Transportation Research Part E 115 (2018) 1–15

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

Green product pricing with non-green product reference

Zhaofu Hong[a,b], Hao Wang[a], Yugang Yu[b,*]

[a] School of Management, Lanzhou University, Lanzhou, PR China
[b] School of Management, University of Science and Technology of China, Hefei, PR China

A R T I C L E I N F O

Keywords:
Stainability
Green product pricing
Product reference
Consumer environmental awareness
Sustainable supply chain management

A B S T R A C T

This study investigates a green-product pricing problem by taking into account consumer environmental awareness (CEA) and non-green (regular) product reference. The pricing strategies under three scenarios are investigated: single-product pricing; dual-product competition; and asymmetric-information case. The analytical results show that differential pricing strategies should be adopted, facing consumers with differential purchase behaviors (i.e., differential levels of CEA and reference recognition). The green product's pricing strategy is significantly affected by asymmetric information. In contrast to the case of symmetric information, the firm should adopt distinguished pricing strategies in consideration of its green production cost.

1. Introduction

Green products have gained increasing attention in recent years, because of their environmental friendliness in the green manufacturing process, low emissions in use, recyclability, and so on. Owing to their potential environmental benefits, an increasing number of firms are focusing on green products. For example, PepsiCo[1] and Coca-Cola[2] developed recyclable PET plastic soft drink bottles instead of corrugated materials in order to reduce the environmental impact of their products. These two soft-drink giants compete against each other not only on product development, but also on pricing their "green products".[3] They face practical issues: how to price their green products? What factors should be taken account into green product pricing? Pricing green products properly is important for firms, thanks to these products are commonly innovative in markets.

Consumer environmental awareness (CEA) is a critical market-driven factor that facilitates green product development and consumption, which should be considered in green product pricing. Empirical studies have shown that consumers are willing to *pay a premium* for green products, owing to the additional utility they gain from purchasing such products (Schlegelmilch et al., 1996; Hopkins and Roche, 2009). In 2014, a Eurobarometer survey on the environment in the 28 member states of the European Union found that 75% of Europeans are willing to pay more for environmentally friendly products, up from 72% in 2011.[4] In contrast, the Accenture Global Auto Consumer Survey of March 2010 showed that 56% of U.S. and Canadian consumers would *not pay more* for a hybrid or electric car, as compared to a fuel-only vehicle (Drozdenko et al., 2011). Facing the differential consumer behaviors on purchasing green products, deciding on a pricing strategy for green products is an important real-world issue for firms. Therefore, this study investigates the effects of CEA on green-product pricing decisions.

* Corresponding author.
E-mail addresses: hongzhf@lzu.edu.cn (Z. Hong), hwang2015@lzu.edu.cn (H. Wang), ygyu@ustc.edu.cn (Y. Yu).

[1] https://www.greenbiz.com/blog/2014/08/14/how-she-leads-letitia-webster-vf (accessed on 31.05.2011).
[2] https://cleantechnica.com/2014/09/10/coca-colas-plantbottle-conquers-the-world/ (accessed on 10.09.2014).
[3] https://economictimes.indiatimes.com/industry/cons-products/fmcg/pepsi-to-cut-600-ml-pet-bottle-price-by-rs-3-coca-cola-unlikely-to-follow-suit/articleshow/16676878.cms (accessed on 05.10.2012).
[4] http://ec.europa.eu/commfrontoffice/publicopinion/index.cfm/Survey/getSurveyDetail/yearFrom/1974/yearTo/2014/surveyKy/2008 (accessed on 05.2014).

https://doi.org/10.1016/j.tre.2018.03.013
Received 1 November 2017; Received in revised form 17 March 2018; Accepted 26 March 2018
1366-5545/

In addition to CEA, reference is another important factor that affects consumer purchase behaviors when choosing/purchasing green products (Joshi and Rahman, 2015). An example is Method, a cleaning product manufacturer, who puts ‘powerful’ before ‘plant-friendly’ in their advertisements when promoting its green product.[5] Its aim is to meet consumer’s comparison of functional attribute with other non-green products, when telling consumers that their products are environmentally friendly. In this study, the non-green product is taken as the reference for consumers when choosing a green product. To the best of our knowledge, few studies consider the reference effects when investigating the pricing problem of green products. This study also differs from the existing literature in that previous studies usually regard price as the reference point. In contrast, we consider the consumer’s utility as the reference point. Compared to the price reference, the utility reference provides a better way to depict consumers’ purchasing behavior, i.e., comparing products’ cost performance when choosing products.

This study is to fill the above research gaps in the literature related to green-product pricing. More specifically, we investigate pricing strategies for a green product that consider consumer environmental awareness and reference behavior. Here, two products, a green product and regular (non-green) product, compete for market share. A valuation-based demand function is formulated for the two products. Then, the problem is investigated in three different scenarios. First, we study a single-product pricing problem, where the price of the regular product is exogenous. This scenario can occur when the price of a regular product is determined by a fully competitive market, and a manufacturer does not have the power to break the price equilibrium. Next, we examine a dual-production competition problem, where a manufacturer produces the regular product, and the other produces the green product. The manufacturers set a price for their respective products, and compete for market share in order to maximize their own profit. Here, a Nash equilibrium is presented, and the optimal pricing strategies of the green and regular products are proposed. The results show that the optimal price of the green product is not always higher than that of the regular product. The green manufacturer should adopt a pricing strategy based on the quality of the green product and on consumers’ levels of reference recognition and environmental awareness. Finally, we consider a case in which asymmetric information exists in the market, where the manufacturer producing the regular product does not know the pricing and cost information of the manufacturer producing the green product. Several interesting analytical results are obtained. Green products are commonly innovative products in markets, and their pricing strategies are affected significantly by asymmetric information. Compared with the strategies under symmetric information, the pricing strategies of both green and regular products are distinguished. The threshold policies are addressed to point out these differences and to support firms’ decisions in different information cases.

The remainder of this paper is organized as follows. Section 2 presents a review of the literature. Section 3 formulates the demand function and presents the analysis for a single-product pricing problem. Section 4 investigates the pricing problem for a dual-product competition scenario. Then, Section 5 examines the effects of asymmetric information, and presents the optimal pricing strategies. The final section concludes the paper.

2. Literature review

Two streams of research are closely related to our work: green product pricing and reference-dependent demand. In the following sections, we review studies relevant to each stream, and highlight the research gap between this study and the existing literature.

2.1. Competition pricing and green-product pricing

Pricing is one of the most common and significant issues drawing attention from industry and the academic community. Pricing strategies are widely investigated in revenue management (Bitran and Caldentey, 2003; Maglaras and Costis, 2006; Chiang et al., 2007; Bacon et al., 2016), supply chain management (Bernstein and Federgruen, 2004; Leng and Parlar, 2005; Maddah and Bish, 2007; Tang and Yin, 2007; Kuo et al., 2013; Niu et al., 2015; Xu et al., 2017), and so on. Specific pricing scenarios are considered in the existing literature, including dynamic and static scenarios, single- and multiple-product scenarios, competitive scenarios, and so on (Soon, 2011). This section reviews research related to *a competitive market scenario with multiple products*, and *consumer demand with environmental awareness*.

Investigating the pricing strategies in *competitive scenarios*, game theories such as Bertrand and Nash games are widely adopted to study the competitive market share and interactive decisions among multiple firms. Sudhir (2001) uses a theory-driven empirical approach to research the competitive pricing behavior in the U.S. auto market. They measure the competitive behavior by the degree of deviation from Bertrand prices. Using a Hotelling model, Pan et al. (2002) establish a price competition game model between a pure e-commerce retailer and a combination of an e-commerce and a traditional retailer. With regard to competition in the supply chain channel, Yao and Liu (2005) use Bertrand and Stackelberg competition models to study the price competition between retail and online channels. Alptekinoğlu and Corbett (2008) study variety and price competition between a mass customization firm and a mass production firm. Chen et al. (2013) use Nash and Stackelberg games to formulate the price competition in a supply chain with one manufacturer and a retailer. Some researchers also consider production decisions in pricing a two-echelon supply chain. Wang et al. (2015) study a jointly pricing and lot-sizing decision in a two-echelon supply chain; while Heydari and Norouzinasab (2015) address a two-level discount policy to coordinate pricing and ordering decisions in the supply chain, where a stochastic consumer demand is involved. To investigate the impacts of competition on the performance of the supply chain, Luo et al. (2017) study the horizontal competition between two manufacturers, and vertical competition between the manufacturers and the retailer in different

[5] https://methodhome.com/.

supply chain structures. The results show that competition leads to higher profits for the entire supply chain. However horizontal competition hurts the manufacturers and benefits the retailer. *Our study* differs from the above literature in that we consider two products with similar functional attributes, but with heterogeneous environmental attributes in the pricing problem. In addition, we consider the substitutability between dual products, and use a valuation-based demand function to analyze the market share.

In pricing strategies for *green products*, consumers' environmental concerns are commonly considered in analyses of product choice and demand. Shamdasani et al. (1993) find that environmental awareness affects consumers' purchasing decisions and behavior. For consumers' environmental purchasing behaviors, Schuhwerk and Lefkoff-Hagius (1995) examine the impact of advertising on consumer choice. Their results, based on laboratory experiments, show that consumers with higher environmental awareness do not care whether an advertisement exhibits more green elements, and always choose environmentally friendly products. Ginsberg and Bloom (2004) point out that in dealing with green market-related issues, researchers and managers cannot ignore that consumers do not want to obtain green benefits at the expense of the original convenience, quality, and other commodity attributes. Chitra (2007) shows that the higher the level of consumer environmental awareness, the more consumers are willing to pay for eco-friendly products. Other studies investigate how green awareness influences supply chain players' operational decisions. Conrad (2005) uses a spatial duopoly model to study the effects of environmental concern on competing firms' decisions. Liu et al. (2012) focus on the impact of consumers' green awareness on supply chain players under competition. Their results show that an increase in consumer environmental awareness benefits retailers and manufacturers that have superior eco-friendly operations. Considering the effects of consumer environmental awareness on consumer demand, Zhang et al. (2015) investigate the green product pricing problem in a two-echelon supply chain, where a manufacturer makes the environmental and traditional products. In addition to the pricing strategies studied by Zhang et al. (2015) and Basiri and Heydari (2017) investigate the green sales effort and green quality decisions of the retailer and manufacturer, respectively. This study also considers the effects of consumer environmental awareness in green product pricing. However, we are different from the previous literature in that consumers' reference behaviors are taken account into demand analysis.

2.2. Reference-dependent demand

Social comparisons are common in the real world. Festinger (1954) notes that people use social comparisons to estimate their self-worth. Specifically, a social comparison needs a reference form, and uses a reference point as the standard for comparison. Thus, we review the existing literature from two perspectives: reference forms, and reference points.

The *reference forms* considered in the literature can be classified into two types: attribute- and price-dependent references. Several studies point out that the reference effects of product attributes on consumers' purchases is significant (Kim and Kim, 2015). Bronnenberg and Wathieu (1996) study a brand promotion problem, with quality- and price-reference-dependent consumers. Taking into account product quality, Gavious and Lowengart (2012) examine the relationships between price and reference quality, and their combined effects on profits. For supply chain management issues, Liu et al. (2016) examine the impact of a quality reference on the shared benefits of the manufacturer and the supplier. The latter concept is based on the adaptation-level theory (Helson, 1964), which states that the incentive of current prices for customers also depends on past prices, which act as a reference point in consumers' minds. Many empirical studies have investigated price as a reference point (Kalwani et al., 1990; Dickson and Sawyer, 1990; Kalyanaram and Little, 1994). Han et al. (2001) incorporate probabilistic thresholds for gains and losses in their reference price models, where the thresholds are based on brand. Moon et al. (2006) classify consumers into three types: no reference price, memory-based reference price, and stimulus-based reference price. They find that memory-based consumers are more sensitive to price, and that retailers should set prices based on the type of consumer, and manipulate the price pattern that consumers see. Kopalle et al. (2012) study the role of household-level heterogeneity in the reference-price effects on a retailer's pricing policy. Their results show that the optimal pricing policy of a retailer using their model is more profitable than those of models that ignore the effect of household-level heterogeneity on the reference price. Wang (2016) considers a multi-period pricing problem for a monopolist, where consumers' purchases are affected by their reference prices, which are based on their past shopping experiences.

Several kinds of *reference points* are investigated in the literature, and can be classified into two types: internal reference points (IRP) and external reference points (ERP). The former use past information as the reference point of a product, while the latter use current information as a reference point (Neumann and Böckenholt, 2014). With regard to *IRP* issues, Kalwani et al. (1990) develop a price-expectations model of customer brand choice. However, Dickson and Sawyer (1990) point out that most consumers cannot remember prices clearly. Popescu and Wu (2007) study a two-level supply chain dynamic pricing problem, in which only the retailer considers consumers' price-reference behavior. Based on Popescu and Wu (2007) and Zhang et al. (2014) study the effects on demand of both manufacturers and retailers considering consumers' price-reference behavior. In contrast to the above-mentioned studies, which focus on a single-product reference. Different from Zhang et al. (2014), our study considers the reference effects between two products, and investigates the pricing strategies of multiple products. For *ERP* issues, Tversky and Kahneman (1991) propose that each alternative should have a common reference point. Mazumdar and Papatla (1995) calculate the products of brand loyalty and the current prices of a brand, which they sum to determine the reference price. Klapper et al. (2005) use utility as the reference point in order to analyze consumer choice. Van Oest (2013) points out that for consumers that exhibit the second type of reference behavior, an increase in price has a more significant impact on demand. Our study is mostly closely related to that of Klapper et al. (2005). However, they consider price only as a reference point, we consider the overall utility of a product as a reference point, which includes the quality and the price of the regular product. The utility reference depicts the different cost performance among products, which is a common criterion for consumer choosing products.

2.3. Summary of the literature review

In the literature on product pricing, the competition among products and firms is widely considered, and environmental awareness is an emerging topic in research on green-product pricing. However, the practical questions of whether *environment-conscious consumers will pay a premium for green products,* and *how to determine the price of a green product* need to be answered from the perspective of operations management using. In addition, reference effects are largely ignored in studies on the pricing problem of green products, despite being an important factor affecting consumers' choices of green products. In addition, prior studies rarely consider utility as a reference point, especially the utility of the product as a whole.

This study focuses on these real-world issues and tries to fill the gaps in the existing literature. Consumer environmental awareness and product references are considered in formulating the demand functions of green and regular products. More specifically, the product reference uses the utility of the regular product as the reference point. Using the proposed demand functions, we investigate three scenarios of green-product pricing strategies: single-product pricing, dual-production competition, and asymmetric information.

3. Mathematical formulation and analysis

3.1. Notation and assumption

For easy tracking, we first list the notations and assumptions used in our model below. Note that the detailed explanations on these assumptions are addressed in the context.

Parameters	
V	utility a consumer derives from regular product's functional quality
α	coefficient representing the green product's functional quality compared to the regular one
k	sensitivity of consumers to the green product's greenness
e	greenness degree of green product
β	coefficient indicating consumers' recognition level of the reference
u_r,u_g	utilities a consumer derives from regular and green products, respectively
q_r,q_g	demands of regular and green products, respectively
γ	development cost coefficient of green product
c_r,c_g	marginal costs of making regular and green products, respectively
Decision variables	
p_r,p_g	prices of regular and green products, respectively. p_r is exogenous in the single-product pricing case

Assumption 1. Consumers are environmentally conscious and derive environmental utility (i.e., ke) from purchasing the green product.

Assumption 2. Consumers are heterogeneous in evaluating the functional attributes of the products, where the utility V is normally distributed in $[0,1]$.

Assumption 3. Consumers have reference behaviors when choosing a green product, and the effect of the reference is less than that of the product's functional quality (i.e., $\beta < \alpha$).

Assumption 4. The marginal production cost of the green product (i.e., c_g) is exogenous and not a function of the product's functional quality (i.e., α).

3.2. Problem formulation

We consider a market containing two manufacturers, one of which sells a regular (non-green) product to consumers (hereafter, the *regular manufacturer*), and one that sells a green product to consumers (hereafter, the *green manufacturer*). These two products are similar in terms of their functional attributes, but are heterogeneous in terms of their environmental attributes. The production emissions of the green product are less than those of the regular product, and the green product is the more environmentally friendly of the two. The environmental attribute of the green product is measured by the greenness degree, denoted as e.

Consumers are environmentally conscious and derive environmental utility from purchasing the green product. The environmental utility is assumed to be a linear function, ke (Chen, 2001; Yalabik and Fairchild, 2011), where k is the sensitivity of consumers to the greenness of the green product. Furthermore, consumers are assumed to be heterogeneous in terms of their evaluations of the functional attributes of products. That is, in the real world, consumers have distinct evaluations of the functional attributes of products.

We denote V as the utility a consumer derives from the regular product's functional quality. The utility a consumer derives from the green product's functional quality is αV, where α is a coefficient indicating the difference in functional quality between the two products. Greater utility can be derived from the regular product if $0 < \alpha < 1$, while greater utility can be derived from the green product if $\alpha > 1$. Notice that we here do not consider the case $\alpha = 1$, i.e., the two products are the same in functional attribute. Then, p_r and p_g denote the prices of the regular and green products, respectively.

Consumers know the two products and compare them before purchasing. The reference point used by consumers when choosing a green product is the utility they gain from purchasing a regular product. Let $u_r = V - p_r$ be the utility a consumer derives from the regular product. Then, the reference effect is defined as $u_r - u_g'$, where $u_g' = \alpha V - p_g$ is the utility a consumer derives from the green product. Let β be a coefficient indicating a consumer's recognition level of the reference, and be assumed to be $0 < \beta < \alpha$ to avoid trivial cases. Accordingly, the utilities a consumer derives from the regular and green products are given by

$$\begin{cases} u_r = V - p_r, \\ u_g = \alpha V - p_g + ke - \beta(u_r - u_g'). \end{cases}$$

As is widely adopted in the literature (Ferrer and Swaminathan, 2006; Yenipazarli, 2016), we assume V to be uniformly distributed on $[0,1]$. Furthermore, the market size is assumed to be one, and the decision variables p_r and p_g are constrained in $(0,1)$. Then, the market shares of the two products depend on consumers' choices between the two products. Note that we omit the trivial cases in which only one of the products exists in the market. The demand functions are given by Theorem 1, where the two products share the same market. The conditions are $k > \hat{k}$ $(0 < \alpha < 1)$ and $k \leqslant \hat{k}$ $(\alpha > 1)$, where $\hat{k} = (1+\beta)(p_g - \alpha p_r)/e$ (detailed in Appendix A). This former condition indicates that the demand for the green product is positive only when consumer environmental awareness is sufficiently high (i.e., $k > \hat{k}$), assuming that the quality of the green product is worse than that of the regular product (i.e., $0 < \alpha < 1$). The latter condition indicates that the demand for the regular product is positive only when consumer environmental awareness is sufficiently low (i.e., $k \leqslant \hat{k}$), assuming that the quality of the green product is better than that of the regular product (i.e., $\alpha > 1$). The proof of the theorem is given in Appendix A.

Theorem 1. *The demand functions of the regular and green products are:*

$$\begin{cases} q_r = 1 - \dfrac{(1+\beta)(p_r - p_g) + ke}{1 - (\alpha + \alpha\beta - \beta)}, \\ q_g = \dfrac{(1+\beta)(p_r - p_g) + ke}{1 - (\alpha + \alpha\beta - \beta)} - \dfrac{(1+\beta)p_g - \beta p_r - ke}{\alpha + \alpha\beta - \beta}; \end{cases} \quad (0 < \alpha < 1)$$

and

$$\begin{cases} q_r = \dfrac{(1+\beta)(p_r - p_g) + ke}{1 - (\alpha + \alpha\beta - \beta)} - p_r, \\ q_g = 1 - \dfrac{(1+\beta)(p_r - p_g) + ke}{1 - (\alpha + \alpha\beta - \beta)}. \end{cases} \quad (\alpha > 1)$$

The structure of the demand function, given the consumer environmental awareness and non-green product reference, is complicated. This makes the pricing strategies of the green product difficult to analyze. In this section, we first investigate the pricing problem for a single-product case, where the green manufacturer is a monopolist and determines the price of the green product, while the price of the regular product is exogenous. This scenario can occur when the price of a regular product is determined by the market and the regular manufacturer does not have sufficient power to break the price equilibrium of the regular product.

In such a case, the green manufacturer optimally determines the price of its green product in order to maximize profit. The cost rate of technology development is denoted as γ, and the investment in green technology is denoted as γe^2, which implies a convex increasing cost in terms of greenness (Yalabik and Fairchild, 2011). Denoting c_g as the unit production cost that is dependent with α, we further assume c_g is exogenous and is not a function of α. Accordingly, we have the following profit function: $\pi(p_g) = (p_g - c_g)q_g - \gamma e^2$.

The profit-maximizing manufacturer's decision problem is to maximize $\pi(p_g)$. Because $\pi(p_g)$ is concave in p_g, there exists a unique optimal solution, p_g^*. By solving $\partial\pi(p_g)/\partial p_g = 0$, we obtain the optimal price p_g^* and its related demand q_g^*, as shown in Theorem 2.

Theorem 2. *The optimal price of the green product is*

$$\begin{cases} p_g^* = \dfrac{ke + (1+\beta)c_g + \alpha(1+\beta)p_r}{2(1+\beta)}, & (0 < \alpha < 1); \\ p_g^* = \dfrac{ke + (1+\beta)(\alpha - 1 + c_g + p_r)}{2(1+\beta)}, & (\alpha > 1). \end{cases}$$

and the production quantity related to the optimal price is

$$\begin{cases} q_g^* = \dfrac{ke - (1+\beta)c_g + \alpha(1+\beta)p_r}{2(1-\alpha)(1+\beta)(\alpha + \alpha\beta - \beta)}, & (0 < \alpha < 1); \\ q_g^* = \dfrac{ke + (1+\beta)(\alpha - 1 - c_g + p_r)}{2(1+\beta)(\alpha - 1)}, & (\alpha > 1). \end{cases}$$

From the optimal decisions of the green manufacturer, we have the following propositions on the effects of specific system parameters on the manufacturer's decisions.

Proposition 1. *The optimal pricing strategies have the following properties:*

(i) $\partial p_g^*/\partial k > 0$ and $\partial p_g^*/\partial \beta < 0$. A greater degree of green awareness of consumers induces the green manufacturer to increase the price of the green product, while a higher recognition level of the reference induces the manufacturer to reduce the price.
(ii) $\partial p_g^*/\partial \alpha > 0$. The green manufacturer can increase the price of the green product if the product has greater functional quality.

Consumers with high green awareness have a strong preference for the environmental attributes of the product, and are willing to pay a premium for environmentally friendly products. When faced with these consumers, the green manufacturer can benefit by increasing the price of the green product. However, a higher recognition level of the reference erodes consumers' utility when increasing the price of the green product. In this situation, the manufacturer should reduce the price of the green product. Similarly to the environmental attribute (i.e., the greenness) of the green product, an increase in the functional quality of the product also increases consumers' utility. Therefore, the manufacturer could be beneficial from increasing the price of the green product.

The pricing strategies above apply to the case where the price of the regular product is stable (i.e., an exogenous variable in the model). However, what are the situations in the case of competitive pricing? Do the pricing strategies change and, if so, how do they change? In the coming section, we try to answer these questions by investigating the pricing strategies of a dual-product competitive pricing scenario.

4. Dual-product competitive pricing

In this section, we study the pricing problem for a dual-product competitive pricing scenario, where the regular and green manufacturers compete for market share and determine their pricing strategies simultaneously. In this scenario, the two manufacturers are monopolistic in terms of selling each of the products in the same market. Define the unit cost of the regular product as c_r, and the price of the regular product as p_r. Then, we have the following profit functions for the two manufacturers: $\pi_r(p_r) = (p_r - c_r)q_r$ and $\pi_g(p_g) = (p_g - c_g)q_g - \gamma e^2$.

The two profit-maximizing manufacturers' decision problems are to maximize $\pi_r(p_r)$ and $\pi_g(p_g)$, respectively. The objective functions $\pi_g(p_g)$ and $\pi_r(p_r)$ are concave in p_g and p_r, respectively. By solving $\partial\pi_g(p_g)/\partial p_g = 0$ and $\partial\pi_r(p_r)/\partial p_r = 0$ under a Nash game framework, we obtain the optimal prices corresponding to the Nash equilibrium, which are presented in Theorem 3.

Theorem 3. *The optimal prices of the regular and green products are, respectively,*

$$\begin{cases} p_g^{**} = \dfrac{ke(2-\alpha) + \alpha(1-\alpha)(1+\beta) + (1+\beta)(2c_g + \alpha c_r)}{(1+\beta)(4-\alpha)}, \\ p_r^{**} = \dfrac{(1+\beta)(c_g + 2c_r + 2 - 2\alpha) - ke}{(1+\beta)(4-\alpha)}, \end{cases} \quad (0 < \alpha < 1)$$

and

$$\begin{cases} p_g^{**} = \dfrac{ke(2\alpha-1) + 2\alpha(\alpha-1)(1+\beta) + \alpha(1+\beta)(2c_g + c_r)}{(1+\beta)(4\alpha-1)}, \\ p_r^{**} = \dfrac{(1+\beta)(\alpha + c_g + 2\alpha c_r - 1) - ke}{(1+\beta)(4\alpha-1)}. \end{cases} \quad (\alpha > 1)$$

Then, the manufacturers' respective production quantities related to optimal prices are

$$\begin{cases} q_g^{**} = \dfrac{ke(2-\alpha) + \alpha(1-\alpha)(1+\beta) + (1+\beta)(\alpha c_r - (2-\alpha)c_g)}{(1+\beta)(1-\alpha)(4-\alpha)(\alpha + \alpha\beta - \beta)}, \\ q_r^{**} = \dfrac{(1+\beta)(c_g - (2-\alpha)c_r) + 2(1-\alpha)(1+\beta) - ke}{(1+\beta)(1-\alpha)(4-\alpha)}, \end{cases} \quad (0 < \alpha < 1)$$

and

$$\begin{cases} q_g^{**} = \dfrac{ke(2\alpha-1) + 2\alpha(\alpha-1)(1+\beta) + (1+\beta)(\alpha c_r - (2\alpha-1)c_g)}{(1+\beta)(\alpha-1)(4\alpha-1)}, \\ q_r^{**} = \dfrac{\alpha((\alpha-1)(1+\beta) + (1+\beta)(c_g - (2\alpha-1)c_r) - ke)}{(1+\beta)(\alpha-1)(4\alpha-1)}. \end{cases} \quad (\alpha > 1)$$

From the optimal decisions of the green manufacturer, we derive the following propositions to investigate the effects of specific system parameters on the manufacturers' decisions.

Proposition 2. *The optimal pricing strategies have the following properties:*

(i) $\partial p_g^{**}/\partial k > 0$ and $\partial p_r^{**}/\partial k < 0$. As the green awareness of consumers increases, the green manufacturer increases its price of the green product, and the regular manufacturer decreases its price of the regular product.
(ii) $\partial p_g^{**}/\partial \beta < 0$ and $\partial p_r^{**}/\partial \beta > 0$. With the increase of the recognition level of the reference, the green manufacturer decreases its

price of the green product, while the regular manufacturer increases its price of the regular product.

Proposition 2 shows similar results to those of Proposition 1. In what follows, we investigate the properties of the optimal pricing strategies using other parameters and cases. The following proposition presents the property of the optimal pricing strategies on α, and the interactive impact of k. *Note that the equations of the thresholds of α and k, as discussed in the following proposition, contain β, which means that the non-green product reference has a significant impact on the pricing strategies of the green and regular products. However, for technical convenience, we focus on α and k.* Please refer to Appendix B for the proof of the proposition.

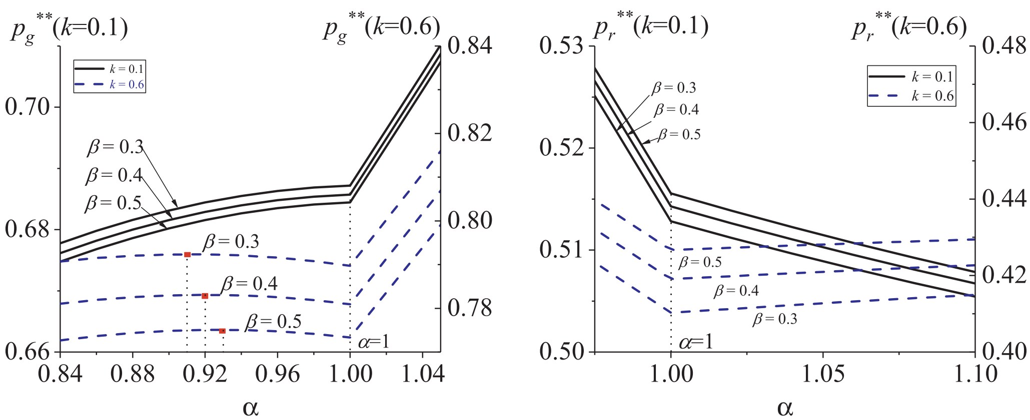
Proposition 3. *There exist some thresholds $\hat{k}_0$,$\hat{\alpha}_1$, and $\hat{k}_1$ (detailed in the appendix), such that the optimal pricing strategies have the following properties:*

(1) *when* $0 < \alpha < 1$*:*
  (i) p_r^{**} is decreasing in α;
  (ii) the monotonicity of p_g^{**} in α depends on $\hat{k}_0$:
   - *if $k < \hat{k}_0$, then p_g^{**} is increasing in α;*
   - *if $k \geqslant \hat{k}_0$, then,*
     – *when $\alpha < \hat{\alpha}_1$,p_g^{**} is increasing in α;*
     – *when $\alpha \geqslant \hat{\alpha}_1$,$p_g^{**}$ is decreasing in α.*

(2) *when* $\alpha > 1$*:*
  (i) p_g^{**} is increasing in α;
  (ii) the monotonicity of p_r^{**} in α depends on $\hat{k}_1$:
   - *if $k < \hat{k}_1$, then p_r^{**} is decreasing in α;*
   - *if $k \geqslant \hat{k}_1$, then p_r^{**} is increasing in α.*

Proposition 3 shows the pricing strategies with respect to the quality of the green product (i.e., α), which provides the corresponding pricing strategies when α changes. In particular, when the quality of the green product is low (i.e., $0 < \alpha < 1$), the utility from purchasing the green product increases in α, and more consumers will choose the green product. Accordingly, the regular manufacturer should decrease its price of the regular product to maintain its market share and profit. In addition, the pricing strategies of the green product are related to consumer environmental awareness (i.e., k): if this is low (i.e., $k < \hat{k}_0$), the utility from purchasing the green product increases significantly with an increase in α. Thus, the green manufacturer could benefit by increasing the price of the green product. However, if the consumer environmental awareness is high (i.e., $k \geqslant \hat{k}_0$), the pricing strategy of the green product depends on its quality. If the quality is low (i.e., $\alpha < \hat{\alpha}_1$), an increase in quality will induce more consumers to choose the green product, in which case, the green manufacturer can benefit by increasing its price. However, when the quality is high (i.e., $\alpha \geqslant \hat{\alpha}_1$), an increase in quality plays a weak role in attracting consumers. In this case, the green manufacturer lowers its price to increase its market share and to earn a greater profit.

When the quality of the green product is high (i.e., $\alpha > 1$), the green manufacturer can always benefit from increasing its price as α increases. That is, a high-price strategy for the green product should be adopted when its quality improves. The regular manufacturer's pricing strategy depends on consumer environmental awareness (i.e., k): if this is low (i.e., $k < \hat{k}_1$), consumers pay more attention to the quality of the green product. In this case, an increase in the quality of the green product attracts additional consumers, and reduces the market share of the regular product. Therefore, the regular manufacturer has to reduce its price to ensure sufficient demand and profit. If consumer environmental awareness is high (i.e., $k \geqslant \hat{k}_1$), the increase in the market share of the green product resulting from an increase in α is not significant. Following the pricing strategy of the green manufacturer (i.e., increasing the



(a) Pricing strategies of the green product (b) Pricing strategies of the regular product

Fig. 1. The pricing strategies with respect to α.

price of the green product), the regular manufacturer can benefit by increasing its price. A numerical example is used to show these managerial insights (see Fig. 1). The parameters used in the example are $\beta = 0.3, e = 0.8, c_g = 0.8, k = 0.1$ in Fig. 1(a) or $k = 0.6$ in Fig. 1(b), and $c_r = 0.4$. Then, we have $\hat{\alpha}_1 = 0.91, \hat{k}_0 = 0.16$, and $\hat{k}_1 = 0.5$.

The following two propositions compare the pricing and production strategies of the green and regular products. The effects of consumers' green awareness (i.e., k) and the quality of the green product (i.e., α) on the strategies are investigated. See Appendices C and D for the respective proofs.

Proposition 4. *There exist some thresholds $\hat{\alpha}_2, \hat{\alpha}_3, \hat{k}_2$, and $\hat{k}_3$ (detailed in the appendix), such that the optimal pricing strategies of the two products have the following relationships:*

(i) when $0 < \alpha < 1$:
- *if $k < \hat{k}_2$, then $p_g^{**} < p_r^{**}$;*
- *if $\hat{k}_2 \leqslant k < \hat{k}_3$, then,*
  - *when $\alpha < \hat{\alpha}_2, p_g^{**} < p_r^{**}$;*
  - *when $\alpha \geqslant \hat{\alpha}_2, p_g^{**} \geqslant p_r^{**}$;*
- *if $k \geqslant \hat{k}_3$, then $p_g^{**} \geqslant p_r^{**}$.*

(ii) *when $\alpha > 1$:*
- *if $k < \hat{k}_2$, then,*
  - *when $\alpha < \hat{\alpha}_3, p_g^{**} > p_r^{**}$;*
  - *when $\alpha \geqslant \hat{\alpha}_3, p_g^{**} \leqslant p_r^{**}$;*
- *if $k \geqslant \hat{k}_2$, then $p_g^{**} \geqslant p_r^{**}$.*

Proposition 4 presents the pricing-strategy comparisons between the green and regular products, which gives answers to the questions "*how to pricing a green product when facing differential consumer purchasing behaviors on green products*". When the quality of the green product is low (i.e., $0 < \alpha < 1$), the functional attributes of the regular product are better than those of the green product. If consumer environmental awareness is very low (i.e., $k < \hat{k}_2$), the green manufacturer should reduce the price of the green product to below that of the regular product to ensure its market share (i.e., $p_g^{**} < p_r^{**}$). In contrast, if consumer environmental awareness is very high (i.e., $k \geqslant \hat{k}_3$), then the green manufacturer can benefit by increasing the price of the green product above that of the regular product (i.e., $p_g^{**} \geqslant p_r^{**}$). This is because consumers are willing to pay more for the environmental attributes of the green product, in which case, its market share can be ensured, even though its price is higher than that of the regular product. However, if consumer environmental awareness falls at a middle level (i.e., $\hat{k}_2 \leqslant k < \hat{k}_3$), the quality of the green product plays a critical role in the pricing strategies of the two products. When the quality of the green product is low (i.e., $\alpha < \hat{\alpha}_2$), the green manufacturer should reduce the price of the green product below that of the regular product; otherwise (i.e., $\alpha \geqslant \hat{\alpha}_2$), the green manufacturer can benefit by increasing the price of the green product above that of the regular product.

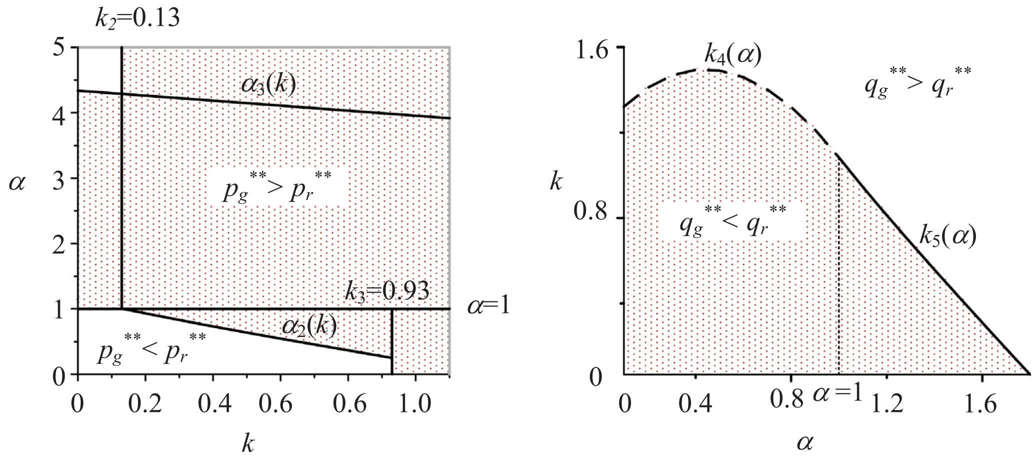
When the quality of the green product is high (i.e., $\alpha > 1$), the green product is better than the regular product in terms of its functional attributes. Intuitively, if consumer environmental awareness is high (i.e., $k \geqslant \hat{k}_2$), the green manufacturer can price the green product above the regular product. However, if consumer environmental awareness is low (i.e., $k < \hat{k}_2$), the quality of the green product affects the pricing strategies of the two products. When the quality of the green product is low (i.e., $\alpha < \hat{\alpha}_3$), the green manufacturer should price the green product below that of the regular product; otherwise (i.e., $\alpha \geqslant \hat{\alpha}_3$), the green manufacturer can benefit by pricing the green product above that of the regular product.

Proposition 5. *There exist two thresholds $\hat{k}_4$ and $\hat{k}_5$ (detailed in the appendix), such that the optimal production strategies of the green and regular products have the following relationships:*

(i) *when $0 < \alpha < 1$:*
- *if $k < \hat{k}_4$, then $q_g^{**} < q_r^{**}$;*
- *if $k \geqslant \hat{k}_4$, then $q_g^{**} \geqslant q_r^{**}$;*

(ii) *when $\alpha > 1$:*
- *if $k < \hat{k}_5$, then $q_g^{**} < q_r^{**}$;*
- *if $k \geqslant \hat{k}_5$, then $q_g^{**} \geqslant q_r^{**}$.*

Proposition 5 indicates that firms should adopt differential production strategies when facing consumers with differential CEA level. It also shows that the market shares of the green and regular products are significantly affected by CEA. More specifically, irrespective of the quality of the green product, as long as consumer environmental awareness is at a relatively high level (i.e., $k \geqslant \hat{k}_4$ or $k \geqslant \hat{k}_5$), more green products should be produced than regular products to satisfy consumers' environmental demand. A numerical example is used to show these managerial insights given in Propositions 4 and 5 (see Fig. 2). The parameters used in the example are $e = 0.9, c_g = 0.3, \beta = 0.2$, and $c_r = 0.5$ in Fig. 2(a), yielding $\hat{k}_2 = 0.13$ and $\hat{k}_3 = 0.93$. Then, the parameters in Fig. 2(b) are $e = 0.6, c_g = 0.8, \beta = 0.3$, and $c_r = 0.3$.



(a) Pricing strategies (b) Production strategies

Fig. 2. Pricing and production strategies for dual-product competition.

5. Asymmetric information

In this section, we investigate a dual-product competitive pricing case within asymmetric information. The green product is an innovative product, newly launched on the market. Here, some information of the green product is unknown to other firms, such as the regular manufacturer considered in this study. This is because specific technologies are usually adopted to produce the green product, and some information, such as cost information, is unknown to other firms.

In the previous section, we proposed a dual-product competition model, where both the green and regular manufacturers know all operational information of the other manufacturer, including the cost information. In what follows, we consider an asymmetric-information case, where the green manufacturer fully knows the regular manufacturer's operational information, but the regular manufacturer does not know the cost information of the green manufacturer. We assume that two optional cost strategies are available to the green manufacturer, namely, a high- and low-cost strategy.

Denote c_{gh} and c_{gl} as the high- and low-costs of the green manufacturer, respectively. The profit functions of the green and regular manufacturers are: $\pi_g(p_g) = (p_g - c_{gi})q_g - \gamma e^2$ $(i = h,l)$ and $\pi_r(p_r) = (p_r - c_r)q_r$. A Bayes model is adopted to analyze their pricing strategies. The equilibrium decisions are presented in Theorem 4 (see Appendix E for the proof).

Theorem 4. *The Bayes equilibrium of the asymmetric-information scenario is given as follows:*

(i) *when* $0 < \alpha < 1$*:*

$$\begin{cases} p_{gh}^* = \dfrac{4(ke(2-\alpha)+\alpha(1-\alpha)(1+\beta))+(1+\beta)((8-\alpha)c_{gh}+\alpha(c_{gl}+4c_r))}{4(4-\alpha)(1+\beta)}, \\ p_{gl}^* = \dfrac{4(ke(2-\alpha)+\alpha(1-\alpha)(1+\beta))+\alpha(1+\beta)c_{gh}+(1+\beta)((8-\alpha)c_{gl}+4\alpha c_r)}{4(4-\alpha)(1+\beta)}, \\ p_r^* = \dfrac{2ke-(1+\beta)(c_{gh}+c_{gl}+4c_r+4(1-\alpha))}{2(4-\alpha)(1+\beta)}. \end{cases}$$

(ii) *when* $\alpha > 1$*:*

$$\begin{cases} p_{gh}^* = \dfrac{2(ke(4\alpha-3)+(\alpha-1)(4\alpha-1)(1+\beta))+(1+\beta)((8\alpha-3)c_{gh}+c_{gl}+2(2\alpha-1)c_r)}{8(2\alpha-1)(1+\beta)}, \\ p_{gl}^* = \dfrac{2(ke(4\alpha-3)+(\alpha-1)(4\alpha-1)(1+\beta))+(1+\beta)(c_{gh}+(8\alpha-3)c_{gl}+2(2\alpha-1)c_r)}{8(2\alpha-1)(1+\beta)}, \\ p_r^* = \dfrac{1}{4}\left(\dfrac{(1+\beta)(c_{gh}+c_{gl})-2(ke-(\alpha-1)(1+\beta))}{(2\alpha-1)(1+\beta)} + 2c_r\right). \end{cases}$$

Based on the above equilibrium decisions and the results of the symmetric-information scenario, we compare the optimal pricing and production strategies between the scenarios with and without asymmetric information. *Note that we also compare the pricing strategies of the green and regular products under the asymmetric-information scenario, and obtain similar results to those of the symmetric-information scenario.* Thus, we omit these analyses here. The main analysis results are presented in the following propositions. The related proofs appear in Appendices F and G, respectively. Note that the proofs of Propositions 8 and 9 are similar to those of and Propositions 6 and 7. Thus, we omit these proofs here.

Proposition 6. *There exist two thresholds $\hat{c}_{g\,1}$ and $\hat{c}_{g\,2}$ (detailed in the appendix), such that the optimal pricing strategies of the symmetric- and asymmetric-information scenarios have the following relationships:*

(i) *when* $0 < \alpha < 1$*:*
- *if* $c_g < \hat{c}_{g\,1}$, *then* $p_{gh}^* > p_g^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,1}$, *then* $p_{gh}^* \leqslant p_g^{**}$.

(ii) *when* $\alpha > 1$*:*
- *if* $c_g < \hat{c}_{g\,2}$, *then* $p_{gh}^* > p_g^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,2}$, *then* $p_{gh}^* \leqslant p_g^{**}$.

Proposition 6 indicates that the production cost of the green product is important to the green manufacturer when it decides on its pricing strategies under the symmetric- and asymmetric-information scenarios. Irrespective of the quality of the green product, if the production cost of the green product (i.e., c_g) is low (i.e., $c_g < \hat{c}_{g\,1}$ or $c_g < \hat{c}_{g\,2}$), the green manufacturer should price its product in the asymmetric-information scenario above that of the symmetric scenario.That is, the green manufacturer can benefit from a high-price strategy under the asymmetric-information scenario if it has a low-cost advantage in the green product. In this case, the green manufacturer can focus on "high-end" consumers who are environmentally conscious. In other words, the asymmetric information provides the green manufacturer with more room in terms of pricing than in the case of symmetric information. However, when its production cost is relatively high, the green manufacturer has to adopt a low-price strategy (i.e., $c_g \geqslant \hat{c}_{g\,1}$ or $c_g \geqslant \hat{c}_{g\,2}$) to increase its market share (see Proposition 7), as well as to recover its development cost and ensure its profit. Green products are commonly innovative products in markets, and it is important for firms to properly determine their pricing strategies in consideration of the asymmetric information scenario.

Proposition 7. *There exist two thresholds $\hat{c}_{g\,3}$ and $\hat{c}_{g\,4}$ (detailed in the appendix), such that the optimal production strategies of the symmetric- and asymmetric-information scenarios have the following relationships:*

(i) *when* $0 < \alpha < 1$*:*
- *if* $c_g < \hat{c}_{g\,3}$, *then* $q_{gh}^* < q_g^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,3}$, *then* $q_{gh}^* \geqslant q_g^{**}$.

(ii) *when* $\alpha > 1$*:*
- *if* $c_g < \hat{c}_{g\,4}$, *then* $q_{gh}^* < q_g^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,4}$, *then* $q_{gh}^* \geqslant q_g^{**}$.

Proposition 7 indicates that the green manufacturer's production strategy is also affected by the production cost of its product in the asymmetric-information scenario. The results are interesting. Fewer green products should be produced if their production costs are low (i.e., $c_g < \hat{c}_{g\,3}$ or $c_g < \hat{c}_{g\,4}$) in the asymmetric-information scenario than in the case of the symmetric scenario. Recalling the pricing strategy analyzed in Proposition 6, a high-price, low-yield strategy is suggested for the green manufacturer if it has a low-cost advantage in the green product. That is, the green manufacturer concentrates on a relative small market share, containing "high-end" consumers. As discussed after Proposition 6, when the production cost of the manufacturer becomes high (i.e., $c_g \geqslant \hat{c}_{g\,3}$ or $c_g \geqslant \hat{c}_{g\,4}$), it should reduce its price in order to compete with the regular product and to acquire a sufficient market share. A numerical example is used to show these managerial insights (see Fig. 3). The parameters used in the example are $k = 0.6, e = 0.6, c_r = 0.4, \beta = 0.3, c_{gh} = 0.7$, and $c_{gl} = 0.3$.

Let $\hat{c}_{g\,5} = (c_{gh} + c_{gl})/2$ and $\hat{c}_{g\,6} = ((4\alpha-1)(1+\beta)c_{gh} + (4\alpha-1)(1+\beta)c_{gl} - 2(ke-(\alpha-1)(1+\beta) + (2\alpha-1)(1+\beta)c_r))/(4(2\alpha-1)(1+\beta))$. Then, the following proposition compares the pricing strategies of the regular product between the symmetric- and asymmetric-information scenarios.

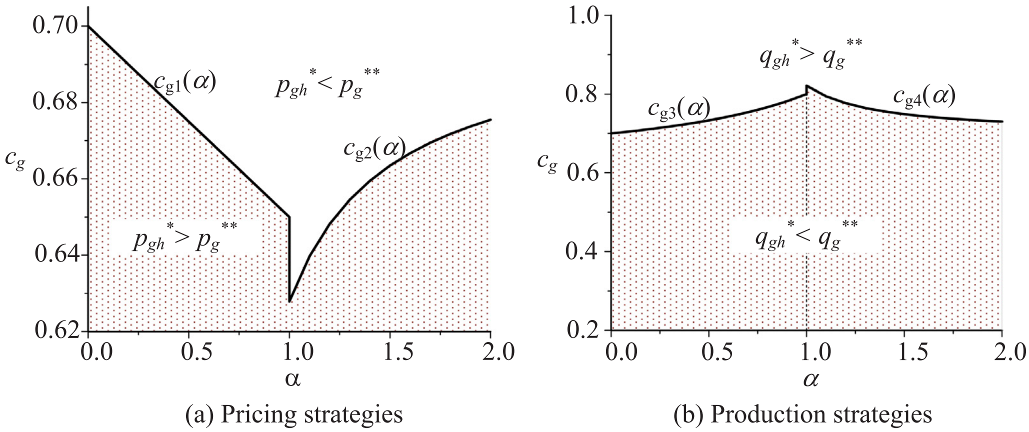


Fig. 3. Pricing and production strategies for the green product in the asymmetric scenario.

Proposition 8. *There exist thresholds $\hat{c}_{g\,5}$ and $\hat{c}_{g\,6}$, such that the optimal pricing strategies have the following properties:*

(i) *when* $0 < \alpha < 1$*:*
- *if* $c_g < \hat{c}_{g\,5}$, *then* $p_r^* > p_r^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,5}$, *then* $p_r^* \leqslant p_r^{**}$;

(ii) *when* $\alpha > 1$*:*
- *if* $c_g < \hat{c}_{g\,6}$, *then* $p_r^* > p_r^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,6}$, *then* $p_r^* \leqslant p_r^{**}$.

Let $\hat{c}_{g\,7} = ((4\alpha-1)(1+\beta)c_{gh} + (4\alpha-1)(1+\beta)c_{gl} + 2(ke-(\alpha-1)(1+\beta) + (2\alpha-1)(1+\beta)c_r))/(8\alpha(1+\beta))$. Then, the following proposition compares the production strategies of the regular product between the symmetric- and asymmetric-information scenarios.

Proposition 9. *There exist thresholds $\hat{c}_{g\,5}$ and $\hat{c}_{g\,7}$, such that the optimal production strategies have the following properties:*

(i) *when* $0 < \alpha < 1$*:*
- *if* $c_g < \hat{c}_{g\,5}$, *then* $q_r^* > q_r^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,5}$, *then* $q_r^* \leqslant q_r^{**}$;

(ii) *when* $\alpha > 1$*:*
- *if* $c_g < \hat{c}_{g\,7}$, *then* $q_r^* > q_r^{**}$;
- *if* $c_g \geqslant \hat{c}_{g\,7}$, *then* $q_r^* \leqslant q_r^{**}$.

Propositions 8 and 9 compare the pricing and production strategies, respectively, of the regular manufacturer between the symmetric- and asymmetric-information scenarios. The results are interesting, in that the regular manufacturer can benefit from the asymmetric-information when the production cost of the green product is low (i.e., $c_g < \hat{c}_{g\,5}$;$c_g < \hat{c}_{g\,6}$, or $c_g < \hat{c}_{g\,7}$). That is, both the price and production quantity of the regular product are higher in the asymmetric-information scenario than they are in the case of the symmetric-information scenario. Thus, the regular manufacturer is more profitable in the asymmetric-information scenario. This is because the green manufacturer focuses on "high-end" consumers and, thus, adopts a high-price, low-yield strategy, while the regular manufacturer obtains a considerable market share. Moreover, the regular manufacturer can partly increase its price to maximize its profit. However, when the production cost of the green product is relatively high, the green manufacturer will adopt a low-price strategy to obtain a sufficiently large market share in order to compete with the regular manufacturer, as discussed in Propositions 7 and 6. In this case, the regular manufacturer reduces the price of the regular product, the market share of which is eroded and smaller than that in the symmetric-information scenario. A numerical example is used to show these managerial insights (see Fig. 4). The parameters used in the example are $k = 0.6$,$e = 0.6$,$c_r = 0.4$,$\beta = 0.3$,$c_{gh} = 0.7$, and $c_{gl} = 0.3$. Thus, we have $\hat{c}_{g\,5} = 0.5$.

6. Conclusion

This study examined the pricing strategies for a green product that competes with a regular product with similar functional attributes. In particular, consumer environmental awareness and non-green product reference are considered in formulating the demand of the green and regular products. The green product is newly launched on the market as an innovative product, and competes with the regular product in terms of market share. We focused on the pricing strategies of the green and regular products in two scenarios, namely dual-product competition and an asymmetric information. In the dual-product competition case, we examined whether consumers will pay a premium for a green product, and how to price a green product. The results show that the green manufacturer should set its price according to the quality of the green product and the levels of consumers' reference recognition and environmental awareness. More specifically, we provide a threshold policy to show how to pricing the green and regular product as

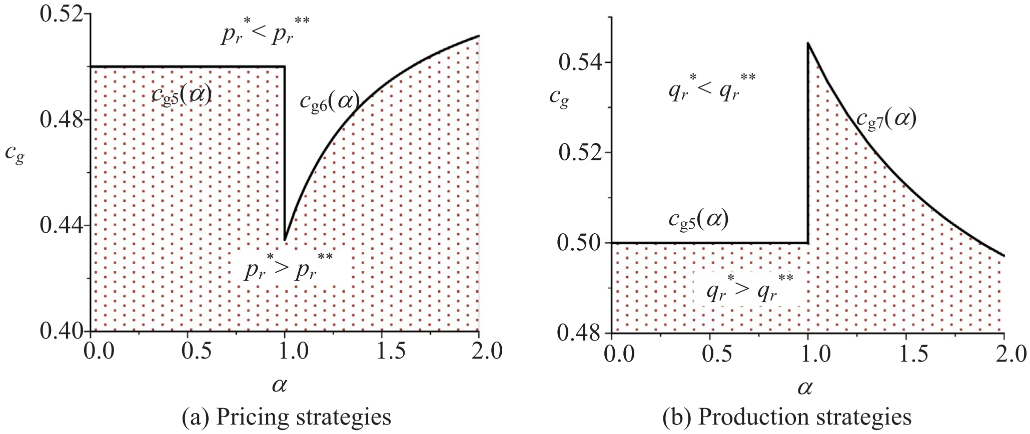


Fig. 4. Pricing and production strategies for the regular product in the asymmetric scenario.

the green product's quality changes (see Proposition 4). A differential pricing and production strategies are presented to help firms to deal with the issue that consumer purchase behaviors are differential (see Propositions 4 and 5).

Symmetric information plays significant impacts on the pricing strategies of both the green and regular products. Compared with the strategies under symmetric information, when the production cost of the green product is low, the green manufacturer adopts a low-price, low-yield strategy under asymmetric information. In this case, the regular product can benefit by increasing its price and production quantity. When the production cost of the green product becomes relatively high, the green manufacturer should reduce its price in order to obtain a greater share of the market, which causes the regular manufacturer to adopt a low-price strategy to ensure its market share.

There are several limitations of this study, providing opportunities to extend this research. First, we do not consider a supply chain environment in our model. Thus, including supply chain partners, such as suppliers or retailers would be an interesting extension. Second, the greenness degree is exogenous in this study. Future research should consider this as a decision variable, based on which, the environmental contributions/impacts of the portfolio strategies on product design and pricing can be investigated. Third, the marginal production cost of the green product (i.e., c_g) is exogenous and is not a function of the product's quality (i.e., α) in our model. It will be interesting to use a function to depict the relationship between c_g and α in the future research. Lastly, from a societal or government perspective, investigating and designing environmental policies to improve environmental sustainability is a further topic for future research.

Acknowledgements

The authors are grateful for the constructive comments and suggestions of the Associate Editor and two anonymous referees. This research is supported by grants from the National Natural Science Foundation of China (NSFC) (Nos. 71401067, 71771108, 71520107002 and 71472079) and the Thousand Young Scholar Program, and the China Postdoctoral Science Foundation (No. 2017M610385).

Appendix A. Proof of Theorem 1

Proof. Let $A=\alpha+\alpha\beta-\beta$, then, when $0<\alpha<1$,$A<1$; when $\alpha>1$,$A>1$. The demand of the two products are: $q_r=P\{u_r>u_g,u_r\geqslant 0\}$ and $q_g=P\{u_g\geqslant u_r,u_g\geqslant 0\}$. Next, we give the specific formula of q_r and q_g.

(I) When $0<\alpha<1$,$q_r=P\{V-p_r>\alpha V-p_g+ke-\beta(u_r-u_g'),V-p_r\geqslant 0\}$; and $q_g=P\{u_g\geqslant u_r,u_g\geqslant 0\}=P\{\alpha V-p_g+ke-\beta(u_r-u_g')\geqslant V-p_r,\alpha V-p_g+ke-\beta(u_r-u_g')\geqslant 0\}$.

To avoid the trivial case that only one product (i.e., either the green or regular product) exists in the market, we have the following condition:

$$\Delta V_1=((1+\beta)(p_r-p_g)+ke)/(1-\alpha)(1+\beta)-((1+\beta)p_g-\beta p_r-ke)/(\alpha+\beta(\alpha-1)),\text{ and}$$
$$=((1+\beta)(\alpha p_r-p_g)+ke)/(1-\alpha)(1+\beta)(\alpha+\beta(\alpha-1))>0$$
$$\Delta V_2=((1+\beta)(p_r-p_g)+ke)/(1-\alpha)(1+\beta)-p_r=((1+\beta)(\alpha p_r-p_g)+ke)/(1-\alpha)(1+\beta)>0.$$

From the inequalities above, we have $k>(1+\beta)(p_g-\alpha p_r)/e$. Let $\hat{k}=(1+\beta)(p_g-\alpha p_r)/e$.

When V is uniformly distributed on [0,1], the demand function is

$$\begin{cases} q_r=1-\dfrac{(1+\beta)(p_r-p_g)+ke}{1-(\alpha+\alpha\beta-\beta)}, \\ q_g=\dfrac{(1+\beta)(p_r-p_g)+ke}{1-(\alpha+\alpha\beta-\beta)}-\dfrac{(1+\beta)p_g-\beta p_r-ke}{\alpha+\alpha\beta-\beta}. \end{cases}\quad(0<\alpha<1).$$

(II) When $\alpha>1$, the demand function can be obtained in the same way, we omit it here.

From the proof above, we know when $0<\alpha<1$, the condition $k>(1+\beta)(p_g-\alpha p_r)/e$ is necessary to ensure that the market share of the green product is positive. That is, when the quality of the green product is at a lower level than that of the regular product, consumers will choose the green product only if the customer's environmental awareness is higher than a certain level. Similarly, when $\alpha>1$, the condition $k<(1+\beta)(p_g-\alpha p_r)/e$ is necessary to ensure a positive market share of the regular product. □

Appendix B. Proof of Proposition 3

Proof. The optimal pricing strategies depend on p_g^{**}'s monotonicity in α and p_r^{**}'s monotonicity in α.

(I) The monotonicity of p_g^{**}:

(*i*) when $0<\alpha<1$, the first derivatives of p_g^{**} in α is $\frac{\partial p_g^{**}}{\partial\alpha}=((1+\beta)(4-\alpha(8-\alpha)+2c_g+4c_r)-2ke)/(1+\beta)(4-\alpha)^2=\eta_1/\sigma_1$, where $\sigma_1>0$. It's not difficult to prove that η_1 is decreasing with α and $\eta_1|_{\alpha=0}>0$. Let $\eta_1|_{\alpha=1}=0$, we have a threshold $\hat{k}_0=(1+\beta)(4c_r+2c_g-3)/2e$.

If $k<\hat{k}_0$,$\eta_1|_{\alpha=1}>0$, which means $\frac{\partial p_g^{**}}{\partial\alpha}>0$. So p_g^{**} is increasing in α.

If $k \geqslant \widehat{k}_0, \eta_1|_{\alpha=1} \leqslant 0$. Notice that there exists a threshold $\widehat{\alpha}_1 = (8+8\beta-\sqrt{(8+8\beta)^2-4(1+\beta)(4-2ke+4\beta+2(1+\beta)(c_g+2c_r))})/2(1+\beta)$ making $\eta_1 = 0$. We have $\eta_1 > 0$, when $\alpha \in (0,\widehat{\alpha}_1)$; $\eta_1 \leqslant 0$, when $\alpha \in [\widehat{\alpha}_1,1)$.

(*ii*) When $\alpha > 1$, the first derivatives of p_g^{**} in α is $\frac{\partial p_g^{**}}{\partial \alpha} = (2ke+(1+\beta)(2(1-2\alpha+4\alpha^2)-2c_g-c_r))/(1+\beta)(1-4\alpha)^2 = \eta_2/\sigma_2$. $\sigma_2 > 0$. We can find that η_2 is increasing in α and $\eta_2|_{\alpha=1} > 0$, which implies $\frac{\partial p_g^{**}}{\partial \alpha} > 0$.

(II) The monotonicity of p_r^{**}:

(*i*) when $0 < \alpha < 1$, the first derivatives of p_r^{**} in α is $\frac{\partial p_r^{**}}{\partial \alpha} = ((1+\beta)(c_g+2c_r-6)-ke)/(1+\beta)(\alpha-4)^2 = \eta_3/\sigma_3$, Notice that $\sigma_3 > 0$ and $\eta_3 < 0$, it implies that $\frac{\partial p_r^{**}}{\partial \alpha} < 0$;

(*ii*) when $\alpha > 1$, $\frac{\partial p_r^{**}}{\partial \alpha} = (4ke+(1+\beta)(3-4c_g-2c_r))/(1+\beta)(1-4\alpha)^2 = \eta_4/\sigma_4$. Notice that $\sigma_4 > 0$. Let $\eta_4 = 0$, we have a threshold $\widehat{k}_1 = (1+\beta)(4c_r+2c_g-3)/4e$ of k. It's easy to find that η_4 is increasing with k, which implies that:

(*1*) when $k < \widehat{k}_1, \eta_4 < 0$. So we have $\frac{\partial p_r^{**}}{\partial \alpha} < 0$, when $k < \widehat{k}_1$;

(*2*) when $k \geqslant \widehat{k}_1, \eta_4 \geqslant 0$. So we have $\frac{\partial p_r^{**}}{\partial \alpha} \geqslant 0$, when $k \geqslant \widehat{k}_1$.

We complete the proof. □

Appendix C. Proof of Proposition 4

Proof. Define $\Delta p = p_g^{**}-p_r^{**}$ as a measurement to investigate the relationship between p_g^{**} and p_r^{**}.

(I) When $0 < \alpha < 1$, let $\Delta p = \eta_5/\sigma_5$, where $\sigma_5 = (1+\beta)(\alpha-4) < 0$ and $\eta_5 = ke(\alpha-3)+(1+\beta)((\alpha-2)(\alpha-1)-c_g-(\alpha-1)c_r)$. Notice that η_5 is convex in α. Let $\eta_5 = 0$, we can obtain two thresholds of α: $\widehat{\alpha}_2 = ((3+c_r)(1+\beta)-ke-\sqrt{(ke-(3+c_r)(1+\beta))^2-4(1+\beta)((1+\beta)(2-c_g+2c_r)-3ke)})/2(1+\beta)$ and $\widehat{\alpha}_2' = ((3+c_r)(1+\beta)-ke+\sqrt{(ke-(3+c_r)(1+\beta))^2-4(1+\beta)((1+\beta)(2-c_g+2c_r)-3ke)})/2(1+\beta)$. Because $\widehat{\alpha}_2' > 1$, it's only necessary to check whether $\widehat{\alpha}_2 \in (0,1)$ or not. Let $\eta_5|_{\alpha=1} = 0$ and $\eta_5|_{\alpha=0} = 0$, we obtain two thresholds $\widehat{k}_2 = (1+\beta)(c_r-c_g)/2e$ and $\widehat{k}_3 = (1+\beta)(2-c_g+2c_r)/3e$ of k, respectively. Then we have:

(*i*) if $k \geqslant \widehat{k}_3$, we have $\eta_5|_{\alpha=0} \leqslant 0$ and $\Delta p \geqslant 0$;
(*ii*) if $k < \widehat{k}_2$, we have $\eta_5|_{\alpha=1} > 0$ and $\Delta p < 0$.
(*iii*) if $\widehat{k}_2 \leqslant k < \widehat{k}_3$, we have $\eta_5|_{\alpha=0} > 0$ and $\eta_5|_{\alpha=1} \leqslant 0$, which implies there exists a α (i.e., $0 < \widehat{\alpha}_2 < 1$) such that
- when $\alpha < \widehat{\alpha}_2, \eta_5 > 0$, which implies $\Delta p < 0$;
- when $\alpha \geqslant \widehat{\alpha}_2, \eta_5 \leqslant 0$, which implies $\Delta p \geqslant 0$.

(II) When $\alpha > 1$, let $\Delta p = \eta_6/\sigma_6$, where $\sigma_6 = (4\alpha-1)(1+\beta) > 0$ and $\eta_6 = 1+\beta+\alpha(2ke+(2\alpha-3)(1+\beta))+(1+\beta)((2\alpha-1)c_g-\alpha c_r)$. Notice that η_6 is convex in α. Let $\eta_6 = 0$, we have two thresholds of α: $\widehat{\alpha}_3' = ((3-2c_g+c_r)(1+\beta)-2ke-\sqrt{8(c_g-1)(1+\beta)^2+(2ke+(1+\beta)(2c_g-c_r-3))^2})/4(1+\beta)$ and $\widehat{\alpha}_3 = ((3-2c_g+c_r)(1+\beta)-2ke+\sqrt{8(c_g-1)(1+\beta)^2+(2ke+(1+\beta)(2c_g-c_r-3))^2})/4(1+\beta)$. We know η_6 achieves its minimum at $\widehat{\alpha}_4 = (2ke+(1+\beta)(2c_g-c_r-3))/-4(1+\beta)$, and $\widehat{\alpha}_4$ is decreasing in k. Let $\widehat{\alpha}_4 = 1$, we have a threshold $\widehat{k}_2' = (1+\beta)(c_r-2c_g-1)/2e < 0$, so $\widehat{\alpha}_4 < 1$, which implies η_6 is increasing in α, when $\alpha > 1$. Let $\eta_6|_{\alpha=1} = 2ke+(1+\beta)(c_g-c_r) = 0$, we have $\widehat{k}_2 = (1+\beta)(c_r-c_g)/2e$, Then we have

(*i*) if $k < \widehat{k}_2, \eta_6|_{\alpha=1} < 0$. It implies that $\eta_6 > 0$, so we obtain $\Delta p > 0$;
(*ii*) if $k \geqslant \widehat{k}_2, \eta_6|_{\alpha=1} \geqslant 0$. So we obtain $0 < \widehat{\alpha}_3 < 1$. Then the relationship between the prices depends on $\widehat{\alpha}_3$:
- when $\alpha < \widehat{\alpha}_3, \eta_6 < 0$, which implies $\Delta p < 0$;
- when $\alpha \geqslant \widehat{\alpha}_3, \eta_6 \geqslant 0$, which implies $\Delta p \geqslant 0$.

We complete the proof. □

Appendix D. Proof of Proposition 5

Proof. Define $\Delta q = q_g^{**}-q_r^{**}$ as a measurement to investigate the relationship between q_g^{**} and q_r^{**}.

(I) When $0 < \alpha < 1$, let $\Delta q = (ke(2+(\alpha-1)\beta)+(\alpha-1)(1+\beta)(\alpha+2(\alpha-1)\beta)-(1+\beta)((2+(\alpha-1)\beta)c_g+(2\beta+\alpha(\alpha-3)(1+\beta))c_r))/(1+\beta)(\alpha-1)(\alpha-4)(\alpha+(\alpha-1)\beta) = 0$, we obtain a threshold $\widehat{k}_4 = (1+\beta)((\alpha-1)(\alpha+2(\alpha-1)\beta)+(2+(\alpha-1)\beta)c_g+(2\beta+\alpha(\alpha-3)(1+\beta))c_r)/e(2+(\alpha-1)\beta)$ of k. Because $\frac{\partial \Delta q}{\partial k} = e(2+(\alpha-1)\beta)/(1+\beta)(\alpha-1)(\alpha-4)(\alpha+(\alpha-1)\beta) > 0$, we know that Δq is increasing in k, which implies that

(*i*) if $k < \widehat{k}_4, \Delta q < 0$; (*ii*) otherwise, $\Delta q \geqslant 0$.

(II) When $\alpha > 1$, let $\Delta q = (ke(3\alpha-1) + \alpha(\alpha-1)(1+\beta) + (1+\beta)((1-3\alpha)c_g + 2\alpha^2 c_r))/(1+\beta)(\alpha-1)(4\alpha-1)$. Notice that it's also increasing in k, we have a threshold $\hat{k}_5 = ((1+\beta)((1-3\alpha)c_g + \alpha(\alpha-1+2\alpha c_r)))/e(1-3\alpha)$ of k, which makes $\Delta q = 0$, then we have

(*i*) if $k < \hat{k}_5, \Delta q < 0$; (*ii*) otherwise, $\Delta q \geqslant 0$.

We complete the proof. □

Appendix E. Proof of Theorem 4

Proof. Without loss of generality, we assume that probability of adopting the high or low cost strategy by the green manufacturer is 1/2.

(I) When $0 < \alpha < 1$, the profit function of the green manufacturer is $\pi_g(p_g) = (p_g - c_{gi})q_g - \gamma e^2, (i = \{h,l\})$. It is concave in p_g. By first-order condition, we have $p_g^* = (ke + (1+\beta)c_g + \alpha(1+\beta)p_r)/(2(1+\beta))$, which is impacted by the regular manufacturer's price strategy and the green manufacturer's cost.

Let p_{gh}^* denote the optimal price when the green manufacturer holds a high cost and p_{gl}^* denote the optimal price when the green manufacturer holds a low cost, then we have $p_{gh}^* = (ke + (1+\beta)c_{gh} + \alpha(1+\beta)p_r)/(2(1+\beta))$ and $p_{gl}^* = (ke + (1+\beta)c_{gl} + \alpha(1+\beta)p_r)/(2(1+\beta))$. The regular manufacturer doesn't know the green manufacturer's real cost, and its profit is $\pi_r(p_r) = \frac{1}{2}(p_r - c_r)(1 - \frac{ke + (1+\beta)(p_r - p_{gh})}{1 - \alpha + \beta - \alpha\beta}) + \frac{1}{2}(p_r - c_r)(1 - \frac{ke + (1+\beta)(p_r - p_{gl})}{1 - \alpha + \beta - \alpha\beta})$. The reaction decision of the regular manufacturer is $p_r^* = \frac{2(1+\beta)c_r + (1+\beta)p_{gh} + (1+\beta)p_{gl} - 2(ke + (\alpha-1)(1+\beta))}{4(1+\beta)}$. Solving the two reaction functions simultaneously, we have the Bayes Equilibrium:

$$\begin{cases} p_{gh}^* = \frac{4(ke(2-\alpha) + \alpha(1-\alpha)(1+\beta)) + (1+\beta)((8-\alpha)c_{gh} + \alpha(c_{gl} + 4c_r))}{4(4-\alpha)(1+\beta)}, \\ p_{gl}^* = \frac{4(ke(2-\alpha) + \alpha(1-\alpha)(1+\beta)) + \alpha(1+\beta)c_{gh} + (1+\beta)((8-\alpha)c_{gl} + 4\alpha c_r)}{4(4-\alpha)(1+\beta)}, \\ p_r^* = \frac{2ke - (1+\beta)(c_{gh} + c_{gl} + 4c_r + 4(1-\alpha))}{2(4-\alpha)(1+\beta)}. \end{cases}$$

The corresponding quantities are

$$\begin{cases} q_{gh}^* = \frac{(1+\beta)(\alpha(c_{gl} + 4c_r) - (8-3\alpha)c_{gh}) + 4(ke(2-\alpha) + \alpha(1-\alpha)(1+\beta))}{4(4-\alpha)(1-\alpha)(1+\beta)(\alpha + (\alpha-1)\beta)}, \\ q_{gl}^* = \frac{\alpha(1+\beta)c_{gh} + (1+\beta)(4\alpha c_r - (8-3\alpha)c_{gl}) + 4(ke(2-\alpha) + \alpha(1-\alpha)(1+\beta))}{4(4-\alpha)(1-\alpha)(1+\beta)(\alpha + (\alpha-1)\beta)}, \\ q_r^* = \frac{(1+\beta)(c_{gh} + c_{gl}) + 2(2(1-\alpha)(1+\beta) - (2-\alpha)(1+\beta)c_r - ke)}{2(4-\alpha)(1-\alpha)(1+\beta)}. \end{cases}$$

(II) When $\alpha > 1$, we can obtain the equilibrium in same way and omit if here.

We complete the proof. □

Appendix F. Proof of Proposition 6

Proof. Define $\Delta p_g = p_{gh}^* - p_g^{**}$ as a measurement to investigate the relationship of the prices of the green product between the asymmetric and symmetric information scenarios.

(II) When $0 < \alpha < 1$, let $\Delta p_g = (8c_g + (\alpha-8)c_{gh} - \alpha c_{gl})/4(\alpha-4) = 0$, we have a threshold $\hat{c}_{g\,1} = ((8-\alpha)c_{gh} + \alpha c_{gl})/8$ of c_g. And it's easy to prove that Δp_g is decreasing in c_g, which implies that

(*i*) if $c_g < \hat{c}_{g\,1}, p_{gh}^* > p_g^{**}$;
(*ii*) if $c_g \geqslant \hat{c}_{g\,1}, p_{gh}^* \leqslant p_g^{**}$.

(II) When $\alpha > 1$, let $\Delta p_g = (16\alpha(1-2\alpha)(1+\beta)c_g + (4\alpha-1)(8\alpha-3)(1+\beta)c_{gh} + (4\alpha-1)(1+\beta)c_{gl} + 2(\beta - 2\alpha(1+\beta))c_r + 2(c_r - ke + (\alpha-1)(1+\beta)))/8(8\alpha^2 - 6\alpha + 1)(1+\beta) = 0$, we have a threshold $\hat{c}_{g\,2} = ((4\alpha-1)(8\alpha-3)(1+\beta)c_{gh} + (4\alpha-1)(1+\beta)c_{gl} - 2(ke - (\alpha-1)(1+\beta) + (2\alpha-1)(1+\beta)c_r))/(16\alpha(2\alpha-1)(1+\beta))$ of c_g. And it's easy to prove that Δp_g is decreasing in c_g, which implies that

(*i*) if $c_g < \hat{c}_{g\,2}, p_{gh}^* > p_g^{**}$;
(*ii*) if $c_g \geqslant \hat{c}_{g\,2}, p_{gh}^* \leqslant p_g^{**}$.

We complete the proof. □

Appendix G. Proof of Proposition 7

Proof. Define $\Delta q_g = q_{gh}^* - q_g^{**}$ as a measurement to investigate the relationship of the prices of the regular product between the asymmetric and symmetric information scenarios.

(I) When $0 < \alpha < 1$, let $\Delta q_g = (4(2-\alpha)c_g + (3\alpha-8)c_{g1} + \alpha c_{g2})/4(\alpha-4)(\alpha-1)(\alpha + (\alpha-1)\beta) = 0$, we have a threshold $\hat{c}_{g\,3} = ((8-3\alpha)c_{gh}-\alpha c_{gl})/4(2-\alpha)$ of c_g. And it's obviously to prove that Δq_g is decreasing in c_g, so we have

(*i*) $\Delta q_g < 0$, if $c_g < \hat{c}_{g\,3}$; (*ii*) $\Delta q_g \geqslant 0$, if $c_g \geqslant \hat{c}_{g\,3}$.

(II) When $\alpha > 1$, let $\Delta q_g = (8(1-2\alpha)^2(1 + \beta)c_g-(4\alpha-1)(8\alpha-5)(1 + \beta)c_{gh} + (4\alpha-1)(1 + \beta)c_{gl} + 2(\beta-2\alpha(1 + \beta))c_r + 2(c_r-ke + (\alpha-1)(1 + \beta)))/8(\alpha-1)(2\alpha-1)(4\alpha-1)(1 + \beta) = 0$, we have threshold $\hat{c}_{g\,4} = (2ke + (1 + \beta)(2-2\alpha + (32\alpha^2-28\alpha + 5)c_{gh} + (1-4\alpha)c_{gl} + 2(2\alpha-1)c_r))/8(2\alpha-1)^2(1 + \beta)$. And it's easy to prove that Δq_g is increasing in c_g, so we have

(*i*) $\Delta q_g < 0$, if $c_g < \hat{c}_{g\,4}$; (*ii*) $\Delta q_g \geqslant 0$, if $c_g \geqslant \hat{c}_{g\,4}$.

We complete the proof. □

References

Alptekinoglu, A., Corbett, C.J., 2008. Mass customization vs. mass production: variety and price competition. Manuf. Serv. Oper. Manage. 10 (2), 204–217.
Bacon, D.R., Besharat, A., Parsa, H., Smith, S.J., 2016. Revenue management, hedonic pricing models and the effects of operational attributes. Int. J. Reven. Manage. 9 (2–3), 147–164.
Basiri, Z., Heydari, J., 2017. A mathematical model for green supply chain coordination with substitutable products. J. Clean. Prod. 145, 232–249.
Bernstein, F., Federgruen, A., 2004. A general equilibrium model for industries with price and service competition. Oper. Res. 52 (6), 868–886.
Bitran, G., Caldentey, R., 2003. An overview of pricing models for revenue management. Manuf. Serv. Oper. Manage. 5 (3), 203–229.
Bronnenberg, B.J., Wathieu, L., 1996. Asymmetric promotion effects and brand positioning. Market. Sci. 15 (4), 379–394.
Chen, C., 2001. Design for the environment: a quality-based model for green product development. Manage. Sci. 47 (2), 250–263.
Chen, Y.C., Fang, S.-C., Wen, U.-P., 2013. Pricing policies for substitutable products in a supply chain with internet and traditional channels. Eur. J. Oper. Res. 224 (3), 542–551.
Chiang, W.C., Chen, J.C.H., Xu, X., 2007. An overview of research on revenue management: current issues and future research. Int. J. Reven. Manage. 1 (1), 97–128.
Chitra, K., 2007. In search of the green consumers: a perceptual study. J. Serv. Res. 7 (1), 173–191.
Conrad, K., 2005. Price competition and product differentiation when consumers care for the environment. Environ. Resour. Econ. 31 (1), 1–19.
Dickson, P.R., Sawyer, A.G., 1990. The price knowledge and search of supermarket shoppers. J. Market. 54 (3), 42–53.
Drozdenko, R., Jensen, M., Coelho, D., 2011. Pricing of green products: premiums paid, consumer characteristics and incentives. Int. J. Bus., Market., Decis. Sci. 4 (1), 106–116.
Ferrer, G., Swaminathan, J.M., 2006. Managing new and remanufactured products. Manage. Sci. 52 (1), 15–26.
Festinger, L., 1954. A theory of social comparison processes. Hum. Relat. 7 (2), 117–140.
Gavious, A., Lowengart, O., 2012. Price equality relationship in the presence of asymmetric dynamic reference quality effects. Market. Lett. 23 (1), 137–161.
Ginsberg, J.M., Bloom, P.N., 2004. Choosing the right green-marketing strategy. MIT Sloan Manage. Rev. 46 (1), 79–84.
Han, S., Gupta, S., Lehmann, D.R., 2001. Consumer price sensitivity and price thresholds. J. Retail. 77 (4), 435–456.
Helson, H., 1964. Adaptation-level Theory. Harper Row, Oxford, England.
Heydari, J., Norouzinasab, Y., 2015. A two-level discount model for coordinating a decentralized supply chain considering stochastic price-sensitive demand. J. Ind. Eng. Int. 11 (4), 531–542.
Hopkins, M.S., Roche, C., 2009. What the 'green' consumer wants. MIT Sloan Manage. Rev. 50 (4), 87–89.
Joshi, Y., Rahman, Z., 2015. Factors affecting green purchase behaviour and future research directions. Int. Strateg. Manage. Rev. 3 (1–2), 128–143.
Kalwani, M.U., Yim, C.K., Rinne, H.J., Sugita, Y., 1990. A price expectations model of customer brand choice. J. Mark. Res. 27 (3), 251–262.
Kalyanaram, G., Little, J.D.C., 1994. An empirical analysis of latitude of price acceptance in consumer package goods. J. Consum. Res. 21 (3), 408–418.
Kim, W., Kim, M., 2015. Reference quality-based competitive market structure for innovation driven markets. Int. J. Res. Mark. 32 (3), 284–296.
Klapper, D., Ebling, C., Temme, J., 2005. Another look at loss aversion in brand choice data: can we characterize the loss averse consumer? Int. J. Res. Mark. 22 (3), 239–254.
Kopalle, P.K., Kannan, P.K., Boldt, L.B., Arora, N., 2012. The impact of household level heterogeneity in reference price effects on optimal retailer pricing policies. J. Retail. 88 (1), 102–114.
Kuo, C.W., Ahn, H.S., Aydin, G., 2013. Pricing policy in a supply chain: negotiation or posted pricing. Prod. Oper. Manage. 22 (3), 626–641.
Leng, M., Parlar, M., 2005. Game theoretic applications in supply chain management: a review. INFOR: Inform. Syst. Oper. Res. 43 (3), 187–220.
Liu, G.W., Sethi, S.P., Zhang, J.X., 2016. Myopic vs. far-sighted behaviours in a revenue-sharing supply chain with reference quality effects. Int. J. Prod. Res. 54 (5), 1334–1357.
Liu, Z.L., Anderson, T.D., Cruz, J.M., 2012. Consumer environmental awareness and competition in two-stage supply chains. Eur. J. Oper. Res. 218 (3), 602–613.
Luo, Z., Chen, X., Chen, J., Wang, X., 2017. Optimal pricing policies for differentiated brands under different supply chain power structures. Eur. J. Oper. Res. 259 (2), 437–451.
Maddah, B., Bish, E.K., 2007. Joint pricing, assortment, and inventory decisions for a retailer's product line. Naval Res. Logist. 54 (3), 315–330.
Maglaras, Costis, 2006. Dynamic pricing strategies for multi-product revenue management problems. Manuf. Serv. Oper. Manage. 8 (21), 136–148.
Mazumdar, T., Papatla, P., 1995. Loyalty differences in the use of internal and external reference prices. Market. Lett. 6 (2), 111–122.
Moon, S., Russell, G.J., Duvvuri, S.D., 2006. Profiling the reference price consumer. J. Retail. 82 (1), 1–11.
Neumann, N., Böckenholt, U., 2014. A meta-analysis of loss aversion in product choice. J. Retail. 90 (2), 182–197.
Niu, B., Wang, Y., Guo, P., 2015. Equilibrium pricing sequence in a co-opetitive supply chain with the odm as a downstream rival of its oem. Omega 57, 249–270.
Pan, X., Shankar, V., Ratchford, B.T., 2002. Price competition between pure play versus bricks-and-clicks e-tailers: analytical model and empirical analysis. Adv. Appl. Microecon. 11, 29–61.
Popescu, I., Wu, Y., 2007. Dynamic pricing strategies with reference effects. Oper. Res. 55 (3), 413–429.
Schlegelmilch, B.B., Bohlen, G.M., Diamantopoulos, A., 1996. The link between green purchasing decisions and measures of environmental consciousness. Eur. J. Mark. 30 (5), 35–55.
Schuhwerk, M.E., Lefkoff-Hagius, R., 1995. Green or non-green? Does type of appeal matter when advertising a green product? J. Adver. 24 (2), 45–54.
Shamdasani, P., Chon-Lin, G.O., Richmond, D., 1993. Exploring green consumers in an oriental culture: role of personal and marketing mix factors. NA-Adv. Consum. Res. 20, 488–493.
Soon, W., 2011. A review of multi-product pricing models. Appl. Math. Comput. 217 (21), 8149–8165.
Sudhir, K., 2001. Competitive pricing behavior in the auto market: a structural analysis. Market. Sci. 20 (1), 42–60.
Tang, C.S., Yin, R., 2007. Joint ordering and pricing strategies for managing substitutable products. Prod. Oper. Manage. 16 (1), 138–153.
Tversky, A., Kahneman, D., 1991. Loss aversion in riskless choice: a reference-dependent model. Q. J. Econ. 106 (4), 1039–1061.
Van Oest, R., 2013. Why are consumers less loss averse in internal than external reference prices? J. Retail. 89 (1), 62–71.
Wang, C., Huang, R., Wei, Q., 2015. Integrated pricing and lot-sizing decision in a two-echelon supply chain with a finite production rate. Int. J. Prod. Econ. 161, 44–53.
Wang, Z., 2016. Technical note intertemporal price discrimination via reference price effects. Oper. Res. 64 (2), 290–296.
Xu, X.P., Zhang, W., He, P., Xu, X.Y., 2017. Production and pricing problems in make-to-order supply chain with cap-and-trade regulation. Omega-Int. J. Manage. Sci. 66, 248–257.
Yalabik, B., Fairchild, R.J., 2011. Customer, regulatory, and competitive pressure as drivers of environmental innovation. Int. J. Prod. Econ. 131 (2), 519–527.
Yao, D.-Q., Liu, J.J., 2005. Competitive pricing of mixed retail and e-tail distribution channels. Omega 33 (3), 235–247.
Yenipazarli, A., 2016. Managing new and remanufactured products to mitigate environmental damage under emissions regulation. Eur. J. Oper. Res. 249 (1), 117–130.
Zhang, J., Chiang, W.Y.K., Liang, L., 2014. Strategic pricing with reference effects in a competitive supply chain. Omega-Int. J. Manage. Sci. 44, 126–135.
Zhang, L., Wang, J., You, J., 2015. Consumer environmental awareness and channel coordination with two substitutable products. Eur. J. Oper. Res. 241 (1), 63–73.