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The impact of online reviews in the presence of customer returns

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\section*{A R T I C L E   I N F O}

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  \item Online reviews
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  \item Returns policy
\end{itemize}

\section*{A B S T R A C T}

We develop a duopoly model to examine how online reviews influence the decisions of two competing online sellers who sell products of differentiated quality under different returns policies. We derive the competing sellers' optimal decisions on price and returns policy with and without online reviews, and we find that online reviews have greater impact on the high-quality seller than on the low-quality seller. If the salvage value of the product is relatively low, the seller has less opportunity to benefit from online reviews when it offers an MBG, as compared to a no-refund policy. The impact of online reviews on the competition between the two sellers has a "symmetric effect area," where reviews may either weaken or intensify the price competition between the two sellers when they both offer a no-refund policy, but always intensify the competition if they both offer an MBG. We have identified the conditions under which online reviews lead to a win-win, or benefit one seller, or present a prisoner’s dilemma for the two online sellers. We also show that MBGs at both sellers help mitigate the prisoner’s dilemma if the net salvage value at both sellers is sufficiently high.

\section*{1. Introduction}

Return of products by customers is a common phenomenon in the retailing industry, especially in online retailing. As shown in a National Retail Federation (2018) report, total merchandise returns account for almost $369 billion in lost sales for US retailers alone, and the retail returns rate was as high as 10\% in 2018. It has been reported that the returns rate from online sales is two to three times of that of brick-and-mortar retailers (Orendorff, 2019) and is typically between 20\% and 40\% (Ratcliff, 2014).

The major reason for the high level of customer returns in online retail is mismatch between customer expectations and the reality of the product (Chen and Chen, 2017a; Ratcliff, 2014). As the customer cannot physically evaluate and experience the product before purchase, there is a significant chance that the purchased product will fail to match the customer’s expectation and taste. Online reviews from previous customers reveal additional information about products, enabling customers to adjust their pre-purchase valuations on products and make better purchase decisions, ultimately reducing the rate of customer returns (Dellarocas, 2003; Kostyra et al., 2016; Masłowska et al., 2017). In practice, BazaarVoice reported that online reviews reduce the number of returned products by 20\% (Sahoo et al., 2018). In an empirical study by Minnema et al. (2016), online customer reviews were shown to help form product expectations, and it was suggested that product returns should be considered when examining the effects of online customer reviews.

Although an attractive returns policy can improve customer satisfaction and thus represent a competitive strength, the lost sales and high cost of handling customer returns significantly affects profitability, and online retailers set their returns policy carefully (McWilliams, 2012; Chen and Chen, 2017b). Furthermore, returns can be managed, and method of handling customers returns may impact the customer’s perception and willingness-to-pay (Appriss Retail, 2019; Pei et al., 2014). To reduce costs associated with customer returns, some retailers tighten their returns policies by offering a no-refund policy (Su, 2009; Choi et al., 2013; Hsiao and Chen, 2015). Online retailers offer a variety of returns policies (Better Business Bureau; Office of Consumer Affairs (Canada)), ranging from the money-back guarantee (for example, Amazon.com and Walmart.com) to no refund (LCDTVs.com). An MBG returns policy is a widely adopted policy, but no-refund policies can also be observed in practice (especially for digital products like games, music, and software). Some sellers specify no-returns policies under certain conditions; the Camera Store states on its website that any printer in which ink has been installed cannot be returned (https://www...
Online sales have increased from 29.6 billion Canadian dollars in 2015 to 44 billion in 2018 (Clement, 2020). In the Covid-19 pandemic period, this number has increased to a record $3.9 billion in May 2020 in Canada, with a 99.3% increase over February, according to Statistics Canada (Toneguzzo, 2020). Many, but not all, online retailers (notably Amazon.com) allow or encourage customers to leave product reviews on their websites, and there are also third-party sites (such as Yelp.com) dedicated to customer reviews. Customers can share their opinions on products or services they have experienced, and seek information from others’ experience of products they are interested in. Furthermore, there are a variety of types of reviews, including star ratings, pictures, and text description of product details and characteristics. Nearly 90% of consumers read online reviews before purchasing (Gilliam, 2017), and 88% of them trust the online reviews as much as personal recommendations; consumers read reviews as part of their pre-purchase research (Rudolph, 2015).

Although a number of studies have examined the impact of online reviews on sellers’ sales, and several empirical studies have considered the influence of online reviews on customer returns (Sahoo et al., 2018; Minnema et al., 2016), we are unaware of any theoretical study that investigates the impact of online reviews on the decisions of competing sellers on prices and returns policies in the presence of customer returns. To fill this gap, we develop a duopoly model to study how online reviews impact customers’ purchases and returns, and how online sellers facing competition can make optimal price and returns policy decisions in the presence of online reviews.

Online reviews provide customers with additional information on products before purchase, and an MBG provides post-sale service; in principle both should reduce the risk of mismatch of the actual product with customer expectations. We are therefore interested in the interactions between online reviews and returns policies, and the influence of online reviews on competing sellers’ price and returns policy decisions. In order to analyze the impact of online reviews in a competitive market with customer returns, we build a three-stage game theoretic model, in which two competing online retailers sell a product at different quality levels. Customers are heterogeneous in their valuations on the products, and they make their purchase decisions based on both information provided by the seller and online reviews.

Not surprisingly, we find that online sellers benefit from favorable reviews (with an increase in both price and demand), and can be hurt by negative reviews (with a decrease in price and demand). Comparable reviews of competing products intensify the competition between the two sellers, so the sellers have to reduce their prices, even at the risk of reduced profits, in order to compete. In addition, not unnaturally, in the presence of online reviews, the seller’s price, demand, and profit increase with the value of the reviews of its own product and decrease with the value of the reviews of its rival’s product.

We identify the condition for a duopoly to offer MBGs. We show that when the net value of the returns service (shared by the customer and an online seller) is positive, the online seller should offer an MBG, no matter what returns policy is offered by its competitor. We also show that online reviews reduce the customer’s need for an MBG, as the reviews can reduce the risk of mismatch that is inherent in an online purchase. As a result, sellers are less likely to offer an MBG when online reviews are available than when they are not.

Online reviews also have several surprising effects. We find that online reviews have greater impact on the high-quality seller than on the low-quality seller. Furthermore, the impact of online reviews on the competition between the two sellers has a “symmetric effect area.” If online reviews of the two products fall in this area, they have the same influence direction on both sellers, either positive or negative; otherwise, they benefit one but hurt the other. In the symmetric effect area, online reviews may either weaken or intensify the price competition between the two sellers when both offer a no-refund policy, but always intensify the competition if both offer an MBG. Even so, salvage value matters; when the salvage values of the two products are both sufficiently high, both sellers are more likely to benefit from online reviews when they offer an MBG.

Our contributions to the literature are two-fold. First, we extend the extant studies on the influence of online reviews to include the effect of reviews on competitive online sellers’ choice of customer returns policies. Our study suggests that online sellers should respond strategically to reviews, not only in pricing but also in returns policies. We demonstrate that online reviews reduce the motivation of online sellers to provide an MBG; this is a new insight in the literature on customer returns. Second, we analyze the interactions between online reviews and returns policies in view of the duopoly’s competition in prices and returns policies (for products of different qualities). We find that online reviews have greater impact on the high-quality seller than on the low-quality seller, and may have different impacts on the competition.

The rest of this paper is organized as follows. Section 2 briefly reviews the relevant research. Section 3 describes the setting and game sequence of our duopoly model. Section 4 examines the two online sellers’ pricing and returns policy decisions under the influence of online reviews, and presents equilibrium results for returns policies with and without online reviews. Section 5 examines the impact of online reviews on online sellers’ optimal prices and profits, and the duopoly’s market when online sellers both offer either a no-refund policy or an MBG. Section 6 concludes the paper and proposes possible extensions for future work. All proofs are presented in the Appendix.

2. Literature review

There are two streams of literature related to this study, on online product reviews and customer returns.

Online product reviews have attracted considerable attention recently, as the growing popularity of reviews has potentially important implications for a wide range of management activities (Dellarocas, 2003; Li and Hitt, 2008). Extensive empirical studies have examined the impact of online reviews and shown that they indeed have an effect on firms’ sales (Chevalier and Mayzlin, 2006; Duan et al., 2008; Luca, 2016; Zhou and Duan, 2016). From an analysis of book reviews at Amazon.com, Chevalier and Mayzlin (2006) find that online reviews have a significant influence on product sales. Similarly, Luca (2011) finds that an increase in ratings on Yelp.com leads to an improvement in the revenues of restaurants. In addition, a large body of detailed work has considered the impact of different characteristics of online reviews, including the association between the variance and volume of product ratings (Clemons et al., 2006; Kostyra et al., 2016; Maslowska et al., 2017), the review text (Archak et al., 2011), and professional ratings and sales (Zhou and Duan, 2016). Differing from those studies, we develop a theoretic model to study the impact of online reviews on customers’ purchasing decisions and on competing online retailers’ customer returns and pricing strategies.

The existing theoretical studies on online reviews focus on the impact of online reviews on customers’ pre-purchase evaluations of products. Online reviews are viewed as an information source and have an effect on customers’ purchase behaviors (Chen and Xie, 2008; Li and Hitt, 2008; Markopoulos et al., 2016; Sun, 2012). Chen and Xie (2008) argue that online reviews can serve as a new element in market communications and as free “sales assistants” to help customers to make purchase decisions. Li and Hitt (2008) model the self-selection bias in early online reviews, which impacts later consumers’ purchases and later product reviews. Sun (2012) models both ratings and variance of product reviews, and examines the impact of the level of variance on products’ subsequent price, demand, and profit. Consumers may have different perceptions of either positive or negative reviews (Pekgün et al., 2018). With the effect of online reviews on customers’ utility, Kwark et al. (2014) and Cai et al. (2018) examine the pricing strategies of different players in a supply chain. Some studies show that online
reviews can be a promotional device, and provide marketing strategy suggestions to sellers (Chen and Xie, 2005; Dellarocas, 2006; Mayzlin, 2006; Kuksov and Xie, 2010). All these studies focus on the effect of online reviews on customers’ behavior before purchase; in the present paper we also consider the effect of online reviews on customer returns after purchase and on online retailers’ decisions on returns policies.

Several empirical studies have examined the impact of online reviews on customer returns (Sahoo et al., 2018; Lohse et al., 2017; Minnema et al., 2016). Sahoo et al. (2018) show that unbiased online reviews help customers make better purchase decisions, leading to fewer product returns. Minnema (2016) and Lohse (2017) find that online reviews affect customers’ purchase decisions as well as returns decisions. De et al. (2013) find that the technologies used for customer reviews have different effects on returns. In contrast to these empirical studies, we develop a game theoretical model for two online retailers who sell quality-differentiated products, to examine the impact of online reviews on the sellers’ pricing and returns policy decisions in a competitive market.

This paper is also related to studies on customer returns. To reduce customers’ risk and improve customer satisfaction, many sellers offer a lenient returns policy, even though it may lead to high costs (Che, 1996). The effect of returns policy on customers and retailers has been extensively studied in the economics and marketing literature. Some studies have found that returns policy can act as a source of product quality information (Moorhy and Srinivasan, 1995; Shieh, 1996). Moorhy and Srinivasan (1995) use a signaling theory to analyze how an MBG signals a high-quality product. Some studies focus on retailers’ strategy in returns policy, and argue that an appropriate returns policy can enhance profits (Chen and Bell, 2012; Davis et al., 2002). Others study pay attention to the influence of returns policy on customer purchase decisions (Anderson et al., 2009; Suwelack et al., 2011; Wood, 2003). Suwelack (2011) argues that MBGs can increase customers’ purchase intentions and willingness to pay a price premium. Griffis et al. (2012) examine how customers’ returns experiences impact their future purchases. In addition, extensive studies in operations management have focused on firms’ strategies facing customers’ returns, including pricing, ordering, and returns strategy decisions in either a monopolistic or a competitive market (McWilliams, 2012; Su, 2009). The optimal strategies of each player in supply chains with different structures have been discussed and analyzed (Ai et al., 2012; Chen and Chen, 2017a; Liu et al., 2014). None of these studies have examined the impact of online reviews on retailers’ returns policies in a competitive market, as we do in this paper. To fill this gap, in this study we develop a model to analyze the online retailers’ optimal decisions in a competitive market in the presence of customer returns and online reviews.

3. Model description

We consider two sellers who compete on an online platform in the presence of online reviews, selling products with differentiated quality. Customers will decide whether or not to buy the product, and from which seller to buy, after reading the online reviews. For example, the customer looking for a blender might consider Vitamix and Oster, which both sell blenders on Amazon.com, but the blender from Vitamix may be of higher quality than the blender from Oster. In the presence of online reviews, we examine how two competing sellers should offer returns policies, and study the impact of online reviews on the sellers’ choice of policy. In practice, companies have to make plans based on projections. Our stylized model will allow a company to envision the effects of reviews and returns policies to optimize operations decisions accordingly.

The two online sellers are vertically differentiated in their ability to provide product quality and customer returns service to their customers. As in McWilliams (2012) and Chen and Chen (2017b), who follow the assumption in Moorhy and Srinivasan (1995) that MBGs can be offered by high-quality firms to signal product quality (where quality is defined as the likelihood of product return) to uninformed consumers (based on signaling theory), high product quality is reflected in a high customer satisfaction rate. We assume that the high-quality retailer $H$ has a customer satisfaction rate $\alpha_H$ and the low-quality retailer $L$ has a customer satisfaction rate $\alpha_L$, where $\alpha_H > \alpha_L$, and satisfaction rate is reflected in returns rate. Therefore, $(1 - \alpha)$ reflects the customer returns rate of Seller $i$, if returns are allowed, where $i = H, L$.

The two sellers each set a returns policy $(k_i)$, either an MBG $(k_i = 1)$ or a no-refund policy $(k_i = 0)$, where $i = H, L$. With a no-refund policy, the product is worth zero to an unsatisfied customer. Each seller incurs a unit product acquisition cost $(c_i)$, and needs to decide on the selling price $(p_i)$. Without loss of generality, we assume that $c_H > c_L$. Let $s_i$ be the salvage value of a returned product and $t_i$ be the customer’s cost of returning the product to retailer $i$ (the hassle cost, reflecting shipping cost and/or time spent returning the product). Seller $i$ incurs a unit handling cost per returned product $(h_i)$.

We assume that the customer’s perceived valuation $(v_i)$ on a satisfactory product with an MBG policy is between 0 and 1, following a uniform distribution, as in McWilliams (2012) and Chen and Chen (2017a). If the customer is unsatisfied with the product, its value is 0. As in Chen and Bell (2012) and Chen and Grewal (2013), we assume that the customer’s perceived valuation on a product with a no-refund policy is lower than that with an MBG policy, to account for the risk of having to keep an unsatisfactory product. In practice, a product with a no-refund policy usually has a lower price than one with return service (Camera Store example in Section 1). Both empirical studies (such as, Pei et al., 2014) and theoretical studies (such as Shang et al., 2017) have found that the customer’s valuation on the product with a no-refund policy is lower than that with an MBG. To capture the difference in the customer’s perceived valuation of products with different returns policies, we assume that the customer has a distility $(\eta)$ on a product purchased under a no-refund policy, and its perceived valuation is $v - \eta$ $(\eta > 0)$ (as in Shang et al., 2017).

In addition to providing the infrastructure to sell the products, an online platform may enable customers to post product reviews and feedback on purchased products. We designate an online platform $W = \{N, R\}$, where reviews are either enabled $(R)$ or not enabled $(N)$. Online reviews provide public information on the product, including quality, fitness, and ease of usage. As pointed out by Sahoo et al. (2018), it is unclear whether online reviews can help customers in making better purchase decisions that may lead to fewer returns, so we denote the value of online reviews, measured by the star and/or score posted by reviewers, as $\theta_i$, where $\theta_i < 1$ and $i = H, L$. A potential customer can use this information along with seller-provided information to evaluate the products before purchase. The higher the score or the larger the number of stars, the higher the value of the online reviews. $\theta_i$ also depends on additional factors such as the descriptive information on the product provided by the seller and the customer’s evaluation of the product after experiencing the product. The reviewer’s valuation $v$ on Product $i$ with online reviews under an MBG or a no-refund policy becomes $rv_i + (1 - r)\theta_i$ and $r(v - \eta) + (1 - r)\theta_i$, respectively, where $r$ and $1 - r$ are the weights on the customer’s own valuation of the product and on the information from online reviews, respectively, and where $r \in (0, 1)$. The online reviews give the customer as second source of information from which to value a product. The assumption that the customer weighs the online reviews the same for both products follows the study of Kwark et al. (2014), in which the information precision of online reviews on products sold on a given online platform is assumed to be the same.

The main notation that will be used in this paper is summarized in Table 1.

4. The model

In the presence of online reviews and customer returns, we model the duopoly competition as a three-stage game. Since a seller’s decision on returns policy is relatively long term, as compared to its price decision, the returns policy should be set before the price decision is made. The
Table 1
Main notation.

| Index          | Description                                      |
|----------------|--------------------------------------------------|
| $i$            | Subscript, index of product/seller, $i = H, L$.   |
| $W$            | Subscript, $W = \{N, R\}$, index of cases without reviews ($N$) and with reviews ($R$) |
| $K$            | Superscript, index of the returns policy combination of the duopoly, $K = k_hk_l$, where $k_i$ is the returns policy of Seller $i$. |

Parameters

- $\nu$: Customer’s valuation on the product with MBG and without online reviews
- $\eta$: Customer’s disutility on the product with no-refund policy
- $\alpha_i$: Probability that a customer is satisfied with purchased Product $i$
- $\theta_i$: Value of online reviews for Product $i$
- $\eta_i$: Salvage value of Product $i$
- $\lambda_i$: Customer’s cost of returning an unsatisfactory Product $i$ to Seller $i$
- $\epsilon_i$: Unit acquisition cost of Product $i$
- $c_i$: Cost of handling a returned Product $i$ by Seller $i$

Decision Variables

- $k_i$: Seller $i$’s returns policy, superscript $k_i = \{0, 1\}$, with $k_i = 0$ for a no-refund and $k_i = 1$ for an MBG policy.
- $p_i$: Selling price of Product $i$.

Game sequence is illustrated in Fig. 1.

In Stage 1, the two sellers simultaneously but separately choose returns policies, either MBG ($K_i = 1$) or no-refund ($K_i = 0$). In Stage 2, both sellers set their optimal selling prices simultaneously. In Stage 3, the customer decides where to buy to maximize utility, based on the returns policy offered ($K = k_hk_l = \{00, 01, 10, 11\}$) and selling price.

We now derive the optimal equilibriums for the duopoly starting with the Stage 3 game.

4.1. Customer’s utility

To examine the impact of online reviews, we consider a benchmark case in which the platform does not enable online reviews (subscript $N$). The customer evaluates the product based on its own valuation on the product. Given the sellers’ returns policies $K$ and Seller $i$’s selling price $p^N_i$, the utility of a customer with valuation $\nu$ on Product $i$ is:

$$U^N_{iw} = \alpha_i[\nu - (1 - k_i)\eta_i] + k_i(1 - \alpha_i)(p^N_{iw} - \eta_i) - p^N_{iw}$$

(1)

where $k_i = \{0, 1\}$. On the right-hand side of Eq. (1), the first and the second terms are the expected valuation when the customer purchases and keeps the product (if the product is satisfactory), and when the product is unsatisfactory and returned (with an MBG from Seller $i$) or kept (with a no-refund policy from Seller $i$).

With online reviews (subscript $R$), for $k_i = \{0, 1\}$, the customer with value $\nu$ on Product $i$ has the utility:

$$U^R_{iw} = \alpha_i[\nu - (1 - k_i)\eta_i] + k_i(1 - \alpha_i)(p^R_{iw} - \eta_i) - p^R_{iw}$$

(2)

Similar to Eq. (1), the first and the second terms of Eq. (2) are the expected valuations if the purchase is satisfactory and kept, or unsatisfactory and returned (if an MBG is offered) or kept either way (if a no-refund policy is offered), respectively. Equations (1) and (2) capture the impact of the seller’s returns policy on the customer’s utility.

With Eqs. (1) and (2), for $W = \{N, R\}$, the customer’s utility function ($U^R_{iw}$) can be generalized as:

$$U^R_{iw} = \alpha_i[\nu - (1 - k_i)\eta_i] + k_i(1 - \alpha_i)(p^R_{iw} - \eta_i) - p^R_{iw}$$

(3)

where $\Gamma = \{1$ if with online reviews, $0$ if without online reviews $\}$ and $k_i = \{0$ with a no-refund policy, $1$ with an MBG policy $\}$.

The customer will buy the product if the utility is non-negative. In addition, the customer will select a seller, either Seller $H$ or Seller $L$, based on maximizing the utility function. With Eq. (3), we see that a customer with valuation $\nu$ will buy Product $i$ if and only if $U^R_{iw} \geq 0$ and $U^R_{iw} \geq U^R_{iw'}$. Then we can derive the indifference values $\nu^*_{iw}$ and $\nu^*_{iw'}$ by setting $U^R_{iw} = 0$ and $U^R_{iw'} = U^R_{iw}$, respectively. $\nu^*_{iw}$ is the indifference value where the customer buys or does not buy the product from Seller $L$, while $\nu^*_{iw'}$ represents the indifference value where the customer buys from either Seller $H$ or Seller $L$. Similarly, the customer will purchase Product $H$ if and only if $U^R_{iw} \geq 0$ and $U^R_{iw} \geq U^R_{iw'}$, which gives the indifference values $\nu^*_{iw}$ and $\nu^*_{iw'}$ by setting $U^R_{iw} = 0$ and $U^R_{iw'} = U^R_{iw'}$, respectively.

Assume that the basic market size is 1. With the customer’s utilities, the demands can be derived:

$$D^R_{iw} = \begin{cases} 
0, & \text{if } \nu^*_{iw} \geq 1; \\
1 - \nu^*_{iw}, & \text{if } 0 < \nu^*_{iw} < 1; \\
K, & \text{if } \nu^*_{iw} \leq 0.
\end{cases}$$

(4)

To examine the impact of online reviews on the two sellers in the competing market, the rest of the paper will focus on the case where both online sellers have sales ($\nu^*_{iw'} < \nu^*_{iw} < 1$). The demands for Seller $H$ and Seller $L$ are:

$$D^R_{iw} = \nu^*_{iw} - \nu^*_{iw'}$$

(5)

4.2. Sellers’ pricing decisions

In the second stage of the game, the two sellers decide their selling prices simultaneously. Given two sellers’ returns policies $K$ set in the Stage 1 game, for $W = \{N, R\}$, Seller $i$’s profit function is:

$$\pi^R_i = \alpha_i[\nu - (1 - k_i)\eta_i] + k_i(1 - \alpha_i)(p^R_{iw} - \eta_i) - c_i$$

(6)

where $\pi^R_i$ is given by the margin profit multiplied by the demand of Seller $i$.

We define $\pi^R_i = \alpha_i[\nu - (1 - k_i)\eta_i] + k_i(1 - \alpha_i)(p^R_{iw} - \eta_i)$ as the highest net valuation of the customer ($\nu = 1$) for Product $i$. Then $\pi^R_{iw}$ is given by the margin profit multiplied by the demand of Seller $i$.

We define $\pi^R_i = \alpha_i[\nu - (1 - k_i)\eta_i] + k_i(1 - \alpha_i)(p^R_{iw} - \eta_i)$ as the maximum net product value shared by the online Seller $i$ and the
customer with the highest net valuation. \( \text{Net}^i_w \) is the summation of \( m^i_{wh} \) and Seller \( i \)'s margin profit, reflecting the efficiency of online Seller \( i \) in selling its product, where \( E^i_w \) and \( m^i_{wh} \) are listed in Table A1 in the Appendix. \( E^i_w \) is referred to as the “maximum net shared value of Seller \( i \)” in this paper (See also Chen and Chen (2017b). Here we are presenting an extension of that work, with consideration of online reviews.). Maximizing the profits of both sellers, the optimal price \( (p^i_w) \) can be derived, as summarized in the following proposition.

**Proposition 1.** For \( W = \{N, R\} \) and any given returns policies of two sellers \( K = k_i k_i \), the duopoly has unique optimal prices for cases with and without online product reviews, as given by:

\[
\begin{align*}
\hat{p}^i_w &= \frac{m^i_{wh}}{1 - (1 - a_i)k_i} - \frac{2a_i E^i_w + a_i E^i_{wh}}{(4a_i - a_i)(1 - (1 - a_i)k_i)^2} \\
\hat{p}^i_{ww} &= \frac{m^i_{wh}}{1 - (1 - a_i)k_i} - \frac{2a_i E^i_w + a_i E^i_{ww}}{(4a_i - a_i)(1 - (1 - a_i)k_i)^2}
\end{align*}
\]

We define \( a_1 = \frac{a_w}{a_h} \) and \( a_2 = \frac{a_h - a_w}{a_h} \). With Eqs. (5)–(7) and Proposition 1, we can derive the corresponding equilibrium demands of the two online sellers:

\[
D^\text{aw}_{w} \left( \frac{2(a_i - a_i)(4a_i - a_i)E^i_{wh}}{(4a_i - a_i)(1 - (1 - a_i)k_i)^2} \right) \quad \text{and} \quad D^\text{aw}_{ww} \left( \frac{a_i a_i E^i_w + a_i E^i_{ww}}{(a_i - a_i)(4a_i - a_i)^2} \right)
\]

\[
D^\text{aw}_{w} \left( \frac{2(a_i - a_i)^2 E^i_{wh}}{(a_i - a_i)(4a_i - a_i)^2} \right) \quad \text{and} \quad D^\text{aw}_{ww} \left( \frac{a_i a_i(4a_i - a_i)^2}{(a_i - a_i)(4a_i - a_i)^2} \right)
\]

We define \( \delta^w = \hat{p}^i_w / E^i_w \) as Seller \( H \)'s efficiency of selling a high-quality product relative to that of Seller \( L \) selling a low-quality product. With Eq. (8), we have the following result.

**Lemma 1.** For \( W = \{N, R\} \) and any given returns policy \( K \) offered by the duopoly, the two online sellers can coexist if and only if

\[
\alpha_i \leq \delta^w_i \leq \alpha_2
\]

**Lemma 1** gives the condition for the two competing online sellers to coexist (\( D^\text{aw}_{w} \geq 0 \) and \( D^\text{aw}_{ww} \geq 0 \)). \( \delta^w \) depends on the returns policies chosen by the two online sellers (\( K = \{00, 01, 10, 11\} \)) and whether or not the platform enables online reviews (\( W = \{N, R\} \)). Lemma 1 implies that as long as the efficiency of Seller \( H \) selling a high-quality product relative to that of Seller \( L \) selling a low-quality product \( (\delta^w) \) is comparable (between \( a_1 \) and \( a_2 \)), the duopoly can coexist. This then implies that when \( r^w_0 < \alpha_i < 1 \), Seller \( H \) will be driven out of the market; when \( r^w_0 > a_2 > 1 \), Seller \( L \) will be driven out of the market. Here we focus on the case when the two online sellers are in sustained competition, that is, they can coexist. Since the boundary values (\( a_1 \) and \( a_2 \)) depend only on the returns rates of the two sellers, they only need to know whether or not their relative efficiency \( (r^w_0) \) falls in the range \( [a_1, a_2] \) to know whether or not they can survive in a competitive market. Obviously, the presence of online reviews affects the efficiencies of both sellers, and thus affects their relative efficiency \( (r^w_0) \), where \( a_1, a_2, r^w_0 \) are listed in Table A1 in the Appendix.

### 4.3. Sellers’ decisions on returns policies

In the first stage of the game, the two online sellers simultaneously decide their own returns policies. We define \( \delta_{iw} = E^i_w - E^0_w \) as the net value of offering an MBG for Product \( i \). We have:

\[
\delta_{iw} = a_i \Gamma + (1 - a_i)(s_i - h_i - t_i)
\]

Notice that \( \Gamma = r \) for \( W = R \) (with online reviews) and \( \Gamma = 1 \) for \( W = N \) (without online reviews). \( a_i \Gamma \) and \( s_i = (1 - a_i)(s_i - h_i - t_i) \) represent the impact of Seller \( i \)'s no-refund policy and online reviews, and the expected recovery value of a returned Product \( i \) on the net value of offering an MBG for Product \( i \), respectively. The net salvage of Product \( i \) (the salvage value after offsetting Seller \( i \)'s costs of handling the returned product and the customer’s cost of returning the product) is \( s_i = s_i - h_i - t_i \). With the profits of the duopoly in Eq. (9), we have the first-stage game decisions on returns policy, as summarized in Proposition 2, where \( s_i, \delta_{iw}, \delta_{ww} \) are listed in Table A1 in the Appendix.

**Proposition 2.** For \( W = \{N, R\} \) and \( i = \{H, L\} \), the first-stage game of the duopoly has a unique returns policy equilibrium: \( k_i^* = 1 \) if \( \delta_{iw} \geq 0 \) and \( k_i^* = 0 \) if \( \delta_{iw} < 0 \).

**Proposition 2** shows that in a duopoly market, offering an MBG is a dominant strategy for both online sellers, as long as the net value of offering an MBG (\( \delta_{iw} \)) is non-negative, no matter what returns policy is offered by the competitor. Chen and Chen (2017b) show that as long as the net salvage value of Product \( i \) is positive (\( \delta_{iw} > 0 \)), Seller \( i \) should offer an MBG returns policy; here Proposition 2 extends this result by considering that the customer’s valuation of a product is discounted for a no-refund policy and adjusted by the availability of online reviews. Even more than in a physical store, where the customer can visually inspect the product, in online shopping a no-refund policy will decrease the customer’s valuation on the product. The implication of Proposition 2 is that with the customer’s dissatisfaction on a no-refund policy, the seller’s choice of whether or not to offer an MBG policy depends on several factors: the net salvage value of the product (\( \delta_{iw} \)), reflecting the efficiency of Seller \( i \) in handling the returns product), the quality of the product, the weight the customer assigns to information from online reviews, and the customer’s dissatisfaction on a no-refund policy (\( \eta \)). Proposition 2 provides an easy-to-implement mechanism for Seller \( i \)'s choice of returns policy, as the decision depends only on the factors/parameters related to its own selling channel and product, independent of the competitor’s. The online seller can and should carefully estimate these factors. Proposition 2 also suggests that even when \( s_i \) is negative, Seller \( i \) may still offer an MBG. The higher the dissatisfaction the customer has on a no-refund policy (\( \eta \)), the more likely the online seller is to offer an MBG.

Comparing \( \delta_{iw} \) and \( \delta_{ww} \) (Eq. (11)), we have a direct result as follows.

**Lemma 2.** For \( i = \{H, L\} \), Seller \( i \) is less likely to offer an MBG in the presence of online reviews.

Eq. (11) gives \( \delta_{iw} < \delta_{ww} \), implying that the value of offering an MBG is reduced (from \( a_{iw} \) to \( a_{ww} \)) in the presence of online product reviews. **Lemma 2** shows that when the customer can obtain information on the product through online reviews before purchase, the value of an MBG is reduced. This is because online reviews provide a customer with additional information on the products before purchase, and reduce the risk of mismatch with expectations, reducing the risk of a need to return the product. **Lemma 2** also suggests that the more information the online reviews provide, the less dependence a customer has on an MBG policy. The implication is that if the members of the duopoly decide not to offer MBGs, they should make efforts to improve the usefulness of their online reviews to reduce the customer’s risk of buying an unsatisfactory product. In this way, the sellers can save the cost of returns service while keeping the customer’s loyalty.

### 5. The impact of online reviews

Eqs. (9)-(10) show that a seller’s demand and profit increase with its own maximum net shared value \( (E^i_w) \), but decrease with the competitor’s maximum net shared value, for any returns policy \( K \) of the duopoly and both with and without online reviews. In this section, we first discuss the impact of online reviews on \( E^i_w \).
5.1. Impact of online reviews on the maximum net shared value

Let $\Delta E_i^K = p_{i}^{\Theta_s} - p_{i}^\Theta$ be the difference in Seller $i$’s efficiency with and without online reviews if it offers a returns policy $k_i$. We have the following results:

**Proposition 3.** $\Delta E_i^K < 0$ if $k_i = 1$; if $k_i = 0$, $\Delta E_i^K > 0$ when $\theta_i > 1 - \eta$ and $\Delta E_i^K < 0$ otherwise.

**Proposition 3** implies that if online Seller $i$ offers an MBG ($k_i = 1$), online product reviews reduce the seller’s efficiency of selling the product. In addition, $\Delta E_i^K$ increases with $\theta_i$ and $r$, and decreases with $a_i$. In general, the value of online reviews ($\theta_i$) reflects the customers’ aggregate valuation on Product $i$ after experiencing the product. An individual customer’s valuation of Product $i$ pre-purchase changes after reading online reviews, in view of other customers’ experiences with the product. **Proposition 3** shows that the presence of online reviews results in a decrease in the maximum net shared value if an MBG is offered. It is interesting to see that if Seller $i$ offers a no-refund policy ($k_i = 0$), the presence of online product reviews will not always reduce Seller $i$’s efficiency in selling the product; if the value of the online product reviews is sufficiently high, the reviews can increase all customers’ expected value on the products, and enhance Seller $i$’s efficiency in selling the product. The implication of **Proposition 3** is that online reviews significantly impact a seller’s efficiency in selling the product, as they change the customer’s valuation and the decision to purchase and/or return the product. In addition, **Proposition 3** suggests that sellers with no refund policy could improve their efficiency in selling products by making efforts to, for example, effectively respond to customers, in order to have favorable reviews on their products.

**Proposition 2** provides a simple condition for a seller when it offers an MBG ($\delta_{ow} > 0$) with and without online reviews. A seller needs to evaluate $\delta_{ow}$ in deciding its optimal returns policies.

To examine the impact of online reviews on sellers’ decisions with and without an MBG, we first compare the equilibrium prices, demands, and profits of both sellers for the cases with and without reviews, and for both sellers with an MBG ($K = k_0k_1 = \{11\}$) and with a no-refund policy ($K = k_0k_1 = \{00\}$). To easily and clearly present the results, we define $\Delta p_i^K = p_i^{\Theta_s} - p_i^\Theta$, $\Delta D_i^K = D_i^{\Theta_s} - D_i^\Theta$, and $\Delta \pi_i^K = \pi_i^{\Theta_s} - \pi_i^\Theta$, where $i = H.L$. We then examine the interactions between the online reviews and customer returns policies.

5.2. Impact of online reviews on the seller’s decision

Let $c_i = c_s - c_s$ be Seller $i$’s unit acquisition cost (if $k_i = 0$) or unit net acquisition cost after offsetting the recovery value of a returned product if $k_i = 1$, where $s_i = (1 - \alpha_i)(s_i - b_i - t_i)$. We also define $\theta_{\Theta_s}^i$, $\theta_{\Theta_s}^H_i$, and $\theta_{\Theta_s}^L_i$ as boundary values for $\Delta p_i^K = 0$, $\Delta D_i^K = 0$, and $\Delta \pi_i^K = 0$, respectively, where we can obtain $\theta_{\Theta_s}^L_i < \theta_{\Theta_s}^H_i < \theta_{\Theta_s}^i$ and $\phi_{\Theta_s}^i$, $\beta_s$, and $\gamma_s$ are listed in Table A1 in the Appendix. Then we have $\theta_{\Theta_s}^i = \gamma_1(1 + l_i) + \phi_{\Theta_s}^i$ and $\theta_{\Theta_s}^i = \gamma_2(1 - l_i) + \phi_{\Theta_s}^i$, for $j = p$, $D$, $\pi$, where $\gamma_1 = \frac{1}{\alpha_i} = \frac{\sum_i \theta_i}{\sum_i \theta_i}$, $r_2 = \alpha_i = \frac{s_i - b_i - t_i}{\sum_i \theta_i}$, and $r_1 < r_2 < 1$; $\phi_{\Theta_s}^i$ and $\phi_{\Theta_s}^H_i$ are summarized in Table A2 in the Appendix. Comparing the optimal prices, demands, and profits with online reviews to those without online reviews in Eqs. (8)-(10), **Proposition 4** presents the impact of the values of online reviews on Seller $i$’s price, demand, and profit, where $i = H.L$.

**Proposition 4.** For $K = \{00, 11\}$, the impact of the online reviews on the optimal prices, demands, and profits of the two sellers are summarized in Table 2 and illustrated in Fig. 3.

Note that in Fig. 3, the changes due to online reviews vary with the value of the reviews. $\theta_{\Theta_s}^L_i$, $\theta_{\Theta_s}^H_i$, and $\theta_{\Theta_s}^i$ are threshold values of online reviews with and without online reviews by comparing with the results of Seller $i$’s demand, profit, and price without online reviews.

| $\theta_i$ | $\theta_{\Theta_s}^L_i$ | $\theta_{\Theta_s}^H_i$ | $\theta_{\Theta_s}^i$ |
|----------|----------------------|----------------------|----------------------|
| $\phi_{\Theta_s}^L_i$ | $\phi_{\Theta_s}^H_i$ | $\phi_{\Theta_s}^i$ |
| $\Delta p_i^K$ | $\Delta D_i^K$ | $\Delta \pi_i^K$ |

**Table 2**

The impact of online reviews on Seller $i$’s optimal price, demand and profit.
profitable.

The impacts of the value of online reviews of Product i (\(\theta_i\)) on the prices, demands, and profits of the two products are summarized in the following proposition.

**Lemma 3.** For \(K = \{00, 11, 1\}\),

\[
\begin{align*}
\text{(a)} & \quad \frac{\partial \pi}{\partial \theta_i} < 0, \quad \frac{\partial D_i}{\partial \theta_i} < 0, \quad \text{and} \quad \frac{\partial p_i}{\partial \theta_i} < 0, \quad \frac{\partial D_{-i}}{\partial \theta_i} < 0, \quad \frac{\partial K_i}{\partial \theta_i} < 0, \quad \text{and} \quad \frac{\partial p_{-i}}{\partial \theta_i} < 0. \\
\text{(b)} & \quad \frac{\partial \pi}{\partial \theta_i} > 0, \quad \frac{\partial D_i}{\partial \theta_i} > 0, \quad \frac{\partial p_i}{\partial \theta_i} > 0, \quad \frac{\partial D_{-i}}{\partial \theta_i} > 0, \quad \text{and} \quad \frac{\partial K_i}{\partial \theta_i} > 0, \quad \frac{\partial p_{-i}}{\partial \theta_i} > 0.
\end{align*}
\]

**Lemma 3** shows that in the presence of online reviews, for given returns policies of the two sellers, \(\theta_i\) positively impacts Seller i’s own selling price, market share, and profit, and negatively impacts the competitor’s price, market share, and profit. Furthermore, the valuation of online reviews on a seller’s own product has a larger effect on price, demand, and profit than that of online reviews of the competitor’s product. **Lemma 3** implies that in a market with competition, an online seller should consider customer reviews on both its own and its rival’s products.

### 5.3. Impact of online reviews on the sellers’ choice of returns policy

Comparing the impact of the value of online reviews (\(\theta_i\)) on the price, demand, and profit of Product i with and without an MBG policy, we summarize the results in **Lemma 4**.

**Lemma 4.** For \(i = H, L\),

\[
\begin{align*}
\text{(a)} & \quad \frac{\partial \pi_i}{\partial \theta_i} > 0 \quad \text{and} \quad \frac{\partial p_i}{\partial \theta_i} = \frac{\partial p_{-i}}{\partial \theta_i}, \\
\text{(b)} & \quad \frac{\partial \pi_i}{\partial \theta_i} > 0 \quad \text{and} \quad \frac{\partial p_i}{\partial \theta_i} > 0, \quad \frac{\partial D_i}{\partial \theta_i} > 0, \quad \frac{\partial D_{-i}}{\partial \theta_i} > 0, \quad \frac{\partial p_{-i}}{\partial \theta_i} > 0, \quad \frac{\partial D_{-i}}{\partial \theta_i} > 0, \quad \text{where} \quad \gamma_1 > \gamma_2.
\end{align*}
\]

**Lemma 4** shows that in the presence of online reviews, the impact of review value on the price of Product i with an MBG is higher than that with a no-refund policy. This suggests that the price with an MBG might be more sensitive to the change of review value than the price with a no-refund policy. The impact of review value on demand, however, is independent of the returns policy, and its impact on the profit of a seller with an MBG depends on the net shared value of the returns service of the seller relative to that of its competitor. When the net shared value of the returns service of Seller i is relatively higher than that of its competitor, its profit with an MBG is more sensitive to change of online review value than with a no-refund policy. This suggests that as the value of its online reviews increases, whether a seller with an MBG can be more profitable depends on the net shared value of its returns service relative to that of its competitor; furthermore, Seller L’s net shared value of returns service should be high relative to that of Seller H for Seller L to be more profitable with an MBG.

These results suggest that when the two sellers decide to offer MBGs (improving the efficiency of handling customer returns), they can benefit more from an increase in the value of online reviews.

### 5.4. Impact of interactions between online reviews and returns policies

Let \(\tilde{S}_{\text{H}} = \gamma_2 S_i, \tilde{S}_{\text{L}} = \gamma_1 S_i, \tilde{S}_{\text{H}} = \gamma_1 S_i + 2\sqrt{r} (a_i - a_i), \) and \(\tilde{S}_{\text{L}} = \gamma_1 S_i + \eta \sqrt{r} (a_i - a_i)\). Comparing \(\theta_i^{11}\) to \(\theta_i^{00}\) (the boundaries which distinguish the positive and negative effects of online reviews on Seller i’s price, demand, and profit with and without returns service, where \(i = p, D, x\)), the impact of the interactions between online reviews and returns policies on the duopoly’s prices, demands, and profits is summarized in **Proposition 5**.

**Proposition 5.** For Seller i,

\[
\begin{align*}
\text{(a)} & \quad \theta_i^{11} > \theta_i^{00}, \\
\text{(b)} & \quad \theta_i^{11} > \theta_i^{00} \quad \text{and} \quad \theta_i^{11} > \theta_i^{00}, \quad \text{if} \quad S_i < \tilde{S}_{\text{H}}; \quad \theta_i^{11} < \theta_i^{00} \quad \text{and} \quad \theta_i^{11} < \theta_i^{00}, \quad \text{if} \quad S_i > \tilde{S}_{\text{L}}.
\end{align*}
\]

**Proposition 5** shows that when it offers an MBG, online Seller i should have a higher value of online reviews, such that it can set a higher price than with a no-refund policy. Without online reviews, the customer evaluates a product based on its own valuation only, and valuation is lower without returns service than with an MBG (because the returns service reduces the customer’s risk of mismatch). Online reviews may improve the customer’s expected value of the product, if they are favorable enough (\(\theta_i > 1 - \eta\)), and reduce the value of the returns service. In such a case, the seller offering a product with good reviews and a no-refund policy has more space to increase the retail price. In other words, the more customers value the returns service, the lower the valuation on a no-refund product, and the more likely that price can be increased in the presence of favorable online reviews. Favorable online reviews have a higher impact on the price of a no-returns product.

As compared to a no-refunds return policy, whether or not online reviews will enable a seller to attract more customers and be more profitable with an MBG depends on \(S_i\) (the expected recovery value of a returned product). If \(S_i\) is low relative to that of its competitor (\(S_i < \tilde{S}_{\text{L}}\)), online Seller i needs better online reviews for its product, such that it can attract more demand and be more profitable with an MBG. This means that online reviews have less positive effect on Seller i’s demand in the case with an MBG (\(\theta_i^{11} > \theta_i^{00}\)). Since the lower net salvage value may suggest a higher cost in handling customer returns, the Seller i who offers an MBG may lose the advantage in competition to gain market share if the reviews are not favorable enough; with the impact on price, it is obvious that Seller i is less likely to benefit from online reviews with an MBG (\(\theta_i^{11} > \theta_i^{00}\)). This is because Seller i has less space to raise the selling price in view of positive online reviews, and less chance of expanding the market, due to the high cost of offering an MBG. If \(S_i > \tilde{S}_{\text{L}}\), a seller is likely to expand its demand by offering an MBG in the presence of online reviews. This furthermore suggests that the higher \(S_i\), the more value the seller can recover from a returned product and the lower the cost of offering an MBG, which provides more space for the seller to reduce its price to compete with its rival in the presence of online reviews. Therefore, by providing a good returns service (an MBG), online Seller i can attract even more demand. Whether or not Seller i is likely to be more profitable from online reviews with an MBG depends on the strength of the positive effect of the demand increase and the negative effect of the price increase. If and only if \(S_i > \tilde{S}_{\text{L}}\) can the advantage due to a higher net expected salvage value offset the lower expected value of an MBG resulting from online reviews, and allow the seller to be more profitable from online reviews with an MBG.

The interactions between the impact of online reviews and customer returns in **Proposition 5** provide some guidance for online sellers in deciding their returns policies. In the presence of online reviews, if the efficiency of handling customer returns is relatively low, they benefit less by offering an MBG; this benefit can be enhanced if the salvage value of a returned product sufficiently high. This result may explain the practice of online sellers in some platforms (such as Tmall.com and Amazon.com) in setting restrictions on returns (requiring intact tags and/or original packaging) to ensure a high salvage value of the returned product.

### 5.5. Impact of online reviews on the competition in the duopoly

We now discuss the impact of online reviews on the competition of the duopoly. We define \(\theta_i^{p} = 1 - (1 - k_i)\eta\) (where \(\Delta \theta_i^{p} = \Delta \theta_i^{x} = 0\) when \(\theta_i = \theta_i^{p}\), see in Fig. 4(a)), \(\theta_i^{x} = \frac{c_k}{\lambda x} \left(\text{where} \Delta \theta_i^{x} = \Delta \theta_i^{x} = 0\right)\) when \(\theta_i = \theta_i^{p}\), see in Fig. 4(b)), and \(\frac{\partial \pi_i}{\partial \theta_i} = \frac{\gamma_1 (1 - [1 - \theta_i] \eta)}{[1 + \gamma_1 \eta]}\) (where \(\Delta \theta_i^{p} = \Delta \theta_i^{x} = 0\) when
The impacts of online product reviews on the two competing sellers

\( \theta_i = \tilde{\theta}_i \) (see in Fig. 4(c)), which suggests that when \( \theta_i^{\lambda} = \tilde{\theta}_i^{\lambda} \), where \( i = L, H \) and \( j = D, \pi \), online reviews have no impact on the price, demand, or profit of either seller. We further define \( \rho_j^{\lambda} = \frac{\Delta \pi_j^{\lambda}}{\Delta \theta_j^{\lambda}} \), reflecting the impact of the value of online reviews on Seller \( j \)'s price, demand, and profit relative to that of Seller \( H \), where \( \theta_j^{\lambda} \), \( \tilde{\theta}_j^{\lambda} \), and \( \rho_j^{\lambda} \) are listed in Table A1 in the Appendix. The whole space \((\theta_i, \theta_j)\) can be divided into eight regions by \( \rho_j^{\lambda} \) and \( \tilde{\rho}_j^{\lambda} \), as shown in Fig. 4. For given returns policies \( K \), Proposition 6 presents the impacts of online product reviews on the competition of the duopoly in terms of prices, demands, and profits. The results are graphically illustrated in Fig. 4.

**Proposition 6.** For \( K = \{0, 11\} \) and \( j = D, \pi \), the impacts of online product reviews on the two competing sellers’ prices, demands, and profits are summarized in Table 3.

Proposition 6 and Fig. 4 show that if \( \rho_j \in (\alpha_1, \alpha_2) \), where \( j = D, \pi \), the presence of online reviews has the same influence trend (either positive or negative) on both sellers’ prices, demands, and profits, respectively; otherwise, online reviews positively influence one seller, but negatively influence the other seller. We refer to the range \((\alpha_1, \alpha_2)\) as the “symmetric effect range.” Now, we discuss the impact of online reviews on both sellers when the ratio of changes due to online reviews is in the symmetric effect range.

Note that in Fig. 4, +/− denotes positive/negative value of \( \Delta \pi_j \), \( \Delta D_j \), and \( \Delta \pi_i \); the slopes of the blue and orange lines are \( \alpha_1 \) and \( \alpha_2 \), respectively, and the lines outline regions of no change for Sellers \( L \) and \( H \), respectively; the solid lines indicate case with MBG and the dotted indicate no-returns case. Proposition 6 shows that the impacts of online reviews on sellers’ optimal prices, demands, and profits depend on the relative difference in value of the online reviews of the two products. Both online sellers will mark down their prices if the values of the online reviews (the scores) of the two products are comparable (in Region V) and low \((\theta_i < \tilde{\theta}_i)\), leading to intensified price competition (negative price effect on the competition). The intuition is that low values of online reviews for both products reduce the difference in the customer’s valuation on the two products, and at the same time reduce the customer’s utility overall, resulting in intensified price competition between the two sellers. On the other hand, when the values of online reviews are high for both products \((\theta_i > \tilde{\theta}_i)\) (in Region I), the presence of online reviews softens the price competition (positive price effect on the competition). When the value of online reviews of one product is significantly higher than that of the competitor’s product, the online reviews have a positive impact on the seller’s price and a negative impact on the competitor’s price (Fig. 4(a)). The implication of the result

**Table 3.** The impacts of online product reviews on the two competing sellers’ prices, demands, and profits.

| \( \theta_i^{\lambda} \) | \( \theta_j^{\lambda} \) | \( \Delta \pi_j^{\lambda} \) | \( \Delta D_j^{\lambda} \) |
|-------------------|-------------------|-------------------|-------------------|
| \( \alpha_1 < \rho_j^{\lambda} < \alpha_2 \) | \( \Delta \pi_j^{\lambda} < 0 \) (Region V) | \( \Delta \pi_j^{\lambda} > 0 \) (Region I) |
| \( \rho_j^{\lambda} > \alpha_2 \) | \( \Delta \pi_j^{\lambda} < 0 \), \( \Delta \pi_j^{\lambda} > 0 \) (Region VI) | \( \Delta \pi_j^{\lambda} > 0 \), \( \Delta \pi_j^{\lambda} < 0 \) (Region II) |
| \( 0 < \rho_j^{\lambda} < \alpha_1 \) | \( \Delta \pi_j^{\lambda} > 0 \), \( \Delta \pi_j^{\lambda} < 0 \) (Region VIII) | \( \Delta \pi_j^{\lambda} < 0 \), \( \Delta \pi_j^{\lambda} > 0 \) (Region IV) |
| \( \alpha_1 < \tilde{\theta}_j^{\lambda} < \alpha_2 \) | \( \alpha_1 < \tilde{\theta}_j^{\lambda} < \alpha_2 \), \( \alpha_1 > \tilde{\theta}_j^{\lambda} \) | \( \alpha_1 < \tilde{\theta}_j^{\lambda} \), \( \alpha_1 < \tilde{\theta}_j^{\lambda} \) |
| \( \rho_j^{\lambda} < 0 \) | \( \Delta \pi_j^{\lambda} < 0 \), \( \Delta \pi_j^{\lambda} > 0 \) (Region VII) | \( \Delta \pi_j^{\lambda} > 0 \), \( \Delta \pi_j^{\lambda} < 0 \) (Region III) |
is that collaboration between the sellers in improving the value of online reviews could soften the price competition. Notice that the dash-lines and solid lines are for the cases $K = \{1, 1\}$ and $K = \{0, 0\}$, respectively, implying that an MBG at both sellers will always intensify the price competition of the duopoly.

The impact on the demands of the two products (Fig. 4(b)) depends on whether the value of product $i$’s online reviews is higher or lower than the net shared cost of the product divided by the customer’s satisfaction ($\bar{\theta}_{\alpha} = \frac{c_{0}}{\sqrt{\alpha}}$ “net unit cost”). If the review values of both products are higher than their net unit costs ($\theta_{i} > \bar{\theta}_{\alpha}$ in Region I), online reviews can serve as a free advertisement for the products, attracting more customers and improving the demand for both sellers. Conversely, if the value of online reviews is low ($\theta_{i} < \bar{\theta}_{\alpha}$ in Region V) for both products, both sellers will risk losing customers, and the total market demand will decrease (positive demand effect on the competition). Negative reviews may imply that the product is not as good as advertised, and both sellers will lose demand (negative demand effect on the competition).

Both sellers benefit in terms of profit from extremely positive reviews ($\theta_{i} > [1 - (1 - k)\eta])$ (Fig. 4(c)), as good reviews provide an opportunity for them to raise their prices and expand market size (positive effects in both price and demand). They both suffer from very negative reviews ($\theta_{i} < \bar{\theta}_{\alpha}$), due to both negative price and negative demand effects. When online reviews are moderate ($\bar{\theta}_{\alpha} > \theta_{i} > \bar{\theta}_{\alpha}$), both sellers will reduce prices due to the lower customer valuation on the products and the intensified market competition, but demands will increase due to the price reduction. If the online reviews are favorable enough ($\theta_{i} > \bar{\theta}_{\alpha}$ in Region I), they will enhance both sellers’ profits, since the positive effect of online reviews (demand expansion effect) outweighs the negative effect of lower customer valuations and intensified market competition.

Proposition 6 suggests that under market competition, when the values of the reviews for the two products are comparable and relatively high, online reviews can benefit both sellers; when the values of the reviews are unbalanced only the high value seller will benefit. In addition, when the values are comparable and relatively low, both sellers are worse off, leading to a “prisoner’s dilemma.” The results suggest that a collaborative effort between the two sellers to improve the quality of online reviews (such as by encouraging answers to questions that customers care most about and rewarding informative reviews), might benefit both sellers.

The impact of online reviews on the two sellers is different, however, under different returns policies. We summarize in Proposition 7.

### Proposition 7

For $j = p, D$, $\pi$ and $i = H, L$,

1. $\tilde{\theta}_{H} > \tilde{\theta}_{L} > \tilde{\theta}_{00}$, if $S_{i} < 0$;
2. $\tilde{\theta}_{H} > \tilde{\theta}_{00} > \tilde{\theta}_{L}$, and $\tilde{\theta}_{H} > \tilde{\theta}_{00}$, if $0 < S_{i} < \eta/\sqrt{\alpha}$;
3. $\tilde{\theta}_{H} > \tilde{\theta}_{00} > \tilde{\theta}_{L}$, and $\tilde{\theta}_{H} > \tilde{\theta}_{00}$, if $S_{i} > \eta/\sqrt{\alpha}$.

When both sellers offer an MBG, they have to mark down their prices because online reviews reduce the customers’ highest valuation on the product (see dash lines in Fig. 4(a); recall that good online reviews reduce the risk of product/expectation mismatch and thus reduce the value of the MBG). When both sellers offer a no-refund policy, the customer’s valuation on the product is low, and if reviews of both products are favorable enough ($\tilde{\theta}_{i} > 1 - \eta$) the reviews may improve the customer’s highest valuation on both products and allow price increases. In other words, online reviews only intensify the competition between two sellers with an MBG, but high value online reviews may soften the price competition between two sellers with a no-refund policy. The results in Proposition 7 imply that as compared to offering a no-refund policy at both sellers, offering an MBG at both sellers intensifies the price competition in the market. This result differs from the study of Chen and
choose a returns policy. Our research also shows that the customer is less likely to rely on an MBG in the presence of online reviews, as online reviews provide additional pre-purchase information and reduce the risk of dissatisfaction. Our results suggest that online reviews with comments that contain a lot of information and small variance may be most useful to customers, so the online seller with useful reviews and small variance can reduce the likelihood of customer returns and reduce the costs (to customer and seller) of returns service.

Our study also suggests that an online seller who sells a high-quality product is more motivated to generate reviews, and will benefit from relatively favorable reviews, as those reviews have more effect on the high-quality seller than on the low-quality seller. For a competing duopoly, online reviews may present the same trend of influence (either positive or negative) on both sellers, when the reviews of the two products are within a symmetric effect region. It is interesting that price competition is intensified between the two sellers if both offer an MBG. Nevertheless, if the salvage value of the product is sufficiently high (for example, durable products), both online retailers are more likely to benefit from online reviews when they offer an MBG.

Our research provides new insights into the behavior of competitive online sellers facing customer returns and online reviews. In setting its returns policy, an online retailer must of course estimate the cost of handling the returned product, the customer’s cost of returning the product, and the salvage value of the returned product. Our results emphasize, however, that the online retailer must also evaluate the online reviews posted by customers who have purchased and experienced the products.

Our study can be extended in several ways. Here we consider the impact of online reviews on the customer’s valuation on product, but it would be interesting to examine how online reviews can affect the customer’s satisfaction rate. The study could also be extended to examine how online reviews impact the decisions of the retailers and manufacturers in a supply chain facing customer returns. Finally, the multi-period case, in which both sellers offer an MBG policy for a certain period of time, but a no-refund policy afterwards (final sale), might shed new light on all of the conditions and results discussed here.

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Appendix

Table A1

| Other notation |
|----------------|
| Description    |

\[ m_{kW}^h \]

The highest net valuation of the customer \((v - 1)\) for Product \(i\). \(m_{kW}^h = a_i(1 - (1 - k_i)\eta)^r + (1 - \eta)^r - (1 - a_i)k_i \eta \).

\[ b_{kW}^h \]

The maximum net shared value of Seller \(i\) \(b_{kW}^h = a_i(1 - (1 - k_i)\eta)^r + (1 - \eta)^r - (1 - a_i)k_i \eta + k_i(1 - a_i)k_i - \tau \).

\[ \Delta_{kW}^h \]

Seller \(i\)'s efficiency of selling a high-quality product relative to that of Seller \(i\) selling a low-quality product. \(\Delta_{kW}^h = \frac{b_{kW}^h}{b_{kW}^l} \).

\[ \delta_k \]

The expected recovery value of a returned Product \(i\) with an MBG for Product \(i\). \(\delta_k = -1 \tau - (1 - a_k)k_i - \tau \).

\[ \Delta_{kW}^\tau \]

The net salvage of Product \(i\). \(\Delta_{kW}^\tau = -1 \tau - (1 - a_k)k_i - \tau \).

\[ C_i^\tau \]

Seller \(i\)'s unit acquisition cost (if \(k_i = 0\)) or unit net acquisition cost after offsetting the recovery value of a returned product (if \(k_i = 1\)). \(C_i^\tau = -1 \tau - k_i \).

Variables for Simplification

- \(\alpha_i, \alpha_2\): the boundary values where the two products coexist in the market, where \(\alpha_1 = \frac{a_1}{2a_1 - a_2}\) and \(\alpha_2 = \frac{2a_1 - a_2}{a_2}\).
- \(\phi_{kW}^h, \phi_{kW}^l, \phi_{kW}^h\)
  - the boundary values of \(\theta_i\) for \(\Delta_{kW}^h = 0, \Delta_{kW}^l = 0\), and \(\Delta_{kW}^h - \Delta_{kW}^l = 0\), respectively.
- \(\phi_{kW}^h\)
  - the boundary values of \(\theta_i\) for \(\Delta_{kW}^h - \Delta_{kW}^l = 0\).
- \(\phi_{kW}^h, \phi_{kW}^l, \phi_{kW}^h\)
  - the boundary values of \(\theta_i\) for \(\Delta_{kW}^h = 0, \Delta_{kW}^l = 0\), and \(\Delta_{kW}^h - \Delta_{kW}^l = 0\), respectively.
- \(\phi_{kW}^h\)
  - the impact of the value of online reviews on Seller \(i\)'s price, demand, and profit relative to that of Seller \(H\), where \(j = p\ D_2\).

Table A2

| \(i = H\) | \(i = L\) |
|----------------|----------------|
| \(\phi_{kW}^h\) | \(\phi_{kW}^l\) |
| \(1 - (1 - k_i)\eta\) + \(\phi_{kW}^h\) | \(1 - (1 - k_i)\eta\) + \(\phi_{kW}^l\) |
| \(\phi_{kW}^h\) | \(\phi_{kW}^l\) |
| \(\phi_{kW}^h\) | \(\phi_{kW}^l\) |
| \(\phi_{kW}^h\) | \(\phi_{kW}^l\) |

Proof of Proposition 1. \(\forall W = \{N, R\}\) and \(k_i = \{0, 1\}\), where \(i = H, L\) with online Seller \(i\)'s profit function in Eq. (6), we have \(\phi_{kW}^h = \frac{a_i}{2a_1 - a_2} < 0\), \(\phi_{kW}^l = \frac{2a_1 - a_2}{a_2} > 0\), and \(\phi_{kW}^h = \frac{a_i}{2a_1 - a_2} < 0\). Thus, the profits of online Sellers \(H\) and \(L\) are concave in \(p_{kW}^h\) and \(p_{kW}^l\)

Proof of Lemma 1. \(\forall W = \{N, R\}\), with demands of two online sellers in Eq. (8), when \(\alpha_1 \leq \alpha_2 \leq \frac{2a_1 - a_2}{a_2}\), we have \(\Delta_{kW}^h = \frac{(2a_1 - a_2)\alpha_1}{a_2}\) and \(\Delta_{kW}^l = \frac{(2a_1 - a_2)\alpha_2}{a_2}\) and \(\Delta_{kW}^h - \Delta_{kW}^l = 0\).

Proof of Proposition 2. With profits of two online sellers in Eq. (9), \(\forall W = \{N, R\}\) and \(\delta_{kW} > 0\), \(\phi_{kW}^h = \frac{2a_1 - a_2}{a_2} > 0\), \(\phi_{kW}^l = \frac{a_2}{a_2} > 0\), \(\phi_{kW}^h = \frac{2a_1 - a_2}{a_2} > 0\), \(\phi_{kW}^l = \frac{a_2}{a_2} > 0\), \(\phi_{kW}^h = \frac{2a_1 - a_2}{a_2} > 0\), \(\phi_{kW}^l = \frac{a_2}{a_2} > 0\).

Proof of Lemma 2. \(\forall W = \{N, R\}\), with demands and profits of two online sellers in (8)-(10), we can see that \(\Delta_{kW}^h = \frac{(2a_1 - a_2)\alpha_1}{a_2}\) and \(\Delta_{kW}^l = \frac{(2a_1 - a_2)\alpha_2}{a_2}\) and \(\Delta_{kW}^h - \Delta_{kW}^l = 0\).

Proof of Proposition 4. \(\forall K = \{00, 11\}\), with prices, demands, and profits of two online sellers in (8)-(10), we can see that \(\Delta_{kW}^h = \frac{(2a_1 - a_2)\alpha_1}{a_2}\) and \(\Delta_{kW}^l = \frac{(2a_1 - a_2)\alpha_2}{a_2}\) and \(\Delta_{kW}^h - \Delta_{kW}^l = 0\).

Proof of Lemma 3. \(\forall W = \{N, R\}\), with demands and profits of two online sellers in Eqs. (7)-(9), for \(k_i = \{0, 1\}\), \(\alpha_1 > \alpha_2\) and \(r < 1\), we can obtain \(\phi_{kW}^h = \frac{2a_2(2a_1 - a_2)(1 - \tau)(1 - r)}{a_2(4a_1 - a_2)\tau^{1 - r}T}\) and \(\phi_{kW}^l = \frac{(2a_2(2a_1 - a_2)(1 - \tau)(1 - r))}{a_2\tau^{1 - r}T}\).

Proof of Proposition 5. \(\forall K = \{00, 11\}\), with prices, demands, and profits of two online sellers in (8)-(10), we can see that \(\Delta_{kW}^h = \frac{(2a_1 - a_2)\alpha_1}{a_2}\) and \(\Delta_{kW}^l = \frac{(2a_1 - a_2)\alpha_2}{a_2}\) and \(\Delta_{kW}^h - \Delta_{kW}^l = 0\).
Proof of Lemma 4. For $a_1 < a_2 < 1$ and $r < 1$, we have $\frac{\partial L}{\partial a_1} - \frac{\partial L}{\partial a_2} = -\frac{2(1-a_1)(1-r)}{(4u_1-a_1)} > 0$ and $\frac{\partial L}{\partial a_1} - \frac{\partial L}{\partial \theta} = -\frac{4u_1(1-a_1)(1-r)}{(4u_1-a_1)^2} < 0$. For Seller H, if $\theta_{HL} > \gamma_1 \theta_{LB}$, then $\frac{\partial L}{\partial \theta} > 0$. For Seller L, if $\gamma_1 \theta_{LB} > \theta_{HL}$, then $\frac{\partial L}{\partial \theta} < 0$.

Proof of Proposition 5. For $\gamma_1 < \gamma_2 < 1$, we have $\frac{\partial L}{\partial \theta} - \frac{\partial L}{\partial \theta} = \eta(1-\gamma_1) > 0$ and $\frac{\partial L}{\partial \theta} - \frac{\partial L}{\partial \theta} = \eta(1-\gamma_2) > 0$. For Seller H, when $S_W < \gamma_2 S_W$, we have $\frac{\partial L}{\partial \theta} > 0$. For Seller L, when $S_W < \gamma_1 S_W$, we have $\frac{\partial L}{\partial \theta} > 0$.

Proof of Proposition 6. By solving $\partial L / \partial \theta = 0$ and $\partial L / \partial \theta = 0$, we can obtain $\theta_H = 1 - (1-k_H)\theta_H$ and $\theta_L = 1 - (1-k_L)\theta_H$. By solving $\partial L / \partial \theta = 0$ and $\partial L / \partial \theta = 0$, we obtain $\theta_H = \frac{c_{\theta_H}}{c_{\theta_H}}$ and $\theta_L = \frac{c_{\theta_L}}{c_{\theta_L}}$. By solving $\partial L / \partial \theta = 0$, we obtain $\theta_H = \frac{c_{\theta_H}}{c_{\theta_H}}$ and $\theta_L = \frac{c_{\theta_L}}{c_{\theta_L}}$.

Given $A^L = \left(1 - r - \frac{a_1}{a_1 - a_2}ight) - \frac{a_1}{a_1 - a_2}$ and $A^H = \left(1 - r - \frac{a_1}{a_1 - a_2}ight) - \frac{a_1}{a_1 - a_2}$, we can obtain $\delta_{HL} = A^L \left(\theta_H - \theta_L\right) \left(\frac{1}{a_1 - a_2} - \frac{1}{a_1 - a_2}\right)$ and $\delta_{HL} = A^H \left(\theta_H - \theta_L\right) \left(\frac{1}{a_1 - a_2} - \frac{1}{a_1 - a_2}\right) > 0$. When $\theta_H > \theta_L$, if $a_1 < a_2$, then $\delta_{HL} > 0$; if $a_1 > a_2$, then $\delta_{HL} < 0$; if $0 < a_1 < a_2$, then $\delta_{HL} > 0$. When $\theta_H < \theta_L$, if $a_1 < a_2$, then $\delta_{HL} > 0$; if $a_1 > a_2$, then $\delta_{HL} < 0$; if $0 < a_1 < a_2$, then $\delta_{HL} < 0$.

Proof of Proposition 7. With $\theta^L_H$ in Lemma 3, for $p = D, x$, and $K \in (0, 11)$, we can obtain $\frac{\partial L}{\partial a_1} - \frac{\partial L}{\partial a_2} = S_t / a_t$ and $\frac{\partial L}{\partial a_1} + \frac{\partial L}{\partial a_2} = S_t / a_t$. Therefore, $\frac{\partial L}{\partial a_1} = \frac{S_t}{a_t}$, $\frac{\partial L}{\partial a_2} = \frac{S_t}{a_t}$.

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