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Abstract

Purpose – The purpose of this paper is to study the advance selling strategies for oligopolists when considering the product diffusion effect.

Design/methodology/approach – The authors consider a market that composes of two competitive sellers who are different in their reputation. The two firms sell the same product in the market over two periods (i.e. the advance selling season and the regular selling season). Due to the effect of product diffusion, the demand of each firm in the regular selling season is dependent on the two firms' advance demands.

Findings – For the firm with lower reputation, it is beneficial to decrease the advance selling price with the diffusion effect caused by its advance demand. For the firm with higher reputation, it is also beneficial to decrease the advance selling price with the diffusion effect caused by its advance demand if the consumers' enthusiasm for the product in regular selling season is high enough; otherwise it should not decrease his advance selling price since this practice cannot greatly increase his demand.

Practical implications – The obtained results can provide operational managers in reality with valuable suggestions in making advance selling decisions.

Originality/value – The paper is among the first to investigate the impact of product diffusion effect on a firm's advance selling strategy in a competitive setting.

Keywords Price competition, Advance selling, Interface on marketing and operations management, Product diffusion

Paper type Research paper

1. Introduction

With the rapid development of network and information technology, advance selling which refers to the practice that a seller accepts customer orders before a product is released has become a common practice in the retail and service industry (Fay and Xie, 2010). For instance, Sprint started taking pre-orders before the actual launch for the Samsung Galaxy Note 4 in the US market on September 26, 2014 (Alan, 2014). By successfully using advance selling, Apple reported that it sold out its inventory for iPad before releasing the product (Berndtson, 2010).

Recent research on advance selling has shown that advance selling can bring many benefits for the seller. For example, the seller can gain more financial capital in advance, reduce inventory and production risk, and use the information obtained through advance selling to improve the demand forecasts in the later periods (Xie and Shugan, 2001; Tang *et al.*, 2004; Shugan and Xie, 2005). Also, the advance selling strategy provides leverage for the seller to charge different prices based on the timing

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of a customer's purchase (Li and Zhang, 2013). Moreover, due to the effect of product diffusion, the advance selling strategy can affect the potential demands in the later periods, and this effect can be either positive or negative (Lim and Tang, 2013).

Product diffusion effect refers to the phenomenon that the later demand is dependent on the early sales (Bass, 1969). This phenomenon does exist when a firm adopts the advance selling strategy for the following reasons. First, due to the development of e-commerce industry, the comments by prior consumers on a product become more public and transparent, which will influence the potential consumers' attitude toward the product (Gu *et al.*, 2012; Berger, 2014). Second, early sales do have the potential of creating awareness of the product (Amini *et al.*, 2012; Ho *et al.*, 2012). For instance, when we scan on Amazon.com and find a product has been extensively pre-ordered, we may have the motivation to buy it as it gives the impression of fashion. Given the existence of the phenomenon in reality, however, the problem of how should a firm in the market determine his advance selling price in the presence of product diffusion effect (i.e. the advance demand has impact on the later demands) has drawn little attention.

This paper investigates the advance selling strategies for oligopolists when considering the effect of product diffusion. As pointed out by Yang *et al.* (2014), when two or more firms sell similar or complementary products, they often utilize advance selling pricing as a strategic tool to compete for customers to achieve the best performance possible. When considering the effect of product diffusion, the advance selling strategy of one firm will affect the other firm's potential customers in the later periods, which will certainly make the advance selling strategy for each seller more complicated but important.

Specifically, we consider a market that composes of two competitive sellers who sell the same product in the market over two periods (i.e. the advance selling season and the regular selling season). The two firms are different in their reputation, thus the consumers' valuations on the products sold by the two firms are also different. Further, due to the effect of product diffusion, the demand of each firm in the regular selling season is dependent on the demands of the two firms in the advance selling season. Through theoretical analyses we have the following observations:

(1) For the firm with lower reputation, it is beneficial to decrease the advance selling price with the effect of product diffusion caused by his advance demand. For the firm with higher reputation, it is also beneficial to decrease the advance selling price with the effect of product diffusion caused by his advance demand if the consumers' enthusiasm for the product in regular selling season is high enough; otherwise the firm should not decrease his advance selling price with the effect of product diffusion since this practice cannot greatly increase his demand in the regular selling season.

(2) When the competition between the two firms is extremely extensive (i.e. the difference between the two firms' reputation is small enough), it is beneficial for the firm with lower reputation to decrease his advance selling price with the consumers' valuation on his product, which is counter-intuitive. This is because that in this case a small increase in the advance selling price may lead to a large decrease in the advance demand, which ultimately reduces his profit.

The rest of the paper is structured as follows. Section 2 provides the literatures related to advance selling under competition and product diffusion. Section 3 introduce and describe the model. Section 4 presents the optimal advance selling strategy when considering the effect of product diffusion. Numerical analysis is presented in Section 5. Section 6 concludes the paper. All proofs are provided in the Appendix.

2. Literature review

With the intensified competition and rapid product replacements, advance selling is increasingly becoming an important tactics to coordinate operation and marketing, and has captured considerable attention from both practitioners and researchers. Some researchers have focussed on a monopolistic firm and show that advance selling can help a firm obtain advance demand information, thus improve the precision of demand forecasts (e.g. Özer, 2003; Tang *et al.*, 2004; Moe and Fader, 2003; Li and Zhang, 2013) and facilitate capacity decisions (e.g. Liu and van Ryzin, 2008; Boyacı and Özer, 2010). Some researchers study the optimal advance selling strategy for a firm with strategic consumers (e.g. Su, 2007; Cachon and Swinney, 2009; Lim and Tang, 2013).

Some researchers have paid attention to the advance selling strategies for oligopolists under various backgrounds. Shugan and Xie (2005) explore the impact of competition on advance selling driven by consumer uncertainty about future consumption states, and find that competition does not diminish the advantage of advance selling. However, Cachon and Feldman (2013) identify two ways in which competition limits the effectiveness of advance selling. They show that with competition the firms may be better off if they sell only in the spot period. Cho and Tang (2013) examine advance selling strategies of a manufacturer who produces and sells a seasonal product to a retailer under uncertain supply and demand. They analyze the impact of supply and demand uncertainties under the strategies and find that both supply and demand uncertainties can be beneficial to the retailer. Ma *et al.* (2015) investigate the value of information updating obtained from the pre-committed order. They find that the firm is able to increase the discount price in the ABD program with information updating.

Capacity control is crucial for firms especially for those in the service industry (Shugan and Xie, 2004). Guo (2009) considers the impact of advance selling in competition with capacity constraints on the profitability and the equilibrium choice of refund policies. They find that partial refunds may endogenously change the nature of strategic interaction between service providers from local monopolies into a competition regime, which moderates the gains from exploiting the efficiency-enhancing effect of partial refunds. Talluri and Martínez-de-Albéniz (2011) study price competition of a homogenous product for an oligopoly in a dynamic setting, where each of the sellers has a fixed capacity. They demonstrate that there is a closed-form solution to the equilibrium price paths for a duopoly with capacity constraints and extend all the results to an n-firm oligopoly. Yu *et al.* (2014) investigate the seller's signaling strategy and find that rationing of capacity in the advance period is an effective tool of signaling product quality. Kuthambalayan *et al.* (2015) analyze the impact of advance selling with limited capacity on a firm's ability to maximize the expected profit. They derive insights into the behavior of the benefits due to advance selling under capacity restrictions.

Since strategic-consumer behavior can lead to severe consequences on the retailers' revenues and profitability (Östermark and Söderlund, 1999), some researchers have also considered the consumer strategic behavior into the competitive firms' advance selling strategy. Levin *et al.* (2009) present a unified stochastic dynamic pricing game of multiple firms where differentiated goods are sold to finite segments of strategic customers who may time their purchases. The key insight is that firms may benefit from limiting the information available to consumers. Liu and Zhang (2013) study dynamic pricing competition between two firms offering vertically differentiated products to strategic consumers. They highlight the asymmetric effect of strategic customer behavior on quality-differentiated firms.

The extant research on advance selling has paid great attention to the optimal advance selling strategies for sellers under various backgrounds (i.e. capacity constraint, strategic consumers). However, except Lim and Tang (2013), the extant research on advance selling has paid little attention to the impact of product diffusion effect on a firm's advance selling strategy. Lim and Tang (2013) focus on the advance selling decision for a monopolistic seller, whereas our paper focusses on the advance selling strategies for competitive sellers in the presence of product diffusion effect. Under competition, the advance selling strategy of one firm may affect the other firm's potential demands, which will certainly make the advance selling strategy for each seller more complicated but important, which is a major reason for our paper.

3. The basic model

Suppose that two firms A and B both sell a kind of product to consumers in the market over two periods. The first period is the advance (selling) period and the second period is the regular (selling) period. The product is assumed to be seasonal, fashion-like and is released at the beginning of the second period. To facilitate the description, some definition of notations are defined in the list below:

Parameters/variables concerning the seller

- c Procurement cost per unit of the product for the seller
- p Unit selling price for the product of firm A sold in the second period
- σp Unit selling price for the product of firm B sold in the second period
- Π_i Expected profit of firm i ($i = A, B$) over the two periods

Parameters/variables concerning consumers and market

- $v_{1,i}$ Consumer's valuation on the product of firm i ($i = A, B$) in the first period
- $v_{2,i}$ Consumer's valuation on the product of firm i ($i = A, B$) in the second period
- $D_{1,i}$ Advance demand for the product of firm i ($i = A, B$) in the first period
- $D_{2,i}$ Regular demand for the product of firm i ($i = A, B$) in the second period
- δ Coefficient of the consumers' enthusiasm for the product in the second period
- β_i Effect of product diffusion caused by firm i ($i = A, B$)'s advance demand

Decision variables

- $p_{1,A}$ Advance selling price for the product of firm A sold in the first period
- $p_{1,B}$ Advance selling price for the product of firm B sold in the first period

The two firms procure the product from the same manufacturer at a unit procurement cost of c, and sell the product at a unit price of $p_{k,i}$ ($k = 1$ or 2; $i =$ A or B) in period k. For simplicity, let $p_{2,A} = p$ and $p_{2,B} = \sigma p$. Suppose that the reputation of firm A is higher than that of firm B, we assume that $0 < \sigma \leqslant 1$. Unsold units at the end of the second period bring no value, and there is no penalty for unsatisfied demand.

Denote by M ($M > 0$) the number of consumers entering the market (i.e. the potential demand) in the advance selling season. Denote by $v_{1,i}$ the valuation of the consumers on the product sold by firm i ($i =$ A or B). Recall that the reputation of firm B is lower than that of firm A, we assume that the valuation of the consumers on the product sold by firm B, $v_{1,B}$, follows $v_{1,B} = \tau v_{1,A}$ with $0 < \tau \leqslant 1$. Considering that the consumers are heterogeneous, we assume that the valuation of the consumers on the product sold by firm A is uniformly distributed on the interval [0, 1], i.e., $v_{1,A} \sim U[0, 1]$.

Suppose that the consumers entering the market in the advance selling season are new technology lovers or loyal fans of the brand, thus they have higher valuation on the product and are willing to pay a premium price for guaranteed early delivery (Li and Zhang, 2013). In this case, a consumer will buy the product in the advance selling season if his surplus is non-negative. That is, $v_{1,i} - p_{1,i} \geqslant 0$ (i = A or B). Further, a consumer will purchase from firm i rather than firm j if $v_{1,i} - p_{1,i} \geqslant v_{1,j} - p_{1,j}$ (i, j = A or B; $i \neq j$). Then the demand of firm i (i = A or B) in the advance selling season (i.e. the advance demand), $D_{1,i}$, follows:

$$D_{1,A} = \begin{cases} M\left(1 - \frac{p_{1,A} - p_{1,B}}{1-\tau}\right) & \text{if} \quad p_{1,B} \leqslant \tau p_{1,A} \\ M(1 - p_{1,A}) & \text{if} \quad p_{1,B} > \tau p_{1,A} \end{cases}, \tag{1}$$

$$D_{1,B} = \begin{cases} M\left(\frac{\tau p_{1,A} - p_{1,B}}{(1-\tau)\tau}\right) & \text{if} \quad p_{1,B} \leqslant \tau p_{1,A} \\ 0 & \text{if} \quad p_{1,B} > \tau p_{1,A} \end{cases}. \tag{2}$$

As shown in Equations (1) and (2), demand of the firm i ($i = A, B$) in the advance selling season depends on both the two firms' pricing decisions. In other words, in order to make the optimal pricing decision, firm i ($i = A, B$) should not only consider its own price, but also the pricing decision of the competitor j ($j = B, A$).

In the regular selling season, the demand of each seller is composed of two parts: the consumers independent of the product diffusion effect; and the consumers triggered by the product diffusion effect. Suppose that there is a number of N ($N > 0$) new consumers independent of the product diffusion effect entering the market. Considering the seasonality in the product or discounting of future consumption, the consumers' enthusiasm for the product is lower than that of the consumers entering the market in the advance selling season (Cachon and Swinney, 2009). Specifically, we assume that the valuations of the consumers for the product in the regular selling season satisfy $v_{2,i} = \delta v_{1,i}$ (i = A or B) with $0 < \delta < 1$. Table I shows the consumers' valuations on the products sold by firms A and B. Similarly, a consumer entering the market in the second period will buy the product if his surplus is non-negative, i.e. $v_{2,i} - p_{2,i} \geqslant 0$ (i = A or B), and will purchase from firm i rather than firm j if $v_{2,i} - p_{2,i} \geqslant v_{2,j} - p_{2,j}$ (i, j = A or B; $i \neq j$).

Following Lim and Tang (2013), we assume that the number of consumers triggered by the product diffusion effect is a function of the total advance demand of the two sellers. Since this part of consumers has enough information on the product, we assume that the triggered consumers are homogeneous and their valuations for the product sold by firms A and B are δ ($\delta > p$) and $\delta\tau$, respectively. Denote by $f(D_1)$ the total

Table I. Characteristics of the consumers' valuations on the product

	Valuation on the product sold by firm A	Valuation on the product sold by firm B
Period 1	$v_{1,A} \sim U(0, 1)$	$v_{1,B} \sim U(0, \tau)$
Period 2	$v_{2,A} \sim U(0, \delta)$	$v_{2,B} \sim U(0, \delta\tau)$

consumers of the two sellers triggered by the effect of product diffusion, and R_i the fraction of the consumers triggered by the effect of product diffusion choosing to purchase from firm i ($i=$ A or B). Hence the demand of firm i in the regular selling season (i.e. the regular demand), $D_{2,i}$, follows:

$$D_{2,A} = N\left(1-\frac{(1-\sigma)p}{(1-\tau)\delta}\right)+R_A f(D_1), \tag{3}$$

$$D_{2,B} = \frac{Np(\tau-\sigma)}{\delta(1-\tau)\tau}+R_B f(D_1). \tag{4}$$

In Equations (3) and (4), the terms $N(1-((1-\sigma)p)/((1-\tau)\delta))$ and $(Np(\tau-\sigma))/(\delta(1-\tau)\tau)$ are the demand independent of the product diffusion effect.

Suppose that each firm makes his decision at the beginning of the advance selling season with the objective to maximize their total profits of the two periods. Specifically, at the beginning of the advance selling season, each firm decides his advance selling price p_{1i} ($i=A, B$) based on his demand and the other firm's pricing decision. Following Prasad *et al.* (2011) and Li *et al.* (2014) we assume that the regular selling prices of the two firms are determined by the market (i.e. exogenous) since the information in the regular selling season is more transparent.

4. Optimal advance selling decisions for the oligopolists

In this section, we explore the optimal advance selling decisions for the oligopolists when considering the product diffusion effect. As a benchmark, we first examine the optimal advance selling decisions for the sellers when not considering the product diffusion effect.

4.1 Benchmark: optimal decisions without considering product diffusion

For the benchmark case, firm i ($i=A, B$) makes his pricing decision in the advance selling season without considering the impact of advance selling on the behavior of the consumers in the regular period, i.e., $f(D_1)=0$. In this case, both the two firms make their pricing decisions to maximize their profits in the advance selling season. Given that firm B charges an advance selling price $p_{1,B}$, then the optimization problem for firm A can be computed as:

$$\max\ \pi_{1,A} = \begin{cases} M\left[1-\frac{p_{1,A}-p_{1,B}}{1-\tau}\right](p_{1,A}-c) & \text{if} \quad p_{1,B} \leqslant \tau p_{1,A} \\ M(1-p_{1,A})(p_{1,A}-c) & \text{if} \quad p_{1,B} > \tau p_{1,A} \end{cases} \tag{5}$$

Similarly, the optimization problem for firm B can be computed as:

$$\max\ \pi_{1,B} = \begin{cases} M\left[\frac{\tau p_{1,A}-p_{1,B}}{(1-\tau)\tau}\right](p_{1,B}-c) & \text{if} \quad p_{1,B} \leqslant \tau p_{1,A} \\ 0 & \text{if} \quad p_{1,B} > \tau p_{1,A} \end{cases} \tag{6}$$

Based on the optimization problems (5) and (6) we have the following result:

Theorem 1. When $2c \leqslant \tau < 1$, there is a unique equilibrium in the advance selling prices $(p^*_{1,A}, p^*_{1,B})$, with $p^*_{1,A}$ and $p^*_{1,B}$ satisfying:

$$p^*_{1,A} = \frac{3c+2-2\tau}{4-\tau}, \tag{7}$$

$$p^*_{1,B} = \frac{(3c+2-2\tau)\tau}{2(4-\tau)} + \frac{c}{2}. \quad (8)$$

Theorem 1 shows that the difference between the optimal advance selling prices of the two firms is only caused by the consumers' valuations on the product sold by the two firms.

Based on Theorem 1, we can have the following observations:

Corollary 1. In the benchmark case, firm A's optimal advance selling price $p_{1,A}{}^*$ is non-increasing in τ; firm B's optimal advance selling price $p_{1,B}{}^*$ is increasing (or independent on) in τ if $2c < \tau \leqslant \tau_0$, and is decreasing in τ if $\tau_0 < \tau < 1$with $\tau_0 = 4-\sqrt{12-6c}$.

Corollary 1 shows the impact of the valuation for firm B's product on the two competing firms' pricing decision. We can observe that the optimal advance selling price of firm A is decreasing in the value of τ. The observation is understandable since a lower advance selling price can lead a larger utility for firm A's product, which will further bring a larger demand for firm A in the advance selling season.

When $2c < \tau \leqslant \tau_0$, the optimal price of firm B is increasing (or independent on) in the value of τ. That is, when the valuation for firm B's product in the advance demand is not very high, the optimal price of firm B is increasing in the valuation for firm B. This is because, as consumers' valuation of firm B's product increases, firm B has the ability to improve their own prices and keep the utility of its products unchanged.

When $\tau_0 < \tau < 1$, however, with the increase of the value τ, $p_{1B}{}^*$ may decrease. This observation is interesting. Intuitively, one might expect that it is beneficial for firm B to increase the advance selling price since the valuation for its product is increasing. However, when the valuation for firm B's product is quite large (i.e. the competition is extremely intensive), a small increase in the advance selling price of firm B may require a large decrease in the advance selling demand of firm B, which ultimately may lead to the decrease of firm B's profit. In this case, firm B cannot blindly increase advance selling price by sacrificing the advance demand.

4.2 Optimal decisions when considering product diffusion

With the release of some fashionable products, strong sales may give the impression of fashion, and drive a higher demand going forward. Likewise, poor pre-launch sales may give the impression of exclusivity and have a dampening effect on late demand arrival. Extant research also indicates that the effect of product diffusion will affect the behavior of consumers in the subsequent selling seasons (Moe and Fader, 2003; Lim and Tang, 2013). Considering these phenomena and following Lim and Tang (2013) and Ho *et al.* (2012), we simply assume that $f(D_1)$ is monotonically increasing (or decreasing) in the value of D_1. This assumption is also consistent with isolated events such as concerts or performances whereby the word of mouth effect is either positive and thus increases the late demand, or negative and in turn leads to a lower late demand. Specifically, we assume that $f(D_1)$ follows:

$$f(D_1) = \beta_i D_i + \beta_j D_j. \quad (9)$$

In Equation (9), the term β_i (β_j) represents the impact of firm *i*'s (*j*'s) advance demand on the total regular demand of the two firms firm *i*'s regular demand (i.e. the effect of product diffusion caused by firm *i* or *j*'s advance demand).

Suppose that the fraction of the consumers triggered by the effect of product diffusion choosing to purchase from firm i (i = A or B) satisfy:

$$R_i = \frac{v_{2,i} - p_{2,i}}{\delta(1+\tau) - (1+\sigma)p}. \tag{10}$$

In Equation (10), the term $v_{2i} - p_{2i}$ represents the surplus of a consumer purchasing from firm i. The term $\delta(1+\tau)-(1+\sigma)p$ is the total surplus of a consumer purchasing from firms i and j in the regular selling season. Hence Equation (10) indicates that the larger the surplus brought by firm i, the higher the fraction of consumers choosing to buy from firm i.

Then the optimization problem for firm A can be computed as:

$$\max \ \pi_A = D_{1,A}\left(p_{1,A} - c\right) + D_{2,A}(p - c). \tag{11}$$

Similarly, the optimization problem for firm B can be computed as:

$$\max \ \pi_B = D_{1,B}\left(p_{1,B} - c\right) + D_{2,B}(\sigma p - c) \tag{12}$$

Based on the optimization problems (11) and (12), we have the following result:

Theorem 2. When $\tau(p-c)(\beta_B-\beta_A)R_A-(2-\tau)(\sigma p-c)(\tau\beta_A-\beta_B)(1-R_A)+(1-\tau)(\tau-2c) \geqslant 0$, there is a unique equilibrium in the selling prices $(\hat{p}^*_{1,A}, \hat{p}^*_{1,B})$, where $\hat{p}^*_{1,A}$ and $\hat{p}^*_{1,B}$ satisfy:

$$\hat{p}^*_{1,A} = p^*_{1,A} + \frac{(1-R_A)(\sigma p - c)\left(\tau\beta_A - \beta_B\right) + 2R_A(p-c)\left(\beta_B - \beta_A\right)}{4-\tau}, \tag{13}$$

$$\hat{p}^*_{1,B} = p^*_{1,B} + \frac{2(1-R_A)(\sigma p - c)\left(\tau\beta_A - \beta_B\right) + \tau R_A(p-c)\left(\beta_A - \beta_B\right)}{(4-\tau)}, \tag{14}$$

with $R_A = \left((\delta - p)/(\delta(1+\tau) - (1+\sigma)p)\right)$.

The condition in Theorem 2 means that the two firms' optimal advance selling prices should satisfy $\hat{p}^*_{1,B} \leqslant \tau\hat{p}^*_{1,A}$. This condition is used to ensure that the profit functions of the firms are joint concave in $(\hat{p}^*_{1,A}, \hat{p}^*_{1,B})$. Theorem 2 shows that each firm's optimal advance selling price is affected by the product diffusion effects of the two firms.

Based on Theorem 2, we can further obtain the following results:

Corollary 2. First, $\hat{p}^*_{1,A}$ is increasing in β_A if $0 < \delta < \delta_0$ and is non-increasing in β_A if $\delta_0 \leqslant \delta < 1$with $\delta_0 = p + ((\tau-\sigma)(\sigma p - c)\tau p)/\left(2(p-c) - \tau^2(\sigma p - c)\right)$. Second, $\hat{p}^*_{1,A}$ is decreasing in β_B if $0 < \delta < \delta_1$ and is non-decreasing in β_B if $\delta_1 \leqslant \delta < 1$ with $\delta_1 = p + ((\tau-\sigma)(\sigma p - c)p)/(2(p-c) - \tau(\sigma p - c))$. Third, $\hat{p}^*_{1,B}$ is non-decreasing in β_A, and is non-increasing in β_B.

We can observe from Corollary 2 that when the consumers' enthusiasm for the product in regular selling season is quite low (i.e. $\delta < \delta_0$), the optimal advance selling price of firm A is increasing in the effect of product diffusion caused by firm A's advance demand. This observation is interesting. Since the increase of the effect of product diffusion will increase the potential demand in the regular selling season, one might expect that the optimal advance selling price of firm A may decrease in the effect of product diffusion. However, as the consumers' enthusiasm for the product in regular selling season is quite low, the decrease of advance selling price cannot greatly increase firm A's demand in the regular selling season; oppositely, a certain level of increase in the advance selling price will not cause a great loss of the regular demand, which can ultimately increase its profit.

Corollary 2 also shows that when the consumers' enthusiasm for the product in regular selling season is higher than a threshold (i.e. $\delta \geqslant \delta_1$), the optimal advance selling price of firm A may increase in the effect of product diffusion caused by firm B's advance demand. This observation is also interesting. Intuitively, one might expect that the optimal advance selling price of firm A may increase in the diffusion effect caused by firm B's advance demand since a larger diffusion effect will lead to a larger demand in the regular period. However, as the price in the regular selling season is lower than that in the advance selling season, the profit of the new demand of firm A in the second period triggered by the early sales is much lower than that of the lost demand triggered by the increase in advance selling price. Consequently, the optimal advance selling price of firm A may increase in the diffusion effect caused by firm B's advance demand.

Denote by $\Delta p_{1,A} = \hat{p}^*_{1,A} - p^*_{1,A}$ and $\Delta p_{1,B} = \hat{p}^*_{1,B} - p^*_{1,B}$. We can further obtain the following result:

Corollary 3. When $\beta_A = \beta_B = \beta$, $\Delta p_{1,A}$ and $\Delta p_{1,B}$ are both decreasing in β.

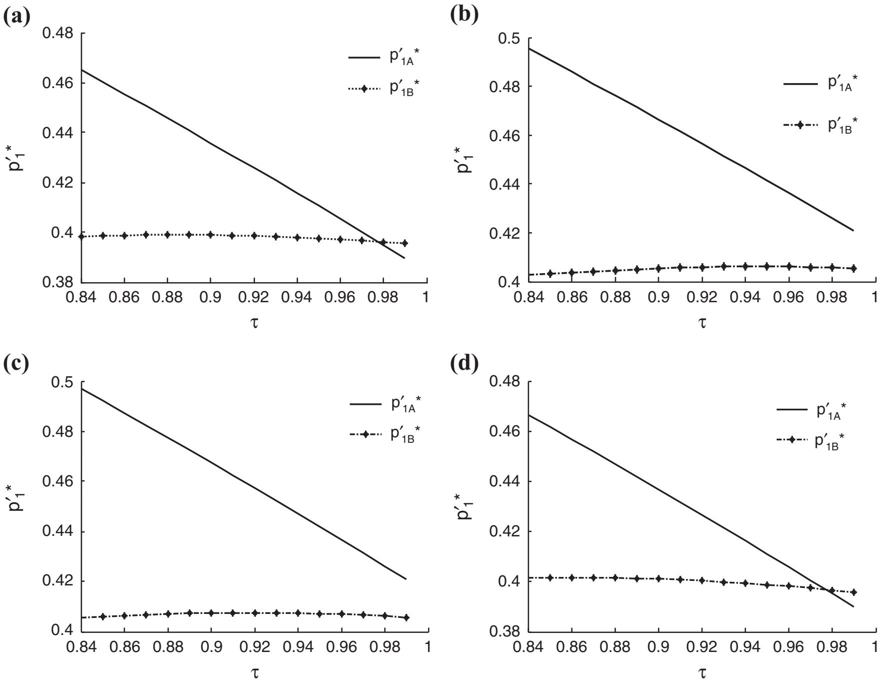
The terms $\Delta p_{1,A}$ and $\Delta p_{1,B}$ describe the difference of the optimal advance selling price of the two firms between the case of considering the product diffusion effect and that without considering the product diffusion effect. Corollary 3 shows that $\Delta p_{1,A}$ and $\Delta p_{1,B}$ are both decreasing in the product diffusion effect. This observation is understandable since the potential demand for both firms A and B will increase in β, which leads to the decreases of the advance selling prices.

5. Numerical illustration

In the section, some numerical studies are presented to further illustrate how the two competitive sellers' advance selling strategies are affected by the effect of product diffusion. Suppose that $c = 0.40$, $\tau = 0.95$, $p = 0.45$, $\sigma = 0.90$. Given these parameters, $\delta_0 \approx 0.45$.

Figure 1 shows the impact of the intensity of competition (τ) on the optimal advance selling price of the two firms. We can observe that the optimal advance selling price of firm A is decreasing in the value of τ, and the optimal advance selling price of firm B is concave in the value of τ. This observation coincides with that in Corollary 1. That is, when the competition between the two firms is extremely extensive, it is beneficial for the firm with lower reputation to decrease his advance selling price with the consumers' valuation on his product. This is because that in this case a small increase in the advance selling price may lead to a large decrease in the advance demand, which ultimately reduces his profit.

Figure 2 presents the difference of the optimal advance selling prices of the two firms between the case considering the product diffusion effect and that without considering the product diffusion effect (the benchmark case). From Figure 2(a), we can observe that when $\beta_B \in (0.01, 0.4)$ and $\beta_A = 1.5\beta_B$, the advance selling price of firm A (B) in the case considering the product diffusion effect is lower (higher) than that in the benchmark case; when $\beta_B \in (0.01, 3)$ and $\beta_A = \beta_B$, the advance selling price of both



Notes: (a) $\beta_B = -0.8$, $\beta_A = -0.1$; (b) $\beta_B = -0.8$, $\beta_A = -1.5$; (c) $\beta_B = 0.8$, $\beta_A = 0.1$; (d) $\beta_B = 0.8$, $\beta_A = 1.5$

Figure 1. Impact of τ on the optimal advance selling prices in the benchmark case

the two firms in the case considering the product diffusion effect is lower than that in the benchmark case; when $\beta_B \in (-3, -0.01)$ and $\beta_A = 1.5\beta_B$, the advance selling price of both the two firms in the case considering the product diffusion effect is higher than that in the benchmark case; when $\beta_B \in (-3, 0.01)$ and $\beta_A = \beta_B$, the advance selling price of firm A (B) in the case considering the product diffusion effect is higher (lower) than that in the benchmark case. These observations coincide with those in Corollaries 2 and 3.

6. Conclusion

The paper is among the first to investigate the advance selling strategies for oligopolists when considering the product diffusion effect. Suppose that there are two competitive sellers in the market who sell the same product in the market over two periods (i.e. the advance selling season and the regular selling season). The two sellers differ in their reputation. Further, due to the effect of product diffusion, the demand of each firm in the regular selling season is dependent on the two firms' advance demands. Through theoretical analysis we show that for the firm with lower reputation, it is beneficial to decrease the advance selling price with the diffusion effect caused by its advance demand. For the firm with higher reputation, it is also beneficial to decrease the advance selling price with the diffusion effect caused by its advance demand if the consumers' enthusiasm for the product in regular selling season is high enough; otherwise it should not decrease his advance selling price since this practice cannot greatly increase his demand. Additionally, when the competition between the two firms

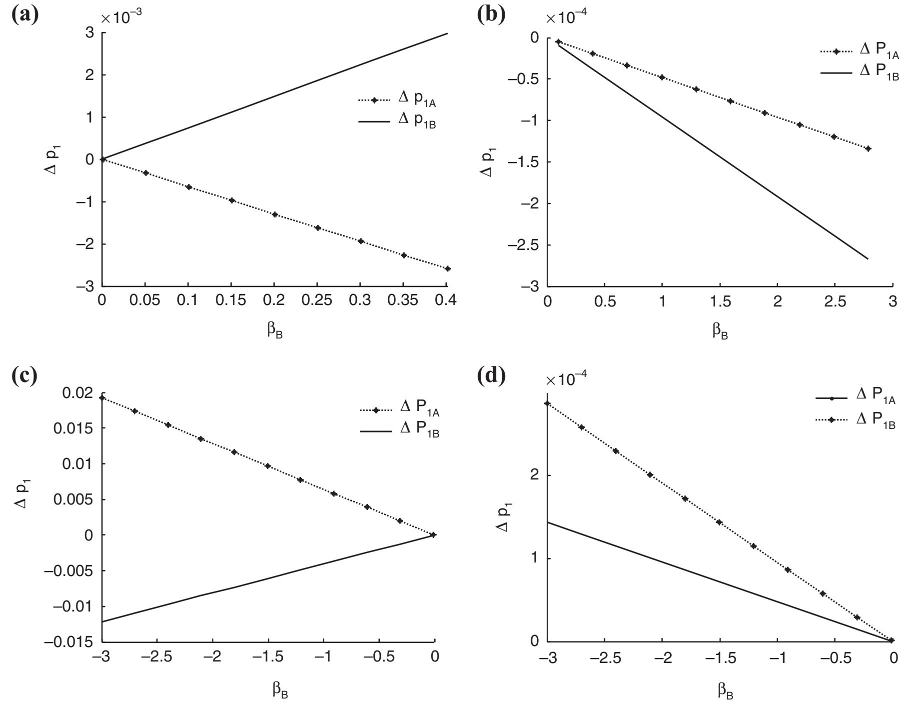


Figure 2. Impact of β on the differences of advance selling prices

Notes: (a) $\beta_A = 1.5\beta_B$; (b) $\beta_A = \beta_B$; (c) $\beta_A = 1.5\beta_B$; (d) $\beta_A = \beta_B$

is extremely extensive (i.e. the difference between the two firms' reputation is small enough), the firm with lower reputation should not increase his advance selling price with the consumers' valuation on his product, which is counter-intuitive. The obtained results can provide operational managers in reality with valuable suggestions in making advance selling decisions.

This paper examines the advance selling strategy when considering the product diffusion effect in a setting with two competitive sellers. In the future research, it would be interesting to introduce strategic-consumer behavior into the model. Additionally, if we incorporate other factors such as capacity constraints or demand variability into the model, the results in this paper also needs to be re-speculated.

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Appendix. Proofs of Theorems and Corollaries

Proof of Theorem 1

In Scenario I, if firm B charges an advance selling price $p_{1,B}$, firm A will maximize its profits in period 1:

$$\max \pi_{1,A} = M\left[1-\frac{p_{1,A}-p_{1,B}}{1-\tau}\right](p_{1,A}-c) \quad \text{if } p_{1,B} \leqslant \tau p_{1,A} \tag{A1}$$

Optimizing (A1), we yield the first-order condition for firm A's price $p_{1,A}$ in period 1 as a function of firm B's choice $p_{1,B}$:

$$p_{1,A} = \frac{1-\tau+p_{1,B}+c}{2}.$$

Similarly, if firm A charges an advance selling price of $p_{1,A}$, maximum profit of the firm B in period 1 is:

$$\max \pi_{1,B} = M\left[\frac{\tau p_{1,A}-p_{1,B}}{(1-\tau)\tau}\right](p_{1,B}-c) \quad \text{if } \ p_{1,B} \leqslant \tau p_{1,A}. \tag{A2}$$

Optimizing (A2) yields the first-order condition for firm A's price $p_{1,B}$ in period 1 as a function of firm B's choice $p_{1,B}$:

$$p_{1,B} = \frac{\tau p_{1,A}+c}{2}$$

Since $p_{1,A} = (1-\tau+p_{1,B}+c)/2$, $p_{1,B} = (\tau p_{1,A}+c)/2$, we obtain the equilibrium prices:

$$p^*_{1,A} = \frac{2-2\tau+3c}{4-\tau}, \quad p^*_{1,B} = \frac{(3c+2-2\tau)\tau}{2(4-\tau)}+\frac{c}{2}.$$

As $p_{1,B} \leqslant \tau p_{1,A}$, we can get that when $2c \leqslant \tau < 1$, we obtain the equilibrium prices:

$$p^*_{1,A} = \frac{2-2\tau+3c}{4-\tau}, \quad p^*_{1,B} = \frac{(3c+2-2\tau)\tau}{2(4-\tau)}+\frac{c}{2}.$$

Hence the results in Theorem 1 hold. ■

Proof of Corollary 1

According to Theorem 1, we obtain that:

$$\frac{\partial p_{1,A}{}^*}{\partial \tau} = \frac{-6+3c}{(4-\tau)^2}, \quad \text{as } 0<c<1, \quad \text{hence } \frac{\partial p_{1,A}{}^*}{\partial \tau} < 0;$$

$$\frac{\partial p_{1,B}{}^*}{\partial \tau} = \frac{G_1(\tau,c)}{(4-\tau)^2}, \quad \text{with } G_1(\tau,c) = (\tau-4)^2+6c-12,$$

when $G_1(\tau, c)=0$, we get $\tau_0 = 4-\sqrt{12-6c}$, $\tau_1 = 4+\sqrt{12-6c}$.

As $2c \leqslant \tau < 1$, we can get $0<c<1/2$, further, we can find that $2c < 4-\sqrt{12-6c} < 1$.

When $4-\sqrt{12-6c} < \tau < 1$, $G_1(\tau) < 0$; when $2c < \tau \leqslant 4-\sqrt{12-6c}$, $G_1(\tau) \geqslant 0$.

Since $(4-\tau)^2 > 0$, therefore:

$$\frac{\partial p_{1,B}{}^*}{\partial \tau} \geqslant 0 \quad \text{if } \tau \in (2c,\ \tau_0); \quad \frac{\partial p_{1,B}{}^*}{\partial \tau} < 0 \quad \text{if } \tau \in (\tau_0,\ 1).$$

With $\tau_0 = 4-\sqrt{12-6c}$.

Combining the above results, hence Corollary 1 holds. ■

Proof of Theorem 2

In Scenario II, if firm B charges a pre-sale price $\hat{p}_{1,B}$, firm A will maximize its total profits of periods 1 and 2:

$$\max \pi_A = \pi_{1,A}+\pi_{2,A}, = D_{1,A}\left(p_{1,A}-c\right)+D_{2,A}(p-c) \tag{A3}$$

Optimizing (A3), we yield the first-order condition for firm A's price $\hat{p}_{1,A}$ in period 1 as a function of firm B's choice, $\hat{p}_{1,B}$:

$$\hat{p}_{1,A} = \frac{\left(\hat{p}_{1,B}+c\right)+(1-\tau)+R_A(p-c)\left(\beta_B-\beta_A\right)}{2}$$

Similarly, if firm A charges a pre-sale price of $p_{1,A}$, firm B will maximize its total profits of periods 1 and 2:

$$\max \pi_B = \pi_{1,B}+\pi_{2,B}, = D_{1,B}\left(p_{1,B}-c\right)+D_{2,B}(\sigma p-c) \tag{A4}$$

Optimizing (A4) yields the first-order condition for firm A's price $\hat{p}_{1,B}$ in period 1 as a function of firm B's choice, $\hat{p}_{1,B}$:

$$\hat{p}_{1,B} = \frac{\left(\tau\hat{p}_{1,A}+c\right)+(1-R_A)(\sigma p-c)\left(\tau\beta_A-\beta_B\right)}{2}.$$

Since $\hat{p}_{1,A} = ((\hat{p}_{1,B}+c)+(1-\tau)+R_A(p_2-c)(\beta_B-\beta_A))/2$, $\hat{p}_{1,B} = ((\tau\hat{p}_{1,A}+c)+(1-R_A)(\sigma p-c)(\tau\beta_A-\beta_B))/2$.

As $\tau p_{1,A} \geqslant p_{1,B}$, we can get that when:

$$(\tau-2)(1-R_A)(\sigma p-c)\left(\tau\beta_A-\beta_B\right)+\tau R_A(p-c)\left(\beta_B-\beta_A\right)+(1-\tau)(\tau-2c) \geqslant 0,$$

we obtain the equilibrium prices:

$$\hat{p}^*_{1,A} = p^*_{1,A}+\frac{(1-R_A)(\sigma p-c)\left(\tau\beta_A-\beta_B\right)+2R_A(p-c)\left(\beta_B-\beta_A\right)}{4-\tau}$$

$$\hat{p}^*_{1,B} = p^*_{1,B}+\frac{2(1-R_A)(\sigma p-c)\left(\tau\beta_A-\beta_B\right)+\tau R_A(p-c)\left(\beta_B-\beta_A\right)}{(4-\tau)}$$

hence Theorem 2 holds. ■

Proof of Corollary 2

Proof of the first part of Corollary 2:
According to Theorem 2, we obtain that:

$$\hat{p}_{1,A}^{*} = \frac{(1-R_A)(\sigma p-c)(\tau\beta_A-\beta_B)+2R_A(p-c)(\beta_B-\beta_A)+2(1-\tau)+3c}{4-\tau}$$

$$\frac{\partial\hat{p}_{1,A}^{*}}{\partial\beta_A} = \frac{\tau(\sigma p-c)(1-R_A)-2(p-c)R_A}{4-\tau}.$$

Recall that $R_A = (\delta-p)/(\delta(1+\tau)-(1+\sigma)p)$, we can obtain that:

$$\frac{\partial\hat{p}_{1,A}^{*}}{\partial\beta_A} = \frac{2p(p-c)-\tau\sigma p(\sigma p-c)-\left[2(p-c)-\tau^2(\sigma p-c)\right]\delta}{(4-\tau)[\delta(1+\tau)-(1+\sigma)p]}.$$

Hence if $\delta > \delta_0$, $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_A) < 0$; if $\delta \leqslant \delta_0$, $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_A) \geqslant 0$, with $\delta_0 = p+((\tau-\sigma)\tau p(\sigma p-c))/(2(p-c)-\tau^2(\sigma p-c))$.

Proof of the second part of Corollary 2:
According to Theorem 2, we obtain that:

$$\hat{p}_{1,A}^{*} = \frac{(1-R_A)(\sigma p-c)(\tau\beta_A-\beta_B)+2R_A(p-c)(\beta_B-\beta_A)+2(1-\tau)+3c}{4-\tau}$$

$$\frac{\partial\hat{p}_{1,A}^{*}}{\partial\beta_B} = \frac{[2(p-c)+(\sigma p-c)]R_A-(\sigma p-c)}{4-\tau},$$

(1) If $R_A \geqslant (\sigma p-c)/(2(p-c)+(\sigma p-c))$, then $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_B) \geqslant 0$.

(2) If $R_A < (\sigma p-c)/(2(p-c)+(\sigma p-c))$, then $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_B) < 0$.

Since $R_A = (\delta-p)/(\delta(1+\tau)-(1+\sigma)p)$, from $R_A \geqslant (\sigma p-c)/(2(p-c)+(\sigma p-c))$, we can further get that if $\delta \geqslant p+((\tau-\sigma)(\sigma p-c)p)/(2(p-c)-\tau(\sigma p-c))$, $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_B) \geqslant 0$; from $R_A < (\sigma p-c)/(2(p-c)+(\sigma p-c))$, we can further get that if $\delta < p+((\tau-\sigma)(\sigma p-c)p)/(2(p-c)-\tau(\sigma p-c))$, $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_B) < 0$; hence we have if $\delta \geqslant \delta_1$, $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_B) \geqslant 0$; if $\delta < \delta_1$, $(\partial\hat{p}_{1,A}^{*})/(\partial\beta_B) < 0$ with $\delta_1 = p+((\tau-\sigma)(\sigma p-c)p)/(2(p-c)-\tau(\sigma p-c))$.

Proof of the third part of Corollary 2:
According to Theorem 2, we obtain that:

$$\hat{p}_{1,B}^{*} = \frac{2(1-R_A)(\sigma p-c)(\tau\beta_A-\beta_B)+\tau R_A(p-c)(\beta_A-\beta_B)-\tau^2+(c+1)\tau+2c}{(4-\tau)}$$

$$\frac{\partial\hat{p}_{1,B}^{*}}{\partial\beta_A} = \frac{\tau[2(\sigma p-c)(1-R_A)+(p-c)R_A]}{(4-\tau)}.$$

Recall that $R_A = (\delta-p)/(\delta(1+\tau)-(1+\sigma)p)$, since $0 < R_A < 1$, then we can get that $(\partial\hat{p}_{1,B}^{*})/(\partial\beta_A) > 0$. Similarly, since $\hat{p}_{1,B}^{*} = (2(1-R_A)(\sigma p-c)(\tau\beta_A-\beta_B)+\tau R_A(p-c)(\beta_A-\beta_B)-\tau^2+(c+1)\tau+2c)/(4-\tau)$, then $(\partial\hat{p}_{1,B}^{*})/(\partial\beta_B) = (-2(1-R_A)(\sigma p-c)-\tau R_A(p-c))/(4-\tau) = ([2(\sigma p-c)-\tau(p-c)]R_A-2(\sigma p-c))/(4-\tau)$.

Since $2(\sigma p-c)-\tau(p-c) < 2(\sigma p-c)$ and $0 < R_A < 1$, we can get that $[2(\sigma p-c)-\tau(p-c)]R_A-2(\sigma p-c) < 0$, then $(\partial\hat{p}_{1,B}^{*})/(\partial\beta_B) < 0$.

Hence Corollary 2 holds. ■

Proof of Corollary 3

According to Theorem 2, we obtain that:

$$\hat{p}^*_{1,A} = \frac{(1-R_A)(\sigma p-c)\left(\tau\beta_A-\beta_B\right)+2R_A(p-c)\left(\beta_B-\beta_A\right)+2(1-\tau)+3c}{4-\tau}$$

$$\hat{p}^*_{1,B} = \frac{2(1-R_A)(\sigma p-c)\left(\tau\beta_A-\beta_B\right)+\tau R_A(p-c)\left(\beta_A-\beta_B\right)-\tau^2+(c+1)\tau+2c}{(4-\tau)}$$

When $\beta=\beta_A=\beta_B$, we can get that:

$$\hat{p}^*_{1,A} = \frac{(1-R_A)(\sigma p-c)(\tau-1)\beta+2(1-\tau)+3c}{4-\tau},$$

$$\hat{p}^*_{1,B} = \frac{2(1-R_A)(\sigma p-c)(\tau-1)\beta-\tau^2+(c+1)\tau+2c}{(4-\tau)},$$

then $\Delta p^*_A = ((1-R_A)(\sigma p-c)(\tau-1)\beta)/(4-\tau)$, $\Delta p^*_B = (2(1-R_A)(\sigma p-c)(\tau-1)\beta)/(4-\tau)$.

Hence $\left(\partial\Delta p_{1,A}\right)/(\partial\beta) = ((1-R_A)(\sigma p-c)(\tau-1))/(4-\tau)$, and $\left(\partial\Delta p_{1,B}\right)/(\partial\beta) = (2(1-R_A)(\sigma p-c)(\tau-1))/(4-\tau)$.

Since $\sigma p > c$, $0<\tau<1$ and $0<R_A<1$, we can get that $\left(\partial\Delta p_{1,A}\right)/(\partial\beta)<0$, $\left(\partial\Delta p_{1,B}\right)/(\partial\beta)<0$.

Hence Corollary 3 holds. ■

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