta t)}{\alpha+\theta t}\right) + (p_1(1-\theta t) - w_1)\left(\frac{p_1-(p_1-\alpha-\theta t)}{\alpha+\theta t} - \frac{(p_1-\alpha-\theta t)-p_2}{1-\delta-\alpha-\theta t}\right) + (p_2 - w_2)\left(\frac{(p_1-\alpha-\theta t)-p_2}{1-\delta-\alpha-\theta t} - \frac{p_2-(p_2-\alpha-\theta t)}{\alpha+\theta t}\right) + (p_2(1-\theta t) - w_2)\left(\frac{p_2-(p_2-\alpha-\theta t)}{\alpha+\theta t} - \frac{p_2-\alpha-\theta t}{\delta}\right)$$

subject to $0 \leq \frac{p_1-(p_1-\alpha-\theta t)}{\alpha+\theta t} \leq \frac{(p_1-\alpha-\theta t)-p_2}{1-\delta-\alpha-\theta t} \leq \frac{p_2-(p_2-\alpha-\theta t)}{\alpha+\theta t} \leq \frac{p_2-\alpha-\theta t}{\delta} \leq 1$.

Taking first-order and second-order partial derivatives of the profit function with respect to p_1 and p_2, we obtain the Hesse matrix:

$$H = \begin{bmatrix} -\frac{2}{\alpha+\theta t} + \frac{2(1-\theta t)}{1-\delta-\alpha-\theta t} & -\frac{2(1-\theta t)}{1-\delta-\alpha-\theta t} + \frac{2}{\alpha+\theta t} \\ -\frac{2(1-\theta t)}{1-\delta-\alpha-\theta t} + \frac{2}{\alpha+\theta t} & \frac{2}{\alpha+\theta t} - \frac{2(1-\theta t)}{1-\delta-\alpha-\theta t} - \frac{2\theta t}{\delta} \end{bmatrix}$$

Similar to the above proof, to simplify calculations, we assume $\theta = \beta = 1$. Through calculation, we find that the first-order principal minor of this Hesse matrix is less than 0, and the second-order principal minor is always greater than 0 when $t > \frac{1}{4}$, indicating that H is negative definite. Using the same method as in Appendix 1, we obtain the optimal retail price decisions $p_1^D = \frac{C-D\delta}{\delta(1-\delta)}$ and $p_2^D = \frac{C-D}{1-\delta}$. Theorem 3 is proved.

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Note: Figure translations are in progress. See original paper for figures.