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Supply chain optimization considering consumers' mental accounting by time dimension in advance selling

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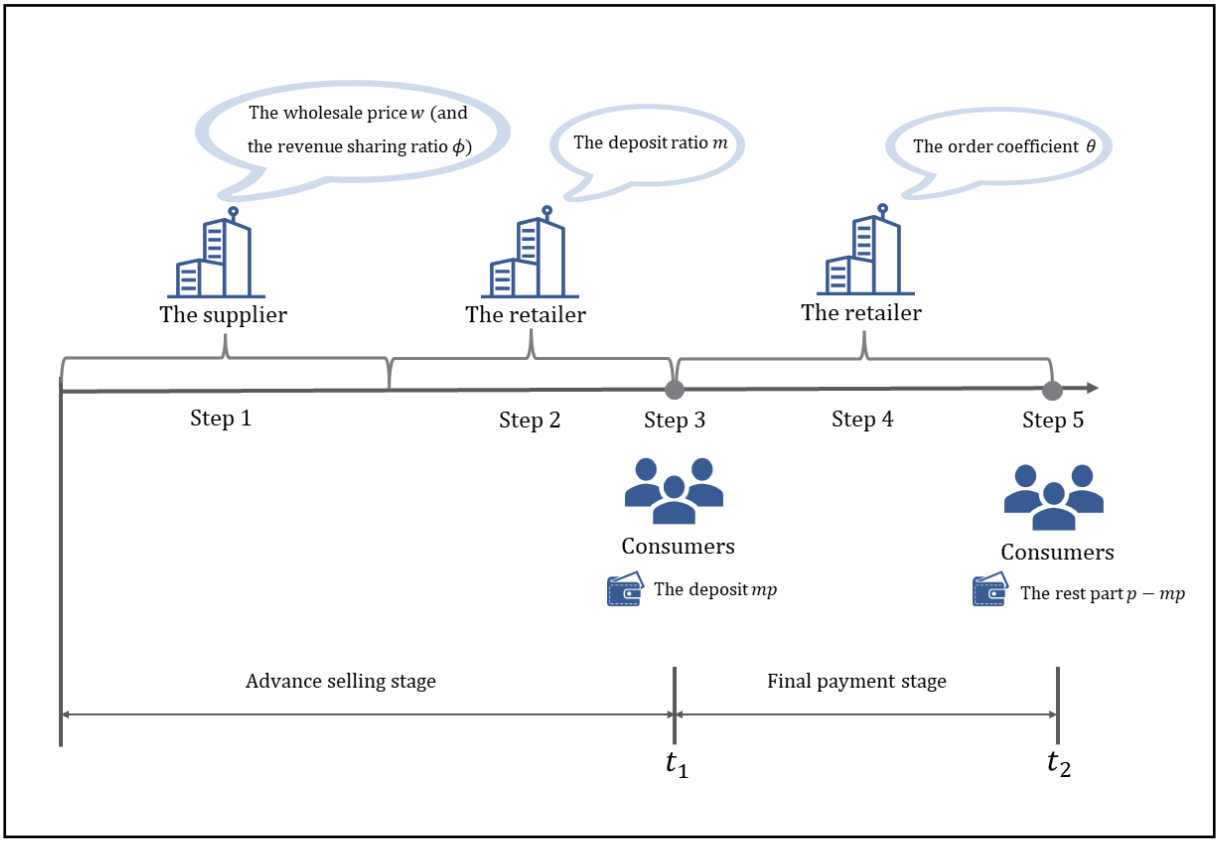
Graphical abstract



The structure of the paper containing the supply chain members' decision sequence.

Public summary

- This paper extends the impact of consumer mental accounting on demand to the decisions of a supplier and a retailer, and applies it to wholesale price contracts and revenue sharing contracts.
- This paper divides mental accounting by time dimension and portrays the role of mental accounting on consumers' perception of product valuation and product price by two time coefficients.
- This paper reveals the impact of mental accounting on consumers' perception and purchase decisions, and draws some counterintuitive conclusions.

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Abstract: Advance selling activities based on e-commerce platforms have received much attention from consumers, which is a two-stage sales mode. However, many consumers have indicated that they are relatively happy to pay a deposit and feel more burdened at the final payment stage. That is, consumers feel differently at the two moments even though they know they will pay the same total amount for the product. This psychological behavior can be explained by mental accounting, which means the cognitive-computational process by which individuals or households code, evaluate, and record financial behavior. With the use of advance selling, this research has developed a game theoretical model to investigate how consumers' mental accounting affects the optimal pricing and ordering decisions of supply chain members under wholesale price and revenue sharing contracts. The analysis shows that under wholesale price contracts, regardless of the optimal wholesale price set by the supplier, a portion of consumers will forgo the deposit paid, and the optimal order quantity for the retailer will always be equal to the consumers' demand at the final payment stage. In exceptional cases, the optimal wholesale price may be equivalent to the retail price. The supplier's optimal wholesale price increases monotonically with the consumer's time coefficient for the price and decreases monotonically with the consumer's time coefficient for product valuation. Furthermore, under a revenue sharing contract, there is a situation where the supplier's optimal wholesale price is equal to cost. Additionally, a supplier's optimal wholesale price exists such that none of the consumers will forgo the deposit they have paid. The study contributes to the understanding of mental accounting in advance selling and has implications for supply chain contract design.

Keywords: mental accounting; advance selling; wholesale price contract; revenue sharing contract

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1 Introduction

Due to the improvement of the economy and the construction and development of information networks, the material needs of consumers have gradually expanded, while competition among suppliers and retailers has intensified. This phenomenon has brought about a wide range of channels, forms, and categories of merchandising activities. One of these activities is the sale of goods through e-commerce platforms. In addition, to promote consumers' consumption enthusiasm to a greater extent, thereby increasing sales and profits, suppliers and retailers use a variety of promotional tools, such as the establishment of additional shopping festivals, advance selling, discounts, and full reductions. Among them, suppliers and retailers rely on e-commerce platforms for advance selling promotions, such as "Double 11", "618", and other shopping festivals, which have received widespread attention from consumers. In advance selling, the retailer posts basic information about the product on the e-commerce platform, as well as the deposit and the rest due at the advance selling and the final payment stages, respectively, while the consumer pays at the corresponding advance selling and the final payment stages to complete the purchase of the goods.

However, there are discussions on social media regarding advance selling that deserve attention and research. Many consumers have shown that they are relatively happy when they pay a deposit and that the act of paying a deposit brings a greater sense of satisfaction. At the final payment stage, they feel more regret and a sense of burden brought by the rest part than the ease and pleasure of the deposit. That is, consumers feel differently at the two moments when they know they will pay the same total amount for the product. For a consumer, the purchase of a product is only complete when he or she has completed two steps of payment. These two steps are separated in time, and although the consumer knows that the money he or she has to pay is the total price of the product, his or her perception of the same total price is different at the deposit stage and at the final payment stage, which may lead to different purchase decisions. That is, consumers may forgo paying the rest part and terminate the transaction at the final payment stage. For suppliers and retailers, exploring the reasons why consumers' purchase intentions differ at different moments and exploring the subsequent impact can help them grasp the changes in demand at the deposit stage and the final

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payment stage early enough to make targeted pricing or ordering decisions. In addition, the impact of the time factor can be addressed from a supply chain optimization perspective by considering different supply chain contracts. This paper introduces the concept of mental accounting to study this topic in depth. Thaler[1], in conjunction with previous studies, defined mental accounting as the cognitive-computational process by which individuals or households code, evaluate, and record financial behavior. In essence, mental accounting is the mental process of categorizing, coding, and valuing outcomes (especially monetary outcomes). In this paper, consumers' mental accounting is divided by time dimensions to explain the different perceptions of the same amount of money at different moments. At the time of paying a deposit, the deposit paid, the rest part to be made, and the expected value of the product is valued in one set of accounts; while at the final payment stage, the rest part paid, the deposit paid, and the expected value of the product is valued in another set of accounts, i.e., consumers' perceived value of the same amount is different under different accounts depending on the timing.

Based on advance selling and the behavioral concept of mental accounting, the main research question is to consider consumers' mental accounting in advance selling based on wholesale price contracts and revenue sharing contracts and to investigate how it affects consumers' purchasing decisions, which in turn affects wholesale pricing decisions and retailers' pricing and ordering decisions. The study derives the following important conclusions. In the context of advance selling and the wholesale price contract, regardless of the optimal wholesale price set by the supplier, a portion of the consumers will forgo the deposit paid, and the optimal order quantity for the retailer is always equal to the demand of the consumers at the final payment stage. In exceptional cases, the optimal wholesale price is equal to the retail price. The supplier's optimal wholesale price increases monotonically with the consumer's time coefficient for price and decreases monotonically with the consumer's time coefficient for product valuation. Under the revenue sharing contract, there exists a situation where the supplier's optimal wholesale price is equal to the cost. In addition, a supplier's optimal wholesale price exists such that none of the consumers will give up the deposit they have paid.

The rest of the paper is organized as follows. In Section 2, a review of the literature on mental accounting and advance selling is presented. In Section 3, the paper introduces the basic assumptions and constructs a pricing and ordering model that considers consumers' mental accounting and discusses the important findings of the base model. In Section 4, the paper expands on the context of revenue sharing contracts and explores how mental accounting affects consumers' purchase decisions. In Section5 this paper concludes with a summary and points out several future avenues. All proofs of the propositions can be found in Appendix.

2 Literature review

Many scholars have researched how to classify mental accounting. Early studies mostly classified mental accounting by consumption categories or income categories. For example, Kivetz[2] classified mental accounting into fixed income and windfall according to their sources. Henderson and Peterson[3] classified wealth into seven categories of mental accounting, including gifts, accidental gains, lottery tickets, work bonuses, money owed for restitution, sales of audio, and inheritance. Thaler[1] argued that mental accounting can be divided into two accounts depending on consumption expenditures. Erat et al.[4] investigated the role of mental accounting by dividing the value of products into two accounts with the value of their add-ons.

As research continues, scholars have broadened the dimensions of mental accounting classification. Some scholars classify mental accounting in terms of the time dimension. Prelec and Loewenstein[5] argued that consumers' perceptions of money change over time. Gourville et al.[6] proposed that individuals psychologically track the costs and benefits of consumer transactions to reconcile them when the transaction is completed. In transactions where costs are higher than benefits, this may lead to systematic and economically irrational concerns about sunk costs. It instead predicts that in economic transactions where costs are significantly higher than benefits, consumers will gradually adapt to historical costs over time, thereby reducing the impact of their sunk costs on pending welfare consumption, and refers to this gradual adaptation to costs as payment devaluation. The results of Chen et al.[7] also suggested that consumers' utility differs across payment moments. Quispe-Torreblanca et al.[8] confirmed that when consumers pay off their credit cards, their expenditures on instantaneous forms of consumption are paid off more quickly than their expenditures on consumer durables because the pain of payment can only be offset by the expected future pleasure of consumption when the money is spent on consumption that lasts for some time. Dai et al.[9] argued that temporal milestones such as New Year's wishes and New Year's resolutions divide the passage of time, creating many new mental accounting periods each year.

Many other scholars have explored the direct impact of mental accounting on consumers. Ülkü et al.[10] found that mental accounting for sunk costs drives waiting time to influence consumers' subsequent purchase decisions and that larger purchases allow customers to offset the pain of long waiting times. Kaveh and Nazari[11] suggested that, influenced by mental accounting, customers' participation in promotions directly influences their purchase intention.

Some scholars have investigated the application of mental accounting in operations research. Ho et al.[12] developed a behavioral model for mental accounting for sunk costs and concluded that the decay rate increases with sunk costs when usage is higher than a reasonable value. Ho and Zhang[13] developed two mental accounts, a fixed-cost account for revenue and a sales profit account, to explore fixed-cost contract-related decisions. Becker-Peth et al.[14] found that more than half of the subjects in the experiment formed different mental accounts, including gross profit, excess cost, etc. Davis et al.[15] showed that mental accounting predicts supply chain coordination more accurately than other models while using segmented linear value functions for calculations. Schultz et al.[16] investigated the framing effect of mental accounting in a newsboy model. Gu et al.[17] added mental accounting to the

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value function to determine the individual and combined effects of loss aversion, risk aversion, and risk seeking in shaping newspaper supplier ordering behavior, thus explaining the decision bias and ordering behavior observed in the newsboy experiment.

In addition to the key concept of mental accounting, the sales mode of advance selling is the main scenario applied in this paper. Most scholars explore the application of advance selling in the context of various consumer behavior factors. Shugan and Xie[18] explored the impact of competition driven by consumer uncertainty about the future state of consumption (rather than price discrimination) on advance selling and concluded that advance selling can be an effective marketing tool in a competitive environment, reducing competition and increasing buyer surplus. Nasiry and Popescu[19] investigated the effect of the behavioral factor of consumers' expected regret on whether firms presell. The results suggest that firms should not adopt advance selling when consumers' expected regret exceeds a certain threshold. Yu et al.[20], on the other hand, investigated how the optimal strategy and benefits of advance selling depend on the interdependence of consumer valuation, capacity levels, and other market parameters. Ma et al.[21] investigated whether manufacturers should implement an advance selling strategy, considering their market power and the risk aversion of consumers. Peng et al.[22] studied the price guarantee policy of sellers who practice advance selling when consumers engage in social learning behaviors. Zhang et al.[23] proposed a pricing strategy in advance selling for a supply chain consisting of a manufacturer and an e-tailer under a resale contract or an agency contract, considering the possible influence of consumer loss aversion.

Some scholars have discussed the factors that influence the advance selling strategy. Prasad et al.[24] showed that advance selling strategies are not always optimal and depend on market parameters (e.g., market potential and uncertainty) and consumers-related factors (e.g., valuation, risk aversion, and heterogeneity). Wu et al.[25] suggested that the optimal strategy for advance selling depends on the proportion of consumers likely to buy in advance and the size of the discount required to make them buy in advance. Zhang et al.[26] investigated the impact of partial refunds as a strategic price commitment device in advance selling in the service industry. Xie et al.[27] discussed boundary conditions on whether retailers should sell in advance. Zhang et al.[28] found that whether advance selling is an appropriate option for retailers depends on associated costs, such as losses due to return costs for retailers and consumers and the cost of the hassle for consumers to resolve uncertain values.

At present, the research subjects of mental accounting are mostly consumer groups, and the topics of scholars from an operational perspective are mostly focused on the classification and calculation laws of mental accounting. The advance selling model is more often considered as a scenario for research in conjunction with the optimal decision-making of suppliers and retailers. Relatively few studies have been conducted to investigate how mental accounting affects supply chain production and operation decisions in the context of advance selling.

3 Model notation and assumptions

Under advance selling, this paper studies a supply chain consisting of a supplier and a retailer and a group of consumers who are influenced by behavioral factors of mental accounting in decision-making. With advance selling, consumers prepay a deposit upfront and pay the rest part at the final payment stage. The supply chain members' decision-making sequence is shown in Fig. 1.

First, the supplier decides the wholesale price w. The retailer then makes a pricing strategy and sets a deposit ratio m. The consumer decides whether to pay the deposit at moment t_1 based on the deposit and the rest part. The retailer makes the ordering decision based on the deposit payment at moment t_1 and decides on the order coefficient θ. Finally, the consumer decides at moment t_2 whether to pay the rest part. If the consumer completes the payment of the deposit and the rest part, the consumer will subsequently receive the product, and the transaction will be completed. If the consumer pays the deposit but forgoes the rest part, the transaction is terminated, and the deposit paid is not refunded.

The following assumptions are made to better characterize consumer behavior and the decisions of the retailer and the supplier.

(Ⅰ) The full price of product p has been determined by the market in advance. For simplicity, $p \in [0,1]$. Then, the wholesale price w and the cost c satisfy $0 < c < w < p \leqslant 1$.

(Ⅱ) The consumer's valuation of a product with retail price p is v, $v \in [0,1]$.

(Ⅲ) There is an out-of-stock situation, and the probability is f. If there is an out-of-stock situation, the retailer is required to provide a certain amount of compensation s to the consumers.

(Ⅳ) The time factor influences consumers' perceptions of product valuation and product price. Let α be the consumer's time coefficient for the product valuation. Let β be the consumer's time coefficient for the product price, $0 < \beta < \alpha < 1$ (see Appendix for the proof).

The main variables and parameters are shown in Table 1.

3.1 Consumer utility

Since consumers perceive the value and price of products differently at different times and their decisions are influenced by the behavioral factor of mental accounting, this paper refers to Chen et al.[7] to divide consumers' mental accounting by the dimension of time. At moment t_1 of the payment of the deposit, the consumer's utility is shown below.

$$E_{c1} = \alpha v - mp - \beta(p - mp - fs). \tag{1}$$

In Eq. (1), α represents the consumer's time coefficient for product valuation. Referring to the concept of the pain blunting coefficient proposed by Prelec and Loewenstein[5], let β represent the consumer's time coefficient for product price, $0 < \beta < \alpha < 1$. mp denotes the deposit, while $p - mp$ represents the rest part that the consumer needs to pay at the final payment stage. Due to the existence of mental accounting, consumers' perceptions of valuation and price at nondecision moments may deviate over time. Therefore, consumers at moment t_1 need to multiply the time coefficients α and β when

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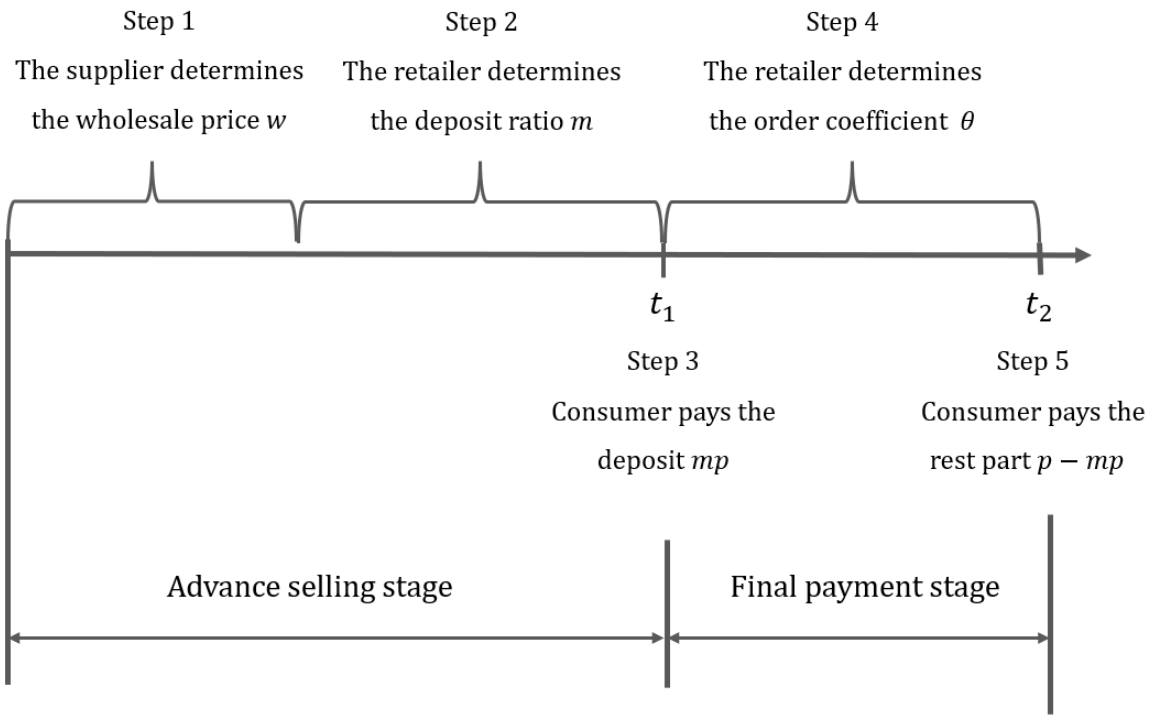

Fig. 1. Supply chain members' decision sequence under the wholesale price contract.

Table 1. The main variables and parameters.

Notations	Definition
v	The consumers' valuation of the product, $v \in [0,1]$
p	The full price of the product, $0 < c < w < p \leqslant 1$
m	The ratio of deposit to full price for the product, $m \in [0,1]$
f	Probability of out of stock, $f \in [0,1]$
s	Compensation of out of stock, $s \in [0,p]$
t_1	The moment when the consumer decides whether to pay the deposit or not
t_2	The moment when the consumer decides whether to pay the rest part or not
d_1	Probability of consumers paying the deposit, i.e., consumers' demand at moment t_1, $0 < d_2 \leqslant d_1 < 1$
d_2	Probability of consumers paying the rest part, i.e., consumers' demand at moment t_2, $0 < d_2 \leqslant d_1 < 1$
α	Consumers' time coefficient for product valuation, $0 < \beta < \alpha < 1$
β	Consumers' time coefficient for product price, $0 < \beta < \alpha < 1$
θ	Retailer's order coefficient, $\theta \in [0,1]$
w	Wholesale price set by the supplier, $0 < w < p \leqslant 1$
c	Product cost for the supplier, $c < w < p \leqslant 1$
E_c	Consumers' utility
E_r	Retailer's utility
E_w	Supplier's utility

considering the product valuation v and price $p-mp-fs$ at moment t_2.

When $E_{c1} = \alpha v - mp - \beta(p-mp-fs) > 0$, i.e., $v > \dfrac{mp+\beta(p-mp-fs)}{\alpha}$, the consumer pays the deposit. Since $v \in [0,1]$, the probability of a consumer paying a deposit (the demand of the consumer at moment t_1) is d_1, where $d_1 = 1 - \dfrac{mp+\beta(p-mp-fs)}{\alpha}$. Considering the realistic meaning represented by d_1, this paper imposes the constraint that d_1 as $0 < d_1 < 1$.

Similarly, the utility of the consumer when paying the rest part at moment t_2 is shown below.

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$$E_{c2} = v - \beta mp - (p - mp - fs). \quad (2)$$

The probability of a consumer paying the rest part, i.e., the demand of the consumer at moment t_2, is as follows.

$$d_2 = 1 - \beta mp - (p - mp - fs). \quad (3)$$

Since only those consumers who pay the deposit are likely to pay the rest part, $0 < d_2 \leqslant d_1 < 1$.

3.2 Retailer utility and supplier utility

Before moment t_1, the retailer only considers the deposit paid by consumers. At moment t_1, the retailer's utility is

$$E_{r1} = mpd_1. \quad (4)$$

Before the final payment stage t_2, the retailer will make an order decision based on consumers' demand d_1, which is represented by θd_1, where θ is the retailer's order coefficient. The quantity ordered by the retailer, θd_1 is determined by both the probability of the consumer paying a deposit d_1 and the retailer's order coefficient θ. Therefore, at moment t_2, the retailer's utility function is as follows.

$$E_{r2} = -w\theta d_1 + (1-m)p\mathrm{Min}\{d_2, \theta d_1\} - \mathrm{Max}\{d_2 - \theta d_1, 0\}s. \quad (5)$$

In Eq. (5), $-w\theta d_1$ represents the cost that the retailer pays when ordering from the supplier. $(1-m)p\mathrm{Min}\{d_2, \theta d_1\}$ represents the retailer's revenue from the consumer paying the rest part at moment t_2. If the consumer's demand d_2 is smaller than the retailer's order quantity θd_1, the actual sales quantity that generates revenue is d_2. If the retailer's order quantity is smaller than the consumer's demand at moment t_2, it is in a shortage situation, and the actual sales quantity is θd_1. $\mathrm{Max}\{d_2 - \theta d_1, 0\}s$ represents the possible out-of-stock compensation.

By combining the retailer's utility at the advance selling stage and the final payment stage, i.e., Eqs. (4) and (5), we can obtain the retailer's total utility function E_r as

$$E_r = mpd_1 - w\theta d_1 + (1-m)p\mathrm{Min}\{d_2, \theta d_1\} - \mathrm{Max}\{d_2 - \theta d_1, 0\}s. \quad (6)$$

Supplier's utility function is

$$E_w = (w - c)\theta d_1. \quad (7)$$

In this paper, we use backward induction to solve the game. First, we find the retailer's optimal order coefficient θ and the optimal ratio of deposit to full price for product m. Subsequently, we solve for the optimal wholesale price w for the supplier. For simplicity of expression, let $w_0 = p + s - \frac{1}{1+\alpha}\frac{\alpha-\beta}{1-\beta}(p - fs)$, $w_1 = p + (1+\alpha)s - \frac{\alpha-\beta}{1-\beta}(p - fs)$, and $w_2 = p + c - \frac{p - fs}{\alpha} + \frac{1+\alpha}{\alpha(1-\beta)}$.

Proposition 3.1. When $0 < p < w_0 < w_1$ and $c < \frac{p - fs}{\alpha} - \frac{1+\alpha}{\alpha(1-\beta)}$, or when $0 < w < w_1 < p$ and $0 < w_2 < w_1$, the supplier's optimal wholesale price $w^* = w_2$. The optimal ratio of deposit to full payment for the product is

$$m^* = \frac{1 + \alpha + c\alpha - p(1 + \alpha - 2\beta) + fs(1 + \alpha - 2\beta) - c\alpha\beta}{p(1+\alpha)(-1+\beta)}.$$

The retailer's optimal order coefficient is

$$\theta^* = \frac{\alpha(c\alpha(-1+\beta) - 2(p - fs)\beta)}{1 + \alpha(2 + c + \alpha - c\beta) - p(1 + \alpha + (-1+\alpha)\beta) + fs(1 + \alpha + (-1+\alpha)\beta)}.$$

Optimal utility for retailer is

$$E_r = -\frac{(-1 + p - fs)(1 + fs + \alpha + c\alpha + p(-1+\beta) - (fs + c\alpha)\beta)}{\alpha(-1+\beta)}.$$

Optimal utility for supplier is

$$E_w = \frac{c(-1 - \alpha + fs(-1+\beta) + p(-1+\alpha)(-1+\beta))}{1+\alpha}.$$

Proposition 3.1 gives the optimal wholesale price for the supplier and the corresponding maximum profit from the advance selling model. At the same time, the retailer can set the optimal deposit percentage and order coefficient to maximize its profit. Before the start of advance selling, the supplier calculates the optimal wholesale price for a given product by working backward from the deposit, the rest part, and the order quantity set by the retailer and the consumer's payment and purchase decision under the influence of mental accounting, combined with production costs and other factors. The retailer then makes a two-step pricing decision based on the supplier's wholesale price and the subsequent payment and purchase decisions of the consumer under the influence of mental accounting and then makes the pricing decision at the time of paying the deposit, i.e., the order decision before the final payment stage, to reverse the optimal deposit ratio and the order coefficient.

This scenario can be used to explain most of the advance selling promotions in domestic and international shopping festivals. In this scenario, from the supplier's point of view, the supplier's profit comes from the difference between the wholesale price and the retail price of the goods sold, and the supplier's decision is a pricing decision about the wholesale price. From the retailer's point of view, the retailer's profit comes from two parts: the difference between the wholesale price and the retail price of the goods sold and the amount of the fixed price of the goods not sold (i.e., the part of the goods for which the consumer pays a deposit and then forgoes the transaction). From the consumer's point of view, the consumer needs to make a two-step purchase decision: whether to pay a deposit or not and whether to pay the remaining part after paying the deposit. The purchase decision is influenced by the interaction of the past cost, the current cost, and the future benefit.

This reveals that retailers and suppliers should consciously consider the impact of mental accounting when dealing with consumers to make optimal pricing and ordering decisions.

Regarding the payment decision of consumers and the optimal order quantity of retailers, the following conclusions are obtained in this paper.

Proposition 3.2. Regardless of the optimal wholesale price set by the supplier, a portion of consumers will forgo the deposit paid, and the optimal order quantity of the retailer is always equal to the demand of the consumer at the final payment stage.

The consumer's utility at the time of paying the deposit is

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affected by three components: the deposit p_1 paid under the consumer's account at the moment of paying the deposit, the remaining part $p-mp-fs$ to be paid in the future, and the expected product value v. Since the rest part $p-mp-fs$ to be paid in the future and the expected product value v does not occur immediately in the present moment, mental accounting is subject to a temporal discount for the consumer's perception. Since these two components are the gain and the cost, respectively, which are different in nature, they are distinguished by the time coefficient α of the consumer's valuation of the product and the time coefficient β of the consumer's valuation for the price. Therefore, the consumer's utility at the time of paying the deposit consists of three components and satisfies $E_{c1}=\alpha v-mp-\beta(p-mp-fs)>0$.

At the final payment stage, the same reasoning leads to the fact that the consumer's utility also consists of three parts: the rest part to be paid under the account at this moment, the deposit paid in the past, and the expected value of the product corresponding to the benefit obtained. However, due to the relative magnitude of α and β, the utility of some consumers in paying the rest part satisfies $E_{c2}=v-\beta mp-(p-mp-fs)<0$. The utility of paying the rest part is negative, that is, the loss of the deposit paid in the past and the loss of the rest part to be paid in the account at this moment is greater than the expected gain in the value of the product. The study by Gourville et al.[6] confirmed this phenomenon in another context: In transactions where costs exceed benefits, consumers may have systematic and economically irrational concerns about sunk costs. Over time, consumers will gradually adapt to historical costs, thus reducing the impact of their sunk costs on pending welfare consumption. This gradual adjustment to costs is called payment devaluation. Since the retailer can anticipate the presence of this segment of consumers, its optimal order quantity is the consumer's demand at the final payment stage, and the retailer avoids the backlog of goods caused by inflated orders.

Thus, when making ordering decisions, retailers should pay attention to the deviation of consumers' perceptions of valuation and price at different times and thus consider that some consumers are likely to forego the final payment to avoid overordering.

Based on the above analysis, we can derive the optimal wholesale price and the retailer's profit as follows.

Proposition 3.3. The retailer's profit comes from two sources: the deposit paid by some consumers and the profit from the difference between the retail price and the wholesale price. When $0<p<w_0<w_1$ and $c>\dfrac{p-fs}{\alpha}-\dfrac{1+\alpha}{\alpha(1-\beta)}$, the optimal wholesale price set by the supplier is equal to the retail price, and the retailer's profit is all derived from the deposit given up by the consumer.

When the consumer's β coefficient is larger, it is closer to the general sales model without considering mental accounting. At this point, some consumers will pay more attention to the influence of the deposit paid in the past, so that the utility at the final payment stage satisfies $E_{c2}=v-\beta mp-(p-mp-fs)<0$. In this case, the utility at the final payment stage is negative, i.e., the deposit paid in the past, and the remaining part required is now greater than the expected value of the product. The deposit is a sunk cost for this part of the consumer, so they will give up the transaction. At this point, the unreturned deposit paid by the consumer will constitute a source of income for the retailer. In contrast, when β is smaller, it deviates more from the general sales model without considering mental accounting. At this point, some consumers will be more unconcerned about the impact of past deposits paid, and their utility at the final payment stage satisfies $E_{c2}=v-\beta mp-(p-mp-fs)>0$. In this case, the utility at the final payment stage is positive, and the consumer will pay the remaining part to complete the purchase. Therefore, the retailer's profit comes from the deposit paid by some consumers and the difference between the retail price and the wholesale price.

However, when $0<p<w_0<w_1$ and $c>\dfrac{p-fs}{\alpha}-\dfrac{1+\alpha}{\alpha(1-\beta)}$, the optimal wholesale price set by the supplier is equal to the retail price, and in this case, all the profits from the difference between the retail price and the production cost are captured by the supplier. In this case, the retailer's role in the supply chain is only to provide an advance selling mode, so there is no profit from the difference between the retail price and the wholesale price. However, the retailer still makes a profit at this point, and the retailer's profit is derived entirely from the deposit forgone by the consumer.

For the supplier, if the retailer has other sources of profit (in this case, deposit revenue), it can earn profit by setting a higher wholesale price. For the retailer, if the supplier sets a higher wholesale price, the retailer earns less profit from the difference between the retail price and the wholesale price, but it can earn revenue from other sources.

By collating the above propositions, this paper concludes how mental accounting influences decisions of a retailer and a supplier .

Proposition 3.4. The optimal wholesale price increases monotonically with the consumers' time coefficient for the price (β) and decreases monotonically with the consumers' time coefficient for product valuation (α).

When the time coefficient β is larger, it can be regarded as having less influence on the mental accounting factor in the advance selling scenario, and it is closer to the general sales model without considering mental accounting. At this point, the more consumers are concerned about the price paid at the nonpresent point in time, i.e., the cost paid in the past can influence the purchase decision in the present to a greater extent. Meanwhile, the optimal wholesale price w is higher. From the retailer's perspective, it is reasonable that the time factor β and the optimal wholesale price w have the same direction of change. A higher time coefficient β implies that consumers are more concerned about the price they pay at the nonpresent point in time; a higher wholesale price w implies that the retailer makes less profit from the difference between the retail and wholesale prices. In response, the retailer will try to increase the deposit ratio as much as possible so that consumers cannot ignore the deposit already paid upfront when paying the rest part to reduce the number of consumers who forego paying the rest part. The fewer consumers forgo paying the rest part, the more profit the retailer can make

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from the difference between the retail price and the wholesale price. This phenomenon can also explain the sunk cost effect on individual consumption decisions. That is, the larger the time coefficient β is, the more consumers are concerned about the price that is not happening in the present moment, which means that they are more sensitive to sunk costs, and the same unit of the sunk cost will bring more utility loss to consumers.

When the time factor α is smaller, the influence of mental accounting in the advance selling scenario is greater. At this point, the less the consumer is concerned about the nonpresent point-in-time utility, the higher the optimal wholesale price w of the supplier. Similarly, from the retailer's perspective, it makes sense that the time coefficient α and the optimal wholesale price w have opposite directions of movement. A smaller time coefficient α implies that consumers are less concerned about the nonpresent point-in-time benefit. In contrast, the other part of the consumer's utility component, the price paid at the nonpresent point in time, has a greater influence on the consumer's decision. In this case, a smaller time coefficient α is similar to the case of a larger time coefficient β discussed above.

Thus, when setting wholesale prices, suppliers should pay due attention to the characteristics of their target consumer groups about the time factor to develop targeted sales strategies.

4 Revenue sharing contract

This section studies the case when the revenue sharing contract is adopted in advance selling. The point of the revenue sharing contract in this model is that the supplier and the retailer are more integrated. The supplier sells the product to the retailer at a lower wholesale price, and when the product is sold to consumers, the profits are then divided between the retailer and the supplier according to a percentage they negotiated. The decision-making sequence for the supply chain members is shown in Fig. 2.

The difference in this model when using the revenue sharing contract is that the supplier first decides on the wholesale price w and the revenue sharing ratio of the retailer, ϕ, where $\phi \in [0,1]$. Specifically, the retailer and the supplier split the revenue in the ratio of $\phi : 1-\phi$. The remaining decision steps are the same as for the base model.

Similar to the base model, the probability that the consumer pays the deposit, i.e., the demand of the consumer at moment t_1, is d_1. The probability that the consumer pays the rest part, i.e., the demand of the consumer at moment t_2, is d_2.

The retailer's utility can be expressed as follows.

$$E_{\mathrm{r}} = \phi m p d_1 - w\theta d_1 + \phi(1-m)p\mathrm{Min}\{d_2, \theta d_1\} - \mathrm{Max}\{d_2 - \theta d_1, 0\}s. \tag{8}$$

The supplier's utility is

$$E_{\mathrm{w}} = (1-\phi)mpd_1 + (1-\phi)(1-m)p\mathrm{Min}\{d_2, \theta d_1\} - (c-w)\theta d_1. \tag{9}$$

Like the wholesale price contract model, this section also uses backward induction to draw the following conclusions.

Proposition 4.1. Under the revenue sharing contract, there exists a situation where the supplier's optimal wholesale price equals the cost, making the supplier's profit come entirely from the revenue shared with the retailer.

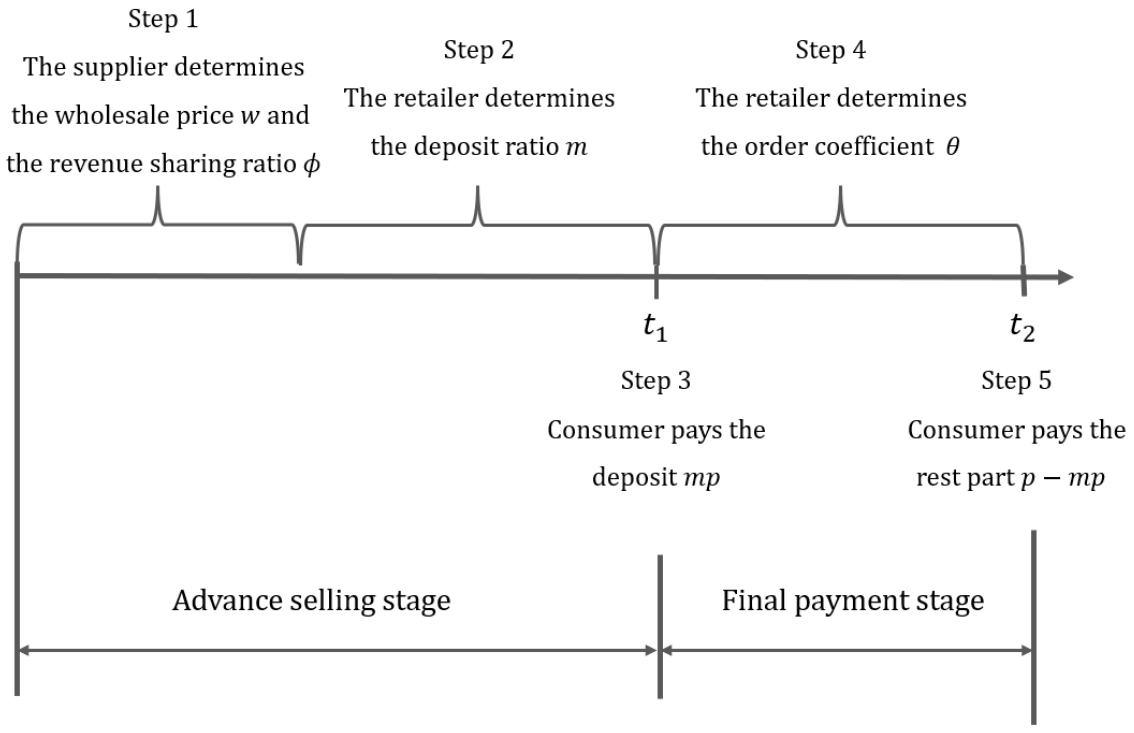

Fig. 2. Supply chain members' decision sequence under the revenue sharing contract.

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As in the base model, in general, the supplier's revenue comes from two sources: the profit from the difference between the wholesale price and the cost of the product and the revenue shared with the retailer. When the supplier's optimal wholesale price is equal to the cost, the profit from the difference between the wholesale price and the cost of the product is zero, and both the supplier and the retailer earn revenue from the deposit and the rest is paid by the consumer. At this time, the supplier and retailer can be seen as a community of interest, in which the supplier is responsible for the production of products, and the retailer is responsible for the sale of products, while no other costs and expenses are incurred from production to sale, and the coordination of the supply chain is achieved to a great extent. The income of both supplier and retailer comes from the profit brought by the deposit, which minimizes the double marginalization of the supply chain, and there is no price difference in the supply chain.

We can find some applications of Proposition 4.1 in practice. Some retailers, in cooperation with suppliers, take advantage of such a mode to avoid the costs of storage and transportation after production and before the sale, as well as the price difference between wholesale and retail prices, to maximize the overall profit of the supply chain.

This has inspired retailers and suppliers to think about earning profits in a new way. For example, when using revenue sharing contracts, even if the supplier is unable to earn a profit from the difference between the retail price and the wholesale price, it can earn a profit from the revenue shared with the retailer.

Next, we would like to derive the consumer's decision and the optimal order quantity under the revenue sharing contract.

Proposition 4.2. Under the revenue sharing contract, there is an optimal wholesale price such that no consumer gives up the deposit paid and the optimal order quantity of the retailer is always equal to the demand of the consumer at the time of paying the deposit.

Unlike Proposition 3.2 in the base model, in this model based on the revenue sharing contract, when the mental accounting coefficient β takes a smaller value, consumers will be more unconcerned about the impact of past deposits paid, such that the utility at the final payment stage satisfies $E_{c2} = v - \beta mp - (p - mp - fs) > 0$. The impact of the deposit paid by the consumer as a sunk cost at the final payment stage can be ignored. The consumer's benefit from purchasing the product is greater than the sum of the deposit paid and the rest part to be paid, so the consumer will not give up the deposit paid and will pay the rest part to complete the transaction. In this case, the consumer's demand d_1 at the first stage of the deposit payment is equal to the consumer's demand d_2 at the second stage of the final payment, which is the retailer's optimal order quantity. Under this condition, there is no out-of-stock loss, and the retailer does not need to pay the cost caused by out-of-stock loss.

This suggests that one of the factors influencing whether to benefit from the deposit forgone by the consumer is the contract used by the retailer and the supplier. Retailers and suppliers should consider supply chain contracts in conjunction with their pricing and ordering decisions to achieve profitability through different strategies.

5 Conclusions

This paper considers the behavioral factor of consumers' mental accounting and explores how it affects suppliers' pricing decisions and retailers' pricing and ordering decisions. At the theoretical level, this study draws some counterintuitive conclusions. At the practical level, this research model is based on a real business situation, which is of great practical significance, and it also enlightens the supply chain members to consider the irrational factors of consumers in their actual business activities and provides them with ideas to make and adjust their production and operations decisions to help them maximize their business benefits.

This paper draws the following important conclusions. On the one hand, under the wholesale price contract, no matter what wholesale price the supplier sets, some consumers will give up their deposits, and the retailer's optimal order quantity is always equal to the consumer's demand at the final payment stage. In this case, the retailer's profit is derived from the deposit forgone by the consumers and the difference between the retail and wholesale prices. In the special case, the supplier sets the optimal wholesale price equal to the retail price, and the retailer's profit comes from the deposit already paid by the consumer. In addition, the supplier's optimal wholesale price increases monotonically with the consumer's time coefficient for price and decreases monotonically with the consumer's time coefficient for product valuation. On the other hand, under the revenue sharing contract, there is a situation where the supplier's optimal wholesale price equals the cost so that the supplier's profit is entirely derived from the revenue shared with the retailer. Besides, the existence of the supplier's optimal wholesale price means that no consumer forgoes the deposit paid, and the retailer's optimal order quantity is always equal to the consumer's demand at the time of the first stage of the deposit.

However, this paper only considers the influence of consumers' mental accounting on the decision-making of supply chain members under the two contracts, i.e., the wholesale price contract and the revenue sharing contract. Future research can be conducted in the following directions. First, mental accounting can be considered under other supply chain contracts, for example, applying the influence of mental accounting to repurchase contracts, quantity flexibility contracts, and so on. Second, the context of dual-channel and multichannel sales can be considered to broaden the application scenarios of mental accounting. Finally, the impact of other behavioral factors, such as cognitive hierarchy models and uncertainty avoidance, on consumer decisions and the ripple effects upstream of the supply chain can be explored.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix

Proof of $\beta < \alpha$. According to the retailer's total utility function $E_r = mpd_1 - w\theta d_1 + (1-m)p\mathrm{Min}\{d_2, \theta d_1\} - \mathrm{Max}\{d_2 - \theta d_1, 0\}s$, when $\alpha \leqslant \beta$, the retailer's optimal solution $m^* = 0$, $\theta^* = 1$, the demand $d_1 = 1 - \dfrac{\beta(p-fs)}{\alpha}$, and the retailer's optimal utility $E_r = (p-w)\left(1 - \dfrac{\beta(p-fs)}{\alpha}\right)$. By the supplier's total utility, the supplier's optimal utility is $E_w = (w-c)\left(1 - \dfrac{\beta(p-fs)}{\alpha}\right)$. Since $d_1 = 1 - \dfrac{\beta(p-fs)}{\alpha} \geqslant 0$, the optimal wholesale price is $w^* = p$, the supplier has no profit and the transaction is not valid, so $\beta < \alpha$.

Proof of Proposition 3.1. When $0 < p < w_0 < w_1$ and $c < \dfrac{p-fs}{\alpha} - \dfrac{1+\alpha}{\alpha(1-\beta)}$, or when $0 < w < w_1 < p$ and $0 < w_2 < w_1$, from the retailer's utility E_r, the retailer's optimal order coefficient $\theta^* = \dfrac{\alpha(c\alpha(-1+\beta) - 2(p-fs)\beta)}{1+\alpha(2+c+\alpha-c\beta) - p(1+\alpha+(-1+\alpha)\beta) + fs(1+\alpha+(-1+\alpha)\beta)}$

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is obtained, the optimal ratio of deposit to full payment for the product $m^* = \frac{1+\alpha+c\alpha-p(1+\alpha-2\beta)+fs(1+\alpha-2\beta)-c\alpha\beta}{p(1+\alpha)(-1+\beta)}$. The retailer's optimal utility $E_r = -\frac{(-1+p-fs)(1+fs+\alpha+c\alpha+p(-1+\beta)-(fs+c\alpha)\beta)}{\alpha(-1+\beta)}$. From the supplier's utility E_w, the optimal wholesale price of the supplier can be obtained as $w^* = w_2$, and the supplier's optimal utility $E_w = \frac{c(-1-\alpha+fs(-1+\beta)+p(-1+\alpha)(-1+\beta))}{1+\alpha}$.

Proof of Proposition 3.2. When $0 < p < w_0 < w_1$ and $c < \frac{p-fs}{\alpha} - \frac{1+\alpha}{\alpha(1-\beta)}$, or when $0 < w < w_1 < p$ and $0 < w_2 < w_1$, from the retailer's utility E_r, the retailer's optimal order coefficient $\theta^* = \frac{1-\{\beta m^*(w)p+[(1-m^*(w))p-fs]\}}{1-\frac{m^*(w)p+\beta[(1-m^*(w))p-fs]}{\alpha}} = \frac{d_2}{d_1}$ is obtained. We can obtain the optimal order quantity $\theta d_1 = d_2$. There is no out of stock and $d_2 < d_1$, so it can be inferred that some consumers have forgone the deposit paid.

Proof of Proposition 3.3. When $0 < p < w_0 < w_1$ and $c > \frac{p-fs}{\alpha} - \frac{1+\alpha}{\alpha(1-\beta)}$, from the retailer's utility E_r, the retailer's optimal order coefficient $\theta^* = \frac{1-\{\beta m^*(w)p+[(1-m^*(w))p-fs]\}}{1-\frac{m^*(w)p+\beta[(1-m^*(w))p-fs]}{\alpha}}$, the optimal ratio of deposit to full payment for the product $m^* = \frac{(\alpha-\beta)(p-fs)}{(1+\alpha)(1-\beta)p}$. From the supplier's utility E_w, the optimal wholesale price for supplier $w^* = p$. From the composition of the retailer's profit, it can be deduced that the retailer's profit comes entirely from the deposit forgone by the consumer.

Proof of Proposition 3.4. When $0 < p < w_0 < w_1$ and $c < \frac{p-fs}{\alpha} - \frac{1+\alpha}{\alpha(1-\beta)}$, or when $0 < w < w_1 < p$ and $0 < w_2 < w_1$, the supplier's optimal wholesale price $w^* = w_2 = p + c - \frac{p-fs}{\alpha} + \frac{1+\alpha}{\alpha(1-\beta)}$, where $\frac{\partial w^*}{\partial \beta} > 0$, $\frac{\partial w^*}{\partial \alpha} < 0$.

Proof of Propositions 4.1. This section is demonstrated by numerical examples. Let $p = \frac{9}{10}$, $s = \frac{1}{100}$, $c = \frac{1}{10}$, $\alpha = \frac{9}{10}$, $\beta = \frac{8}{10}$. From the retailer utility E_r, a set of optimal solutions $\theta^* = 1$, $m^* = \frac{8999}{34200}$ and subsequently $\phi^* = \frac{34}{25}$, $w^* = \frac{1}{10}$, can be found. At this point, the supplier's profit and the retailer's profit are both greater than zero. That is, this situation exists.

Proof of Propositions 4.2. The proof of this proposition is similar to that of Proposition 4.1 and is omitted here.

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