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Competitive pricing and product strategies in the presence of consumers' social comparisons

Ting Zhang [a], Tsan-Ming Choi [b,*], Tai-Chiu (Edwin) Cheng [c]

[a] *University of Bristol Business School, 11-13 Tyndall's Park Road, Bristol, BS8 1PY, United Kingdom*
[b] *Centre for Supply Chain Research, University of Liverpool Management School, Chatham Building, Liverpool L69 7ZH, United Kingdom*
[c] *Department of Logistics and Maritime Studies, Logistics Research Centre, The Hong Kong Polytechnic University, Hong Kong SAR, China*

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ABSTRACT

When buying products that are used in public (e.g., smart phones and cars), consumers may compare their products with those of others they meet in their community. This behavior is referred to as "social comparisons". In these comparisons, the consumers make (incur) a psychological gain (loss) when they find that their product is superior (inferior). Analytically examining this psychological gain (loss) from "the consumer's social-comparison benefit (cost)", we show how it would affect the pricing, quality, and product-line strategies of two competing firms. We find that a greater consumer's social-comparison benefit may increase both firms' profits by reducing their price competition, while a higher consumer's social-comparison cost may decrease both firms' profits by intensifying their price competition. When the firms can strategically choose their product quality, a greater consumer's social-comparison benefit will lead the firms to increase their quality difference, and a higher consumer's social-comparison cost will lead the firms to reduce their quality difference. When the firms can extend their product lines to sell more than one product, their product lines tend to shrink (expand) as the consumer's social-comparison benefit (cost) increases. If the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, both firms earn higher profits when they can extend their product lines (versus when they cannot extend their product lines). This result highlights that relative to reducing the quality difference between the two firms, the product-line extension strategy can be a more effective way for the firms to manage consumers' social comparisons. Our results show that understanding consumers' social comparisons is important for firms to formulate an effective product offering strategy.

1. Introduction

When buying products that are used in public (e.g., cars, clothes, watches, and cellphones), consumers may compare their products with those of others they meet in their community. This behavior, referred to as "social comparisons", is pervasive (Festinger, 1954; Dreze & Nunes, 2009). In these comparisons, consumers enjoy positive emotions (e.g., happiness, pleasure, and pride) when they find that their products are superior, suffer negative emotions (e.g., upset, dissatisfaction, and envy) when they find that their products are inferior, and have neutral emotions when they find that their product quality is similar to others'. For example, consumers wearing cashmere (polyester) coats may consider themselves more (less) charming than those wearing polyester (cashmere) coats, as cashmere in general has higher quality than

polyester; consumers driving cars with a 4.0-liter (2.0-liter) engine may consider themselves cooler (less cool) than those driving cars with a 2.0-liter (4.0-liter) engine because, generally, the larger the engine's displacement, the more powerful is the car. So, in the presence of social comparisons, consumers care about the product's absolute quality as well as its relative quality compared with others. The empirical experiments of Weaver et al. (2015) show that consumers may choose an objectively inferior product with high relative standing (e.g., a car rated 6/10 in quality, with others' cars rated 4/10) over an objectively superior product with low relative standing (e.g., a car rated 7/10 in quality, with others' cars rated 9/10). This shows the impact of social comparisons.

As a measure of emotions, the consumer's psychological utility in social comparisons depends not only on the quality difference between their product and others' but also on the probabilities of meeting consumers that have bought different products, i.e., the products' market shares. For example, the consumer will derive a higher psychological utility, i.e., feeling more positive emotions,

* Corresponding author.
E-mail address: T.M.Choi@liverpool.ac.uk (T.-M. Choi).
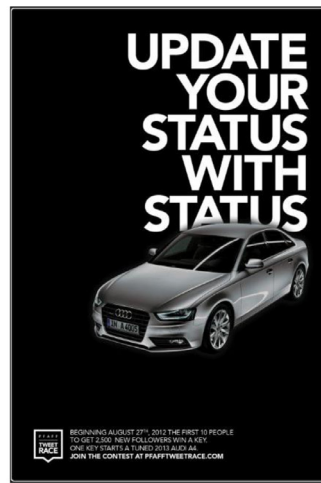
(a) Advertisement inducing the consumer's
social-comparison benefit
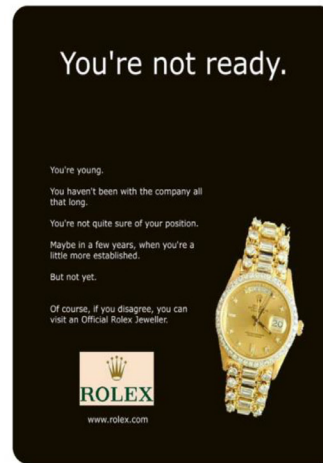
(b) Advertisement sensitizing the consumer's
social-comparison cost

Fig. 1. Advertisements with different impacts on consumers' social comparisons.[1]

when their car is superior to those of 90% of consumers than when their car is superior to only 50% of consumers. Similarly, the consumer will derive a lower psychological utility, i.e., feeling more negative emotions, when their car is inferior to those of 90% of consumers than their car is inferior to those of 50% consumers. Understanding consumers' social comparisons is important for firms to make optimal pricing and product decisions because such decisions determine the products' market shares, which in turn affect consumers' psychological utilities in social comparisons that affect consumers' product choices.

In this paper we build analytical models to study how consumers' social comparisons affect the pricing and product strategies of two competing firms that sell quality differentiated products. The consumer's utility of a product consists of the consumption utility and social-comparison utility, where the former captures the functional benefits from using the product, while the latter captures the consumer's psychological utility from comparing their product quality with that of others they meet. In each comparison, the consumer will perceive a psychological gain if their product has higher quality than others', a psychological loss if their product has lower quality than others', and neither psychological gain nor loss if the quality of the products is identical. We measure this psychological gain/loss based on "the consumer's social-comparison benefit/cost". To better explain the meaning, Fig. 1 illustrates two advertisements that aim to affect the consumer's social-comparison benefit and cost, respectively. In Fig. 1(a), Audi's advertisement indicates that using a higher-quality car (such as Audi's) signals a higher social status, allowing consumers to show off. So, this advertisement can increase the consumer's sensitivity to the psychological gain of being superior to others, i.e., increasing the consumer's social-comparison benefit. In Fig. 1(b), Rolex's advertisement indicates that if a consumer is "not ready" to use a Rolex's watch, then they are "not quite sure of their position" and not yet "established". Put differently, the inability of using a Rolex's watch signals a lower position in the social hierarchy. So, Rolex's advertisement can increase the consumer's sensitivity to the psychological loss from being inferior to others, i.e., increasing the consumer's social-comparison cost. Through analyses of a series of models, we find that the consumer's social-comparison

benefit and cost will critically affect the firms' pricing, quality, and product-line strategies.

Our research questions and main results are as follows: First, how do consumers' social comparisons affect the price competition between the two firms? We find that the consumer's social-comparison benefit reduces the price competition between the two firms, and the consumer's social-comparison cost intensifies it. Under price competition, as the consumer's social-comparison benefit increases, the higher-quality firm's profit always increases, and the lower-quality firm's profit increases (decreases) when the quality difference between the two firms is high (low). This indicates that when the quality difference between the two firms is high, both firms will be better off by increasing the consumer's social-comparison benefit. So, in this case, it is wise for the firms to use advertisements such as Fig. 1(a). As the consumer's social-comparison cost increases, the higher-quality firm's profit increases (decreases) when the quality difference between the two firms is high (low), and the lower-quality firm's profit always decreases. This indicates that when the quality difference between the two firms is low, both firms will be better off by reducing the consumer's social-comparison cost. So, in this case, the firms should avoid using advertisements such as Fig. 1(b).

Second, in the presence of consumers' social comparisons, how should the firms determine their optimal product quality? We find that as the consumer's social-comparison benefit increases, the higher-quality (lower-quality) firm tends to improve (reduce) its product quality, leading to a larger quality difference between the two firms. However, as the consumer's social-comparison cost increases, the higher-quality (lower-quality) firm tends to reduce (improve) its product quality, leading to a smaller quality difference between the two firms. So, when the firms can strategically choose their product quality, the consumer's social-comparison benefit can increase both firms' profits by reducing their price competition and increasing their quality difference, and the consumer's social-comparison cost can decrease both firms' profits by intensifying their price competition and reducing their quality difference. This indicates that the endogeneity of product quality can increase the positive effect of the consumer's social-comparison benefit and the negative effect of the consumer's social-comparison cost on the firms, further highlighting that the firms should be cautious about using advertisements such as Fig. 1(b). If these advertisements have appeared while the consumers have high social-comparison costs, the firms should try to avoid

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quality changes. For example, a feasible method is that the higher-quality firm commits not to reduce its product quality.

Third, in the presence of consumers' social comparisons, how should the firms design their product lines? We find that the firms' product lines tend to shrink (expand) as the consumer's social-comparison benefit (cost) increases. If the consumer's social-comparison benefit is high relative to the consumer's social-comparison cost (e.g., when advertisements such as Fig. 1(a) are common), the firms should not extend their product lines because, in this case, the consumer's social comparisons positively affect both firms' profits, whereas product-line extension reduces this positive effect by introducing an intermediate-quality product as a social-comparison buffer for consumers. In contrast, if the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost (e.g., when advertisements such as Fig. 1(b) are common), both firms should extend their product lines to reduce the negative effect of the consumer's social comparisons. If the consumer's social-comparison benefit is moderate relative to the consumer's social-comparison cost, in equilibrium, only one firm extends its product line. Moreover, we find that if the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, both firms will earn higher profits when they can extend their product lines (versus when they cannot extend their product lines). This is because product-line extension provides an additional means to reduce the negative effect of the consumer's social comparisons on the firms, which is more effective than reducing the firms' quality difference.

The contributions of our paper are as follows: First, our paper contributes to the literature by complementing the findings of Iyer and Soberman (2016). Though both our paper, and Iyer and Soberman (2016) show that the consumer's social-comparison benefit would mitigate the firms' price competition, and the consumer's social-comparison cost aggravates the firms' price competition, our paper provides some novel insights into the competing firms' quality choice and product-extension strategies. For example, as the consumer's social-comparison benefit increases, the competing firms tend to increase their quality difference or shrink their product lines; as the consumer's social-comparison cost increases, they tend to reduce their quality difference or expand their product lines. These findings are new and contribute to the operational research (OR) literature. Second, our results provide important managerial insights into how to formulate the optimal product strategies considering consumers' social comparisons. For example, we give analytical conditions that help firms decide whether they should use advertisements (like Fig. 1(a) or (b)). We show that if a company uses advertisement to increase the consumer's social-comparison benefit like Fig. 1(a) (e.g., Audi), then both the company itself and its competitor can be better off, so it becomes a wise "all-win" strategy. If a company uses advertisement to increase the consumer's social-comparison cost like Fig. 1(b) (e.g., Rolex), then both the company and its competitor may be worse off, so it becomes an unwise "all-cost" strategy. These findings can partially explain the product strategies taken by firms such as Audi and Rolex in practice.

We organize the rest of the paper as follows: In Section 2 we review the related literature. In Section 3 we build the base model to study the price competition between two quality-differentiated firms. In Section 4 we extend the base model to consider the scenario where the firms can strategically choose their quality levels. In Section 5 we allow the firms to extend their product lines to sell more than one product. We provide all the technical proofs in E-Companion A. In E-Companion B, we conduct robustness checking by showing that relaxing some model assumptions will not affect our main results.

2. Literature review

Our paper is related to two streams of literature, namely product strategies and social influences. We review them in Sections 2.1 and 2.2. In Section 2.3, we discuss the differences between our paper and the literature.

2.1. Literature on product strategies

Our paper is related to the vast literature on product strategies in operations management. Product strategies, especially in the contexts of pricing, quality choice, and product-line design in competitive environments, have been studied extensively. Shaked and Sutton (1982), and Moorthy (1988) show that competitive firms can use product differentiation to soften price competition. Desai (2001) studies a firm's pricing and quality decisions in the monopoly and duopoly markets, showing that the firm may serve only part of the consumers in the monopoly market but will serve all the consumers in the duopoly market. Johnson and Myatt (2003) find that facing an entrant, an incumbent tends to expand its product line when the entrant offers only low-end products. Moreover, they also show that the incumbent will never offer products with quality inferior to that of the entrant's lowest-quality product. Chambers et al. (2006) study the quality and price competition between two firms and show the effects of the cost structures. Heese and Swaminathan (2006) analytically study a manufacturer's product-line decisions when it can design the product components. They uncover that an optimally designed product line involving common components may yield higher revenues than a product line based on different variants. Matsubayashi et al. (2009) consider that if consumers differ in their quality valuations, a firm can just serve consumers with the higher quality valuation in a monopolistic market, and can serve consumers with the lower quality valuation under competition. Liu and Cui (2010) theoretically find that when a manufacturer sells through a decentralized supply chain, its product-line length may be larger than when it sells through a centralized channel. Qi et al. (2016) explore a firm's optimal quality and pricing decisions when consumers differ not only in their willingness to pay for quality but also in their reservation utility for the product. Joshi et al. (2016) find that a firm's product-line extension can benefit itself and also its competitor, even in the absence of market size expansion. They explain their findings by highlighting that a broader scope leads the firm to raise prices for its core customers, increasing its competitor's demand. Besbes and Sauré (2016) find that competition leads a firm to offer a broader set of products compared with the case where it operates as a monopolist. Ji et al. (2018) study the effect of public sustainability concerns on a firm's product-line decision under centralized and decentralized channel structures. Zou et al. (2020) study a firm's optimal product-line design in the presence of consumers' anticipated regret. They find that the quality differences between the firm's offerings will be larger (smaller) if consumers' anticipated regret increases (reduces). Naeeni et al. (2022) find that firms may be worse off from offering a socially responsible product. Zhang et al. (2023) find that a manufacturer prefers "selling low-quality products and renting high-quality products" to "selling high-quality products and renting low-quality products" if the quality differentiation degree is high. The aforementioned literature studies the product strategies without considering social influences.

2.2. Literature on social influences

Our study is particularly related to research on product strategies under social influences, i.e., the phenomenon that consumers'

Table 1
OM literature that considers social influences.

Example	Meaning	Modeling	Literature
Social comparison	Consumers tend to compare themselves with others they meet.	Consumers derive a positive (negative) psychological utility when finding themselves superior (inferior) to others.	Iyer and Soberman (2016), and our paper.
Reference dependency	Consumers form a reference point (e.g., reference price) and compare their status quo (e.g., actual price) with the reference point.	Consumers derive a positive (negative) psychological utility if their status quo is better (worse) than the reference point.	Amaldoss and Jain (2010), Amaldoss and Shin (2011), Roels and Su (2013), Zhang et al. (2013), Sun et al. (2021), Orhun (2009), L. Sun et al. (2022), and Yan et al. (2022).
Conspicuous consumption	Consumers use products to signal their social status. Exclusivity is usually treasured.	Consumers' valuation of a product depends on the social status of its buyers.	Li (2019), Amaldoss and Jain (2015), Zhang et al. (2022).
Fairness concern	Consumers care about whether they are treated fairly (e.g., whether they pay more for the same product than others).	Consumers derive a positive (negative) psychological utility if treated fairly (unfairly).	Chen and Cui (2013), Yu et al. (2022).

behaviours are influenced by their peers (Chiu et al., 2018). The prior studies capture social influences by assuming that consumers' utilities of a product depend on others' purchase decisions. Specifically, Amaldoss and Jain (2010) consider a market consisting of leader and follower consumers, where the leaders value the product more as fewer followers buy it, while the followers value the product more as more leaders buy it. In this market, limited editions and multiple products are found to be able to improve firms' profits. Following Amaldoss and Jain (2010), Sun et al. (2022) consider the presence of leader and follower consumers and analytically study a firm's equilibrium product-upgrade strategy. Amaldoss and Shin (2011) consider that as the number of low-valuation consumers increases, on average, consumers' willingness to pay decreases. They show that a larger low-end market may dampen price competition and improve profits by leading firms to increase their quality difference. Chen and Cui (2013) find that when consumers are concerned about price fairness, firms can benefit from uniformly pricing their branded variants because it would help reduce their price competition. Amaldoss and Jain (2015) find that when consumers' desire for uniqueness is high, individual branding is more profitable in monopolistic markets, and umbrella branding is more profitable in competitive markets. Li (2019) studies vertical-line extensions in status-goods markets in which consumers use their group's average quality valuation to signal their status. She shows that incumbents should introduce downward extensions when they are monopolists and upward extensions when they face competition from lower-quality entrants. Note that Amaldoss and Shin (2010, 2011, 2015) and Li (2019) focus on luxury products, whose valuations depend on the numbers of their buyers. Our study applies to both non-luxury and luxury products, as long as consumers exhibit social comparisons by comparing their product quality with others they meet. Apfelstaedt and Mechtenberg (2021) reveal that competitive retailers' optimal product lines depend on whether the product's price or quality draws consumers' attention. Geng et al. (2021) study how the market-expansion effect, i.e., the total market expands as a result of the firms' sales, and the network effect, i.e., the consumer's utility of buying from a firm increases with the firm's sales volume, affect competition between two vertically differentiated firms. Chen and Chen (2021) show that due to the strong network effect, under competition, the firm selling inferior products can retain market dominance. Yan et al. (2022) study a monopolistic firm's price and product strategies under reference price effects. These studies consider various types of social influences, including reference dependency (Amaldoss & Jain 2010; Amaldoss & Shin 2011, Sun et al. 2021, Yan et al. 2022), conspicuous consumption (Li 2019; Amaldoss & Jain 2015), fairness concern (Chen & Cui 2013), network effects (Geng et al. 2021, Chen & Chen 2021), and context sensitivity (Apfelstaedt & Mechtenberg 2021). In Table 1, we illustrate the different forms of social influences.

2.3. Research gaps

A form of social influences, called "social comparison", is underexplored in the literature. Social comparison, proposed by Festinger (1954), indicates that people have the motivation to compare with each other. Specifically, we consider consumers' social comparison by assuming that consumers compare their product quality with that of others they meet. Note that social comparison is different from conspicuous consumption. Under conspicuous consumption, consumers tend to care about their product's exclusivity, and if they own something others don't have, they can be happier. The related literature, e.g., Li (2019) and Amaldoss and Jain (2015), assumes that under conspicuous consumption, consumers' valuation of a product depends on its buyers' social status. Under social comparison, consumers tend to care about their product's superiority, and if they own something better than other's, they can be happier. Conspicuous consumption often occurs in the luxury-goods industry, and social comparison occurs in both luxury- and non-luxury-goods industries. Moreover, consumers' utility from conspicuous consumption may not depend on the product's attributes, and consumers' utility from social comparisons depends on the product's attributes. Note also that consumers' social comparisons are different from consumers' reference dependency, highlighting our differences with Orhun (2009), who studies product-line extensions considering consumers' reference dependency. Orhun (2009) considers that under reference dependency, consumers derive a positive (negative) psychological utility from buying a higher-quality (lower-quality) product if they know a lower-quality (higher-quality) product existing in the market, no matter whether they meet buyers of the lower-quality (higher-quality) product in the market. Our paper considers that under social comparison, consumers derive a positive (negative) psychological utility from buying a higher-quality (lower-quality) product from meeting buyers of the lower-quality (higher-quality) product in the market. For example, under social comparison, consumers do not care someone they will never meet is using superior or inferior products. So, different from Orhun (2009), in our paper, the consumer's overall psychological utility from social comparisons depends on the probabilities of meeting buyers that have bought different products, i.e., the market shares. Based on their expectation of market shares, consumers make purchase decisions, which in turn affect the real market shares. Then, we derive the rational-expectation equilibrium under which the consumers' expected market shares equal the real ones. Such sophisticated interactions of consumers are absent in the reference-dependency model of Orhun (2009), making our social-comparison model more realistic than Orhun (2009)'s. Moreover, Orhun (2009) looks at the monopolistic market, while we look at the competitive market. Our result shows that consumers' social comparisons can benefit firms under competition. Roels and Su (2013) study how social planners

should exploit social comparisons to pursue their objectives. But in their paper, "social comparisons" is defined differently from ours and in fact more like "reference dependency".

Our paper is most closely related to Iyer and Soberman (2016), which examine the critical effect of market shares on consumers' expected psychological utilities from social comparisons, using the rational-expectation equilibrium to analyze consumers' decisions. The definition of "social comparisons" in Iyer and Soberman (2016) is similar to that in our paper. It is worth mentioning that our paper differs from Iyer and Soberman (2016) in two significant ways. First, Iyer and Soberman (2016) consider that consumers compare solely on their products' social-responsibility levels, while our paper considers that consumers compare product qualities (which are also endogenous decisions of the competing firms). Without being limited to socially responsible products, our model is more general and applies to products as long as they are used in public. Second, while Iyer and Soberman (2016) focus on the price competition between two firms, our paper studies both the price and product strategies, obtaining novel insights into competing firms' quality choices and product-line decisions under consumers' social comparisons. For example, we find that as the consumer's social-comparison benefit increases, the competing firms tend to increase their quality difference or shrink their product lines; as the consumer's social-comparison cost increases, they tend to reduce their quality difference or expand their product lines. Moreover, we find that if the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, the competing firms earn higher profits when they can extend their product lines than when they cannot extend their product lines. To our best knowledge, our paper is the first that comprehensively studies the effects of consumers' social comparisons on competing firms' product strategies.

3. Base model

Our model consists of two competing firms, indexed by A and B. Firm $i \in \{A, B\}$ produces a product with quality q_i at a marginal cost c_i.[2] In this base model, the firms' product quality is exogenously given (in the extended model in Section 4, we consider that the firms can strategically choose their product quality). Without loss of generality, we assume that firm A's product quality is higher than firm B's, i.e., $q_A > q_B$. To capture the fact that the higher-quality product incurs a higher marginal cost than the lower-quality product, we have $c_A > c_B$. The firms' fixed costs are normalized to zero.[3] In this base model, we study the pricing game in which firm A and firm B simultaneously choose their prices p_A and p_B, respectively.

There is a unit mass of consumers, each of whom buys at most one product. The consumer's utility of a product consisting of both the consumption utility (e.g., functional benefits from the consumption of the product) and the social-comparison utility (e.g., the psychological utility from comparing their product with those of others') is as follows:

Utility = Consumption utility + "Social−comparison" utility.

The consumer's consumption utility of firm i's product is $v + \theta q_i - p_i$, where v is the base consumption value and θ reflects the consumer's willingness to pay for product quality (we will also refer to θ as the consumer's quality valuation interchangeably in the paper). Consumers have heterogeneous willingness to pay for product quality, which we assume to follow a uniform distribution, i.e., $\theta \sim \text{uniform}[0, 1]$, in the population of consumers.[4] To focus on the effects of product quality on consumer behaviours, we consider the case where consumers have the same base consumption value v for the two products, which captures the common functional benefits provided by the products to consumers. For example, both higher- and lower-quality cars provide a functional benefit of traffic, and both higher- and lower-quality watches provide a functional benefit of timing. Following Li (2019), we assume that v is sufficiently high so that, in equilibrium, each consumer will buy a product, i.e., the market is fully covered.[5] This assumption excludes the market-expansion effect, facilitating us to investigate the competition between the two firms. For example, we consider this scenario as when the consumer has to buy a car for commuting to work, and the problem is whether to buy a higher- or lower-quality car.

In addition to the consumption utility, consumers consider the social-comparison utility in choosing between the two products. Note that our model applies to markets of publicly-consumed goods (e.g., cars, watches, clothes, and cellphones), in which consumers can "see" the products owned and used by others. Moreover, based on what they see, consumers can identify the product quality because, generally, the higher- and lower-quality products look different. For example, cashmere coats look prettier than polyester coats; silk shirts look brighter than polyester shirts; some cars show their engine displacements. The literature commonly assumes that consumers can distinguish and identify product quality (e.g., Orhun (2009) and Li (2019)).[6] Specifically, we consider the situation where consumers can distinguish the product with higher quality q_A from that with lower quality q_B, knowing the exact quality of each product they see. The observable difference in product quality leads consumers to engage in social comparisons. Specifically, when meeting another consumer, a consumer (referred to as "she") will compare their product's quality. If her product quality is higher than the other's, she will perceive a psychological gain, which is captured by a positive social-comparison utility; however, if her product quality is lower than the other's, she will perceive a psychological loss, which is captured by a negative social-comparison utility. The larger the quality difference between the two consumers' products, the larger is the magnitude of the social-comparison utility. We use $\alpha \in [0, 1)$ to measure the consumer's psychological gain from finding her product quality being superior, and use $\beta \in [0, 1)$ to measure the consumer's psychological loss from finding her product quality being inferior. Formally speaking, when meeting a consumer with product quality q_j, the consumer with product quality q_i will derive a social-comparison utility $\alpha \cdot \max\{q_i - q_j, 0\} + \beta \cdot \min\{q_i - q_j, 0\}$, where $\alpha \cdot \max\{q_i - q_j, 0\}$ captures the consumer's psychological gain from finding her product quality being superior, i.e., $q_i > q_j$, and $\beta \cdot \min\{q_i - q_j, 0\}$ captures the consumer's psychological loss from finding her product quality being inferior, i.e., $q_i < q_j$. If the two products have the same quality, i.e., $q_i = q_j$, the comparison will be a tie, leading to zero social-comparison utility for the consumer. In the rest of the paper, we refer to α as "the consumer's social-comparison benefit"

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[2] In this paper we assume that that a product's quality depends on its intrinsic attributes and does not depend on the brand's image. In practice, the consumer's perceived product quality may also be related to the brand's image. Suppose that a firm's product depends on both its intrinsic attributes and the brand's image. Specifically, the quality of firm $i \in \{A, B\}$'s product j is $q_{ij} = B_i + Q_{ij}$, where B_i is firm i's brand image and Q_{ij} is the product's intrinsic vertical attributes. Then, the insights in our paper are still valid, i.e., considering brand image will not affect our insights.

[3] In E-companion B, we will show that relax this assumption will not qualitatively affect our main results.

[4] In E-companion B, we will show that if the consumer's quality valuation follows a different distribution, our main results still hold.

[5] In E-companion B we show that our main results remain valid for the case of partial coverage.

[6] In E-companion B, we conduct a robustness check by showing that if consumers may be not able to identify the product quality, our main results still hold.

and β as "the consumer's social-comparison cost". A higher α indicates that the consumer is more sensitive to the psychological gain from finding their product quality being superior, and a higher β indicates that the consumer is more sensitive to the psychological loss from finding their product quality being inferior. We assume $\alpha < \beta$ because according to prospect theory, people are more sensitive to loss than to gain (Kahneman, 1979). Note that our main results remain valid for $\alpha \geq \beta$. Note that the consumer's social-comparison behavior is common and justified by empirical experiments. For instance, Wheeler and Miyake (1992) ask ten college students to record details of their social comparisons over two weeks, finding that social comparison is common in everyday life, where upward comparison, i.e., comparing with another in a superior position, decreases the "subjective well-being", and downward comparison, i.e., comparing with another in an inferior position, increases it. Weaver et al. (2015) show that consumers may choose an objectively inferior product with a high relative standing (e.g., "a car rated 6/10 in quality, with others' cars rated 4/10") over an objectively superior product with a low relative standing (e.g., "a car rated 7/10 in quality, with others' cars rated 9/10").

In aggregate, the consumer's social-comparison utility depends on the probabilities of meeting consumers whose product choices are different, i.e., the market shares of the two firms. Suppose that, in equilibrium, consumers with $\theta \in [\hat{\theta}, 1]$ buy from the higher-quality firm A and consumers with $\theta \in [0, \hat{\theta})$ buy from the lower-quality firm B, where $\hat{\theta}$ is the quality valuation of the consumer that is indifferent to buying from any of the two firms (recall that we assume v to be sufficiently high such that all the consumers will buy a product). Recall that $\theta \sim \text{Uniform}[0, 1]$. So, among the consumers, a proportion $1 - \hat{\theta}$ of them will buy firm A's product, and a proportion $\hat{\theta}$ of them will buy firm B's product (see Fig. 2). We assume that all the consumers live in the same community and they can randomly encounter any other consumer. So, each consumer has a probability of $1 - \hat{\theta}$ of meeting firm A's product buyers and s probability of $\hat{\theta}$ of meeting firm B's product buyers. Based on their expectations of the consumer's indifference point $\hat{\theta}$, consumers anticipate that the social-comparison utilities of buying from firm A and firm B are $\hat{\theta}\alpha(q_A - q_B) > 0$ and $-(1 - \hat{\theta})\beta(q_A - q_B) < 0$, respectively. To better understand this formulation, let us consider the market as a city, where a car consumer will encounter others during driving. Then, our formulation indicates that this consumer will derive a higher social-comparison utility when their car is superior to a larger proportion of consumers and will derive a lower social-comparison utility when their car is inferior to a smaller proportion of consumers.

To sum up, the consumer's net utility, i.e., surplus, depends on which interval their θ falls in as follows :[7]

$$U(\theta) = \begin{cases} v + \theta q_A - p_A + \hat{\theta}\alpha(q_A - q_B) & \text{if} \quad \theta \in [\hat{\theta}, 1], \\ v + \theta q_B - p_B - (1 - \hat{\theta})\beta(q_A - q_B) & \text{if} \quad \theta \in [0, \hat{\theta}). \end{cases}$$

Note that consumers make purchase decisions based on their expectations of the products' market shares, i.e., $\hat{\theta}$ and $1 - \hat{\theta}$, while the products' market shares depend on consumers' purchase de-

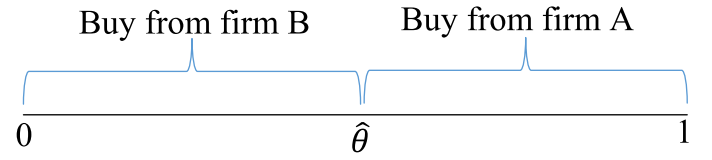**Buy from firm B** **Buy from firm A**

0 $\hat{\theta}$ 1

Fig. 2. Consumers' purchase decisions in the base model.

cisions. We adopt the rational-expectation concept by assuming that in equilibrium, consumers' expectations of the products' market shares equal the real ones. The rational-expectation concept is widely adopted in the literature, e.g., Su and Zhang (2008), and Iyer and Soberman (2016). Using the rational-expectation concept, we find that the indifference point $\hat{\theta}$ should satisfy $v + \hat{\theta}q_A - p_A + (1 - \hat{\theta})\alpha(q_A - q_B) = v + \hat{\theta}q_B - p_B - \hat{\theta}\beta(q_A - q_B)$, from which we obtain $\hat{\theta} = \frac{p_A - p_B - \beta(q_A - q_B)}{(1 + \alpha - \beta)(q_A - q_B)}$. The demands of firm A and firm B are $1 - \hat{\theta}$ and $\hat{\theta}$, respectively. To ensure that both firms have positive demands, i.e., $0 < \hat{\theta} < 1$, in equilibrium, we focus on the parameter region $2\beta - \alpha - 1 < \frac{c_A - c_B}{q_A - q_B} < 2 + 2\alpha - \beta$, which indicates that the relative quality-cost efficiency $(\frac{c_A - c_B}{q_A - q_B})$ between the two firms is moderate. One can show that firm A will price firm B out of the market if firm A's quality-cost efficiency is very high relative to firm B's, i.e., when $\frac{c_A - c_B}{q_A - q_B}$ is very low, and if firm A's quality-cost efficiency is very low relative to firm B's, i.e., when $\frac{c_A - c_B}{q_A - q_B}$ is very high, firm B will price firm A out of the market. To facilitate discussion of the subsequent results, Lemma 1 summarizes the effects of α and β on consumer demands with prices given.

Lemma 1. *For given prices: (i) The consumer's social-comparison benefit α has a positive effect on firm A's demand and a negative effect on firm B's demand, where both effects become weaker as the quality difference between the two firms increases. (ii) The consumer's social-comparison cost β has a positive effect on firm A's demand and a negative effect on firm B's demand, where both effects become stronger as the quality difference between the two firms increases.*

Lemma 1 shows the direct effects of consumers' social comparisons on demands. Specifically, it shows how the consumer's social-comparison benefit α and cost β would affect the two firms' demands when the prices are given. As one would expect, for given prices, as the consumer's social-comparison benefit/cost increases, consumers care more about their product-quality difference with others, leading more consumers to choose the higher-quality product over the lower-quality product. Formally speaking, $\frac{\partial(1-\hat{\theta})}{\partial\alpha}, \frac{\partial(1-\hat{\theta})}{\partial\beta} > 0$. Moreover, the effects of α and β on demands are found to be moderated by the quality difference between the two firms, i.e., $q_A - q_B$. Given prices, a larger $q_A - q_B$ indicates that firm A is more advantaged over firm B in terms of product quality, allowing firm A to cannibalize more consumer demands from firm B. So, as $q_A - q_B$ increases, firm A's buyers are less likely to meet firm B's buyers to obtain the social-comparison benefit, diminishing the effect of α on demands, i.e., $\frac{\partial(1-\hat{\theta})}{\partial\alpha\partial(q_A-q_B)} < 0$; however, as $q_A - q_B$ increases, firm B's buyers are more likely to meet firm A's buyers to incur the social-comparison cost, amplifying the direct effect of β on demands, i.e., $\frac{\partial(1-\hat{\theta})}{\partial\beta\partial(q_A-q_B)} > 0$. As we will show in Propositions 1–2, these moderating effects of $q_A - q_B$ will determine how α and β affect the equilibrium under the firms' price competition.

Anticipating consumers' purchase decisions, i.e., consumer demands, firm A and firm B simultaneously decide their prices to maximize their respective profits, which are as follows:

$$\pi_A = (p_A - c_A)(1 - \hat{\theta}),$$

---

[7] Note that consumers' social comparison is different from consumers' reference dependency. Suppose that we consider the consumer's reference effect. Then, the consumer's net utility is $U(\theta) = \begin{cases} v + \theta q_A - p_A + \alpha'(q_A - q_B) & \text{if} \quad \theta \in [\hat{\theta}, 1] \\ v + \theta q_B - p_B - \beta'(q_A - q_B) & \text{if} \quad \theta \in [0, \hat{\theta}) \end{cases}$, where α' indicates the consumer's reference-dependency benefit, and β' indicates the consumer's reference-dependency cost. This indicates that the consumer's psychological utility from reference dependency depends on the products' quality difference only, whereas the consumer's psychological utility from social comparisons depends on not only the products' quality difference but also the probabilities of meeting buyers of different products. We can show that consumers' reference dependency always benefits the higher-quality firm and harms the lower-quality firm, whereas consumers' social comparisons can benefit both the higher- and lower-quality firms.

$\pi_B = (p_B - c_B)\hat{\theta}.$

We can verify that $\frac{\partial^2 \pi_A}{\partial p_A^2} < 0$ and $\frac{\partial^2 \pi_B}{\partial p_B^2} < 0$. Solving the first-order conditions, i.e., $\frac{\partial \pi_A}{\partial p_A} = 0$ and $\frac{\partial \pi_B}{\partial p_B} = 0$, we derive the firms' equilibrium prices as $p_A^* = \frac{2c_A + c_B + (2+2\alpha-\beta)(q_A - q_B)}{3}$ and $p_B^* = \frac{2c_B + c_A + (1+\alpha-2\beta)(q_A - q_B)}{3}$, which yield profits of $\pi_A^* = \frac{[(2+2\alpha-\beta)(q_A-q_B) - c_A + c_B]^2}{9(1+\alpha-\beta)(q_A-q_B)}$ and $\pi_B^* = \frac{[(1+\alpha-2\beta)(q_A-q_B) + c_A - c_B]^2}{9(1+\alpha-\beta)(q_A-q_B)}$ for the firms. Note that the superscript '*' denotes the equilibrium. In Propositions 1 and 2, we analyze the effects of consumers' social comparisons on the equilibrium.

Proposition 1. *Under price competition, as the consumer's social-comparison benefit α increases, the following results will occur:*

(i) The firms' prices increase;

(ii) If $q_A - q_B < \frac{c_A - c_B}{\beta}$, then firm A's demand increases and firm B's demand decreases, and if $q_A - q_B > \frac{c_A - c_B}{\beta}$, then firm A's demand decreases and firm B's demand increases;

(iii) Firm A's profit always increases, and firm B's profit increases if $q_A - q_B > \frac{c_A - c_B}{\alpha+1}$ and decreases if $q_A - q_B < \frac{c_A - c_B}{\alpha+1}$.

Proposition 1 shows how the consumer's social-comparison benefit α affects the firms' equilibrium prices, demands, and profits. To understand Proposition 1, note that the consumer's social-comparison benefit has two effects. First, all else being equal, the consumer's social-comparison benefit directly increases their surplus of buying from the higher-quality firm A, allowing firm A to charge a higher price. Second, with the existence of the consumer's social-comparison benefit, the consumer's utility of buying from firm A increases with firm B's demand because when firm B's demand is larger, firm A's buyers are more likely to meet firm B's buyers to perceive a psychological gain in the advantaged comparison. This indicates that firm B's demand has a positive effect on firm A, leading firm A to compete less fiercely with firm B. As α increases, the two effects of the consumer's social-comparison benefit become stronger, prompting firm A to raise its price. Firm B will respond by raising its price because the prices of the two firms are strategic complements to each other. Thus, as shown in Proposition 1(i), a larger α reduces the price competition between the two firms.

Given that the market is fully covered and each consumer buys from either the higher- or lower-quality firm, one may expect that as the consumer's social-comparison benefit α increases, in equilibrium, the higher-quality firm A will cannibalize more demands from the lower-quality firm B. However, Proposition 1(ii) shows that this is not necessarily the case. To understand the rationale, note that α has direct and indirect (strategic) effects on the firms' equilibrium demands when the firms compete in setting their prices. The direct effect has been characterized in Lemma 1(i): For given prices, a larger α leads to a higher demand for firm A and a lower demand for firm B. The indirect effect is that as α increases, the firms will strategically increase their prices, whereas firm A's price increases more steeply than firm B's such that the price difference between the two firms becomes larger. Contrary to the direct effect, the indirect effect negatively affects firm A's equilibrium demand and positively affects firm B's equilibrium demand. Recall from Lemma 1(i) that the direct effect becomes stronger as the quality difference ($q_A - q_B$) between the two firms decreases. Thus, when the quality difference between the two firms is small, i.e., $q_A - q_B < \frac{c_A - c_B}{\beta}$, the direct effect of α on the equilibrium demands dominates the indirect effect, and as one would expect, a larger α increases firm A's equilibrium demand and decreases firm B's equilibrium demand. In contrast, when the quality difference

between the two firms is large, i.e., $q_A - q_B > \frac{c_A - c_B}{\beta}$, the indirect effect of α on the equilibrium demands dominates the direct effect and, counterintuitively, a larger α decreases firm A's equilibrium demand and increases firm B's equilibrium demand.

Proposition 1(iii) shows that as the consumer's social-comparison benefit α increases, the higher-quality firm A's equilibrium profit increases. Interestingly, a larger α may also increase the lower-quality firm B's equilibrium profit. Though a larger α can cannibalize consumer demands from firm B to firm A, it reduces the price competition between the two firms, allowing firm B to charge a higher price (cf. Proposition 1(i)). When $q_A - q_B > \frac{c_A - c_B}{\beta}$, as α increases, in equilibrium, firm B's price and demand increase, leading to a higher profit for firm B. When $\frac{c_A - c_B}{\alpha + 1} < q_A - q_B < \frac{c_A - c_B}{\beta}$, as α increases, firm B's equilibrium profit increases because its benefit from the increased price outweighs its loss from the cannibalized demand. When $q_A - q_B < \frac{c_A - c_B}{\alpha + 1}$, as α increases, firm B's equilibrium profit decreases because its loss from the cannibalized demand outweighs its benefit from the increased price. Summarizing the results, we see that when the quality difference between the two firms is high, i.e., $q_A - q_B > \frac{c_A - c_B}{\alpha + 1}$, a larger α will benefit both firms. This indicates that in markets in which firms' product differentiation is large, the firms should evoke consumers' psychological gains from using a superior product, e.g., the firms can use advertisements such as Fig. 1(a) to tell consumers that using a superior product signals a higher social status.

To sum up, Proposition 1 shows that the consumer's social-comparison benefit α can benefit both firms by reducing their price competition. However, in Proposition 2, we show that the consumer's social-comparison cost β can harm both firms by intensifying their price competition.

Proposition 2. *Under price competition, as the consumer's social-comparison cost β increases, in equilibrium, the following results will occur:*

(i) The firms' prices decrease;

(ii) If $q_A - q_B > \frac{c_A - c_B}{1+\alpha}$, then firm A's demand increases and firm B's demand decreases, and if $q_A - q_B < \frac{c_A - c_B}{1+\alpha}$, then firm A's demand decreases and firm B's demand increases;

(iii) Firm A's profit increases if $q_A - q_B > \frac{c_A - c_B}{\beta}$ and decreases if $q_A - q_B < \frac{c_A - c_B}{\beta}$, and firm B's profit always decreases.

Proposition 2 shows how the consumer's social-comparison cost β affects the firms' equilibrium prices, demands, and profits. To understand Proposition 2, note that the consumer's social-comparison cost has two effects. First, all else equal, the consumer's social-comparison cost directly decreases their utility of buying from firm B, leading firm B to reduce its price. Second, with the existence of the consumer's social-comparison cost, the consumer's utility of buying from firm B decreases with firm A's demand because when firm A's demand is larger, firm B's buyers are more likely to meet firm A's buyers to perceive the psychological loss in the disadvantaged comparison. This effect prompts firm B to compete more fiercely to cannibalize more demands from firm A. As β increases, the two effects of the consumer's social-comparison cost become stronger, leading firm B to reduce its price. Firm A will respond by raising its price because the optimal prices of the two firms are strategic complements. Thus, as shown in Proposition 2(i), a larger β intensifies the price competition between the two firms.

One may expect that as the consumer's social-comparison cost β increases, in equilibrium, the higher-quality firm A will cannibalize more demands from the lower-quality firm B. However, Proposition 2(ii) shows that it is not necessarily the case. To understand the rationale, note that β has direct and indirect (strategic) effects on the firms' equilibrium demands. The direct effect

has been characterized in Lemma 1(ii): For given prices, a larger β leads to a higher demand for firm A and a lower demand for firm B. The indirect effect is that as β increases, the two firms will strategically decrease their prices, whereas firm B's price decreases more steeply than firm A's such that the price difference between the two firms becomes larger. Contrary to the direct effect, the indirect effect negatively affects firm A's equilibrium demand and positively affects firm B's demand. Recall from Lemma 1(ii) that the direct effect becomes stronger as the quality difference ($q_A - q_B$) between the two firms increases. Thus, when the quality difference between the two firms is large, i.e., $q_A - q_B > \frac{c_A - c_B}{1+\alpha}$, the direct effect of β on the equilibrium demands dominates the indirect effect, and as one would expect, a larger β increases firm A's equilibrium demand and decreases firm B's equilibrium demand. In contrast, when the quality difference between the two firms is small, i.e., $q_A - q_B < \frac{c_A - c_B}{1+\alpha}$, the indirect effect of β on the equilibrium demands dominates the direct effect and, counterintuitively, a larger β decreases firm A's equilibrium demand and increases firm B's equilibrium demand.

Proposition 2(iii) shows that as the consumer's social-comparison cost β increases, the lower-quality firm B's equilibrium profit always decreases. Moreover, a larger β may harm the higher-quality firm A's equilibrium profit. Though a larger β can cannibalize consumer demands from firm B to firm A, it reduces the price competition between the two firms, leading firm B to reduce its price (cf. Proposition 2(i)). When $q_A - q_B < \frac{c_A - c_B}{1+\alpha}$, as β increases, in equilibrium, firm A's price and demand decrease, leading to a lower profit for firm A. When $\frac{c_A - c_B}{1+\alpha} < q_A - q_B < \frac{c_A - c_B}{\beta}$, as β increases, firm A's equilibrium profit decreases because its loss from the reduced price competition outweighs its benefit from the cannibalized demand. When $q_A - q_B > \frac{c_A - c_B}{\beta}$, as β increases, firm A's equilibrium profit increases because its benefit from the cannibalized demand outweighs its loss from the reduced price competition (recall from Lemma 1(ii) that the demand-cannibalization effect of β is strong when $q_A - q_B$ is high). Summarizing these results, we see that when the quality difference between the two firms is low, i.e., $q_A - q_B < \frac{c_A - c_B}{\beta}$, a larger β will harm both firms. This indicates that in markets in which firms' product differentiation is small, the firms should minimize consumers' psychological losses from using an inferior product. So it is unwise for such firms to use advertisements such as Fig. 1(b) to tell consumers that using an inferior product signals a lower social status.

So far, we have analyzed the price competition between the two firms when their product quality is exogenously given. Iyer and Soberman (2016) show that when consumers compare their products' social-responsibility levels, the "consumer's social-comparison benefit" can be beneficial to both firms by reducing their price competition, and the "consumer's social-comparison cost" can harm both firms by intensifying their price competition. We show that this result holds when consumers compare product qualities. Moreover, the analyses of pure price competition in this section provide a basis for the further analyses in the following sections where the firms can choose their product quality or product lines before engaging in the price competition.

4. Quality choice

In this section we allow the firms to strategically choose their product quality before setting their prices. This sequence can be justified by real-world practice where the pricing decisions are more flexible than quality decisions. Specially, firm $i \in \{A, B\}$ chooses between a higher quality level q_{iH} and a lower quality level q_{iL} ($< q_{iH}$). We consider discrete quality levels for the following two reasons. First, in reality, firms have discrete rather than continuous options for some vertical attributes, e.g., the number

of engine cylinders in cars, the type of energy used in watches, and the fabric of coats. Second, considering discrete quality levels allows us to obtain closed-form solutions. Moreover, following Li (2019), we assume that owing to the technological difference between the two firms, firm A's product quality is higher than firm B's such that $q_{AH} > q_{AL} > q_{BH} > q_{BL}$. Let c_{iH} and c_{iL} denote firm i's marginal costs of the higher- and lower-quality products, respectively. In line with the base model, in this model, we focus on the parameter region in which the relative quality-cost efficiency between the two firms is moderate, i.e., $2\beta - \alpha - 1 < \frac{c_{Ai} - c_{Bj}}{q_{Ai} - q_{Bj}} < 2 + 2\alpha - \beta$, where $i, j \in \{H, L\}$. This ensures that both firms have positive demands regardless of their choice of product quality.

The game sequence is as follows: In the first stage of the game, the firms simultaneously choose their respective product quality. In the second stage of the game, the firms simultaneously set their respective prices. We derive the subgame perfect equilibrium using the backward induction approach. Given their products' quality, we discussed the firms' optimal prices in the last section. In this section we study the quality competition between the two firms. To derive the equilibrium quality, we each firm's best response quality in the following result.

Lemma 2. *(i) Suppose that firm B's product quality is $q_B \in \{q_{BH}, q_{BL}\}$. Then, firm A will choose the higher quality q_{AH} when $\alpha > \frac{\beta}{2} + f_1(q_B)$ and the lower quality q_{AL} when $\alpha < \frac{\beta}{2} + f_1(q_B)$, where $f_1(q_B) = \frac{c_{AH} - c_{AL}}{2(q_{AH} - q_{AL})} - 1 + \frac{|(c_{AL} - c_B)q_{AH} - (c_{AH} - c_B)q_{AL} + (c_{AH} - c_{AL})q_B|}{2(q_{AH} - q_{AL})\sqrt{(q_{AH} - q_B)(q_{AL} - q_B)}}$.*

(ii) Suppose that firm A's product quality is $q_A \in \{q_{AH}, q_{AL}\}$. Then, firm B will choose the higher quality q_{BH} when $\alpha < 2\beta + f_2(q_A)$ and the lower quality q_{BL} when $\alpha > 2\beta + f_2(q_A)$, where $f_2(q_A) = \frac{|(c_{BH} - c_{BL})q_A - (c_A - c_{BL})q_{BH} + (c_A - c_{BH})q_{BL}|}{(q_{BH} - q_{BL})\sqrt{(q_A - q_{BH})(q_A - q_{BL})}} - 1 - \frac{c_{BH} - c_{BL}}{q_{BH} - q_{BL}}$.

Lemma 2 shows how the firm should choose their optimal product quality when its competitor's quality is given. To better discuss the insights, we show the higher- and lower-quality firms' optimal product quality in Lemma 2(i) and (ii), respectively. Lemma 2(i) shows the higher-quality firm A's optimal choice between the higher quality q_{AH} and the lower quality q_{AL}. Recall that $q_{AH} > q_{AL} > q_B$. So when firm A chooses the higher quality q_{AH}, the quality difference between the two firms will be larger than that when firm A chooses the lower quality q_{AL}. A larger quality difference between the two firms will lead consumers to feel more superior/inferior to those using a different product, increasing the effects of the consumer's social comparisons on the firms. As the consumer's social-comparison benefit α increases, the effect of the consumer's social comparisons on the firms tends to be more positive, prompting firm A to improve its product quality to increase the quality difference between the two firms. However, as the consumer's social-comparison cost β increases, the effect of the consumer's social comparisons on the firms tends to be more negative, prompting firm A to reduce its product quality to decrease the quality difference between the two firms. Thus, firm A will choose the higher quality q_{AH} if the consumer's social-comparison benefit is high relative to the consumer's social-comparison cost, i.e., when $\alpha > \frac{\beta}{2} + f_1(q_B)$, and will choose the lower quality q_{AL} if the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, i.e., when $\alpha < \frac{\beta}{2} + f_1(q_B)$.

Lemma 2(ii) shows the lower-quality firm B's optimal choice between the higher quality q_{BH} and the lower quality q_{BL}. Recall $q_A > q_{BH} > q_{BL}$. So when firm B chooses the lower quality q_{BL}, the quality difference between the two firms will be higher than that when firm B chooses the higher quality q_{BH}. A larger quality difference between the two firms will lead consumers to feel much more superior/inferior to those using a different product, increasing the effects of the consumer's social comparisons on the firms. As the consumer's social-comparison benefit α increases,
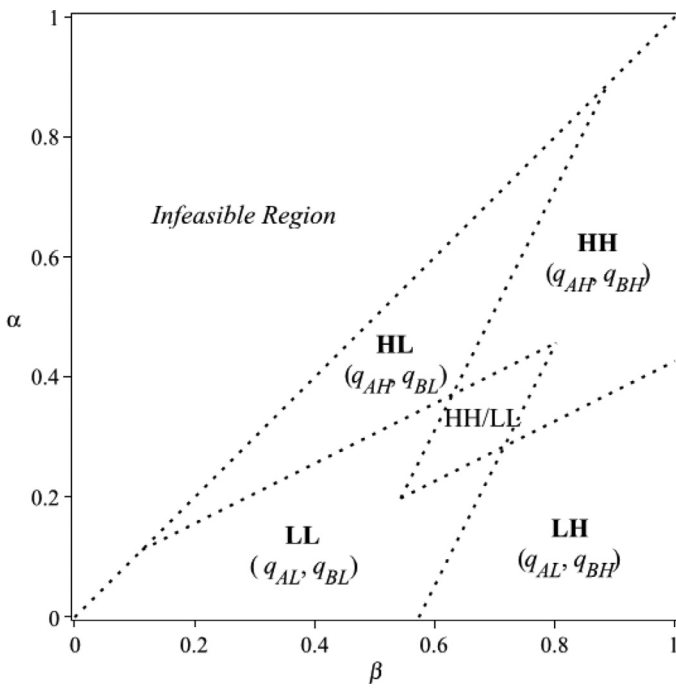
Fig. 3. The firms' quality choices in equilibrium.[8]

the effect of the consumer's social comparisons tends to be positive for the firms, prompting firm B to reduce its product quality to increase the quality difference between the two firms. However, as the consumer's social-comparison cost β increases, the effect of the consumer's social comparisons tends to be negative for the firms, prompting firm B to increase its product quality to decrease the quality difference between the two firms. Thus, as shown in Lemma 3, firm B will choose the lower quality q_{BL} if the consumer's social-comparison benefit is high relative to the consumer's social-comparison cost, i.e., when $\alpha > 2\beta + f_2(q_A)$, and will strategically choose the higher quality q_{BH} if the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, i.e., when $\alpha < 2\beta + f_2(q_A)$.

In Lemma 2, we give each firm's optimal quality. Then, by letting each firm choose its optimal quality, we derive the firms' equilibrium quality decision in Proposition 3.

Proposition 3. *If the firms can strategically choose their product quality before setting their prices, the equilibrium results are as follows:*

When $\alpha < \min\{\frac{\beta}{2} + f_1(q_{BH}), 2\beta + f_2(q_{AL})\}$, firm A will choose its lower quality q_{AL} and firm B will choose its higher quality q_{BH};

When $2\beta + f_2(q_{AL}) < \alpha < \frac{\beta}{2} + f_1(q_{BL})$, firm A will choose its lower quality q_{AL} and firm B will choose its lower quality q_{BL};

When $\frac{\beta}{2} + f_1(q_{BH}) < \alpha < 2\beta + f_2(q_{AH})$, firm A will choose its higher quality q_{AH} and firm B will choose its higher quality q_{BH};

When $\alpha > \max\{\frac{\beta}{2} + f_1(q_{BL}), 2\beta + f_2(q_{AH})\}$, firm A will choose its higher quality q_{AH} and firm B will choose its lower quality q_{BL}.

Proposition 3 shows that the firms' equilibrium quality depends on the consumer's social-comparison benefit and cost, i.e., α and β. Fig. 3 illustrates the result. In region LH where $\alpha < \min\{\frac{\beta}{2} + f_1(q_{BH}), 2\beta + f_2(q_{AL})\}$, i.e., when the consumer's social-comparison benefit is small and the consumer's social-comparison

cost is large, in equilibrium, firm A will choose its lower quality and firm B will choose its higher quality such that the quality difference between the two firms is small. In regions HH and HH/LL where $\frac{\beta}{2} + f_1(q_{BH}) < \alpha < 2\beta + f_2(q_{AH})$, i.e., when the consumer's social-comparison benefit and cost are large, in equilibrium, both firms choose their higher quality such that their quality difference is intermediate. In region HL where $\alpha > \max\{\frac{\beta}{2} + f_1(q_{BL}), 2\beta + f_2(q_{AH})\}$, i.e., when the consumer's social-comparison benefit is large and the consumer's social-comparison cost is small, in equilibrium, firm A will choose its higher quality and firm B will choose its lower quality such that the quality difference between the two firms is large. In regions LL and HH/LL where $2\beta + f_2(q_{AL}) < \alpha < \frac{\beta}{2} + f_1(q_{BL})$, i.e., when the consumer's social-comparison benefit and cost are small, in equilibrium, both firms choose their lower quality such that their quality difference is intermediate. Note that in region HH/LL, two equilibrium scenarios may occur: both firms choosing their higher quality and both choosing their lower quality. In Proposition 4, we summarize the effects of α and β on the quality difference between the two firms.

Proposition 4. *As the consumer's social-comparison benefit α increases or the consumer's social-comparison cost β decreases, in equilibrium, the quality difference between the two firms tends to increase.*

Proposition 4 shows how the consumer's social comparisons affect the quality difference between the two firms. As the consumer's social-comparison benefit α increases, firm A tends to improve its product quality and firm B tends to reduce its product quality, leading to a larger quality difference between the two firms. Note that a larger quality difference between the two firms tends to reduce their price competition. So the consumer's social-comparison benefit not only directly reduces the price competition between the firms by leading them to raise prices (as shown in Proposition 1), but also indirectly reduces price competition by leading the firms to increase their quality difference.

As the consumer's social-comparison cost β increases, firm A tends to reduce its product quality and firm B tends to improve its product quality, leading to a smaller quality difference between the two firms. Note that a smaller quality difference between the two firms tends to intensify their price competition. So the consumer's social-comparison cost not only directly intensifies the price competition between the firms by leading them to reduce prices (as shown in Proposition 2), but also indirectly intensifies price competition by leading the firms to reduce their quality difference.

To better understand the effects of the consumer's social-comparison benefit and cost on the firms' equilibrium profits, we conduct numerical studies and show the results in Fig. 4. Fig. 4(i) shows that as the consumer's social-comparison benefit α increases, both firms earn higher profits. In particular, when α exceeds a threshold, the equilibrium scenario changes from LL, i.e., both firms choosing their lower quality, to HL, i.e., firm A choosing its higher quality and firm B choosing its lower quality, such that the quality difference between the two firms increases. This leads to a surge in firm B's profit. These observations indicate that a larger α can benefit the firms by reducing their price competition as well as increasing their product differentiation. So when the firms can strategically choose product quality, the positive effect of α on the firms can be stronger than when the product quality is exogenous. This further highlights that the firms may achieve the win-win outcome by increasing α with advertisements such as Fig. 1(a).

Fig. 4(ii) shows that as the consumer's social-comparison cost β increases, both firms earn lower profits. In particular, when β exceeds a threshold, the equilibrium scenario changes from HL to HH, i.e., both firms choosing their higher quality, such that the quality difference between the two firms decreases. This leads firm A's profit to plummet. These observations indicate that a larger

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[8] Figure 3 is plotted with $q_{AH} = 10$, $q_{AL} = 9$, $q_{BH} = 8$, $q_{BL} = 7$, $c_{AH} = 6$, $c_{AL} = 4.5$, $c_{BH} = 3.5$, and $c_{BL} = 3$. We can verify that this data set satisfies $2\beta - \alpha - 1 < \frac{c_{Ai} - c_{Bj}}{q_{Ai} - q_{Bj}} < 2 + 2\alpha - \beta$ for any $i, j \in \{H, L\}$ and $0 < \alpha < \beta < 1$.
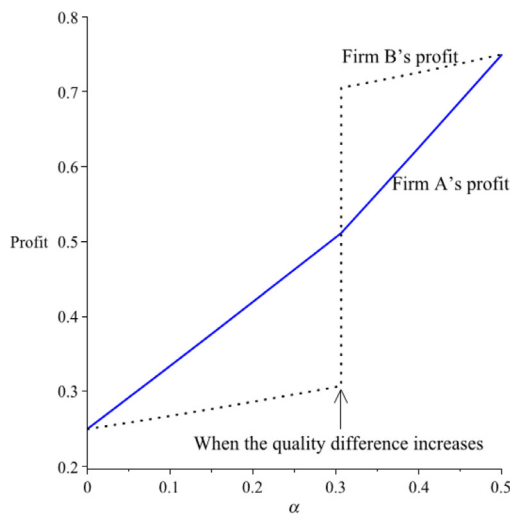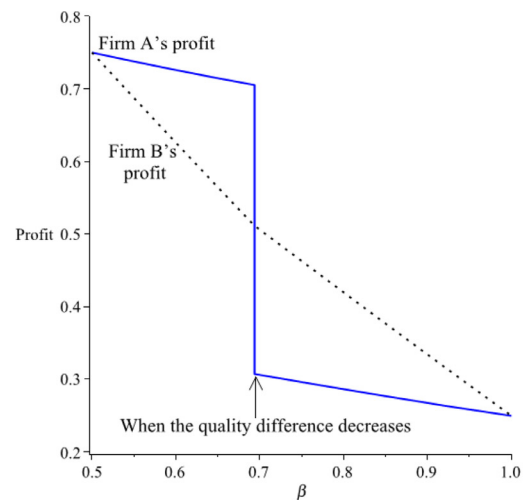
(i) Effects of the consumer's social-comparison benefit α (ii) Effects of the consumer's social-comparison cost β

Fig. 4. Effects of the consumer's social comparison on the firms' equilibrium profits when qualities are endogenous.[9]

Table 2
Summary of the firms' product-line strategies.

	Product line	Firm B		
		Higher-quality product	Lower-quality product	Both products
Firm A	Higher-quality product	(H, H)	(H, L)	(H, B)
	Lower-quality product	(L, H)	(L, L)	(L, B)
	Both products	(B, H)	(B, L)	(B, B)

β can harm the firms by intensifying their price competition as well as reducing their product differentiation. So when the firms can strategically choose product quality, the negative effect of β on the firms can be stronger than when the product quality is exogenous. This further highlights that the firms should be cautious about increasing the consumer's social-comparison cost with advertisements such as Fig. 1(b).

5. Product-line strategy

In the above, we consider that each firm sells a single product, either a higher- or lower-quality product. In this section we allow the firms to sell both products. Then, firm $i \in \{A, B\}$ has three product-line strategies: solely selling its **h**igher-quality product with q_{iH} (denoted by 'H'), solely selling its **l**ower-quality product with q_{iL} (denoted by 'L'), and selling **b**oth of its higher- and lower-quality products (denoted by 'B'). This leads to a total of nine scenarios as summarized in Table 2. Note that (Ω_A, Ω_B) indicates the scenario where firm A chooses the product-line strategy $\Omega_A \in \{H, L, B\}$ and firm B chooses the product-line strategy $\Omega_B \in \{H, L, B\}$. The firms choose their product-line strategies before setting their prices.

Note that the firm's higher- and lower-quality products have different appearances and esthetic designs, e.g., Apple's two quality-differentiated products, iPhone 13 Pro and iPhone 13 Pro Max, differ in their sizes.[10] Based on what they see, consumers can distinguish products with different quality—regardless of whether the products are from the same firm—to make social comparisons.

So consumers will derive the social-comparison utility from comparing inter-firm products (e.g., a product of firm A and a product of firm B) as well as intra-firm products (e.g., firm A's two products). Formally speaking, when meeting a consumer whose product quality is q_{jy}, a buyer whose product quality is q_{ix} will derive the social-comparison utility of $\alpha \max\{q_{ix} - q_{jy}, 0\} + \beta \min\{q_{ix} - q_{jy}, 0\}$, where $i, j \in \{A, B\}$ and $x, y \in \{H, L\}$. Recall that $q_{AH} > q_{AL} > q_{BH} > q_{BL}$. To capture the fact that a higher-quality product incurs a higher marginal production cost, we assume that $c_{AH} > c_{AL} > c_{BH} > c_{BL}$. Moreover, to reduce notational clutter and simplify the algebraic analysis, we assume in this section that $q_{AH} - q_{AL} = q_{AL} - q_{BH} = q_{BH} - q_{BL} = l$, where $l \in (0, \frac{q_{AH}}{3})$ denotes the quality difference between the two products with the closest quality. Then, we have $q_{AL} = q_{AH} - l$, $q_{BH} = q_{AH} - 2l$, and $q_{BL} = q_{AH} - 3l$. To avoid the trivial cases where the firms never extend their product lines, we focus on the parameter regions $\alpha > \max\{\frac{c_{AH} - c_{AL} - l}{l}, \frac{2l(2\beta - 1) - c_{AL} + c_{BL}}{2l}, \frac{(\beta - 2)l - 2c_{AL} + 5c_{BH} - 3c_{BL}}{2l}\}$ and $\beta < \frac{c_{BH} - c_{BL}}{l}$. This is a sufficient condition to ensure that in any subgame, the respective products have positive demands. In Lemma 3, we discuss an interesting result before we provide the firms' optimal product-line decisions in Lemma 4.

Lemma 3. *A firm is better off by introducing a product that is more differentiated from its competitor (than its original product).*

Lemma 3 indicates that firm A is always better off by adding its higher-quality product to its product line, i.e., upward product-line extension, and firm B is always better off by adding its lower-quality product to its product line, i.e., downward product-line extension. Such product-line extensions allow the firms to segment the consumers, without intensifying the price competition between a firm and its competitor—we can verify that firm A's upward product-line extension and firm B's down product-line extension will not lead the firms to alter the prices of their original products. In fact, when adopting this product-line extension, a

firm will internalize the competition from the extended product, which cannibalizes the consumer demand for its original product rather than that for its competitor's product(s). Recall that $q_{AH} > q_{AL} > q_{BH} > q_{BL}$. With the upward product-line extension, firm A's extended product, i.e., the product with q_{AH}, cannibalizes the consumer demand for its original product, i.e., the product with q_{AL}, rather than firm B's; with the downward product-line extension, firm B's extended product, i.e., the product with q_{BL}, cannibalizes the consumer demand for its original product, i.e., the product with q_{BH}, rather than firm A's. Thus, such product-line extensions will not increase the competitor's "degree of rivalry."

From Lemma 3, we conclude that firm A will never choose strategy *L* and firm B will never choose strategy *H*. However, one may still wonder how firm A chooses between strategies *H* and *B*, and how firm B chooses between strategies *L* and *B*. We answer these questions in the following result.

Lemma 4. *(i) Given firm B's product line Ω_B: If $\alpha > \hat{\beta}_A$, firm A will solely sell its higher-quality product,* i.e., *choosing strategy H; if $\alpha < \hat{\beta}_A$, firm A will sell both of its products,* i.e., *choosing strategy B, where*

$$\hat{\beta}_A = \begin{cases} \hat{\beta}_{A1} = \frac{8\beta}{7} - 1 - \frac{c_{AH} - c_{AL}}{7l} + \frac{\sqrt{36(\beta l - c_{AH} + c_{AL})^2 + 14(c_{AH} + c_{BH} - 2c_{AL})^2}}{7l} & if \quad \Omega_B = H \text{ or } B, \\ \hat{\beta}_{A2} = \frac{8\beta}{7} - 1 - \frac{c_{AH} - c_{AL}}{7l} + \frac{\sqrt{324(\beta l - c_{AH} + c_{AL})^2 + 42(2c_{AH} + c_{BL} - 3c_{AL})^2}}{21l} & if \quad \Omega_B = L. \end{cases}$$

increases in β.

(ii) Given firm A's product line Ω_A: If $\alpha > \hat{\beta}_B$, firm B will solely sell its lower-quality product, i.e., *choosing strategy L; if $\alpha < \hat{\beta}_B$, firm B will sell both of its products,* i.e., *choosing strategy B, where*

$$\hat{\beta}_B = \begin{cases} \hat{\beta}_{B1} = 2\beta - 1 - \frac{c_{BH} - c_{BL}}{l} + \frac{\sqrt{81(l\beta - c_{BH} + c_{BL})^2 + 6(c_{AH} + 2c_{BL} - 3c_{BH})^2}}{6l} & if \quad \Omega_A = H, \\ \hat{\beta}_{B2} = 2\beta - 1 - \frac{c_{BH} - c_{BL}}{l} + \frac{\sqrt{9(l\beta - c_{BL} + c_{BH})^2 + 2(c_{AL} + c_{BL} - 2c_{BH})^2}}{2l} & if \quad \Omega_A = L \text{ or } B. \end{cases}$$

increases in β.

Lemma 4 summarizes the optimal product lines of the higher-quality firm A and the lower-quality firm B. While Lemma 3 indicates that the firm is always better off by introducing a product that is more differentiated from its competitor (than its original product), Lemma 4 shows that the firm may be worse off by introducing a less differentiated product. In other words, firm A may be worse off by choosing downward product-line extension and firm B may be worse off by choosing upward product-line extension. This is because such product-line extensions have a positive effect of enabling consumer segmentation and a negative effect of intensifying the price competition between the two firms—we can verify that firm A's downward or firm B's upward product-line extension will lead the firms to reduce the prices of their original products.

To find the dominating effect, note that the negative effect, i.e., the price-competition-intensifying effect, becomes stronger as the consumer's social-comparison benefit α increases or as the consumer's social-comparison cost β decreases. The intuition is as follows: Under firm A's downward or firm B's upward product-line extension, the extended product has intermediate quality relative to that of the original products existing in the market, and the existence of this extended product buffers consumers' social comparisons by leading some consumers to find that their product is not that superior/inferior to the others'. For example, without firm A's downward product-line extension, when meeting consumers that buy firm A's product, the consumer that buys firm B's product with q_{Bj} ($j \in \{H, L\}$) finds their product inferior, perceiving a quality difference of $q_{AH} - q_{Bj}$; however, with firm A's downward product-line extension, the consumer may meet the buyers of firm A's extended product to perceive a quality difference of $q_{AL} - q_{Bj} < q_{AH} - q_{Bj}$. Overall, such a product-line extension decreases consumers' perceived difference in product quality with others, reducing consumers' social-comparison utilities and alle-

viating the associated effects. Recall that a larger α or a smaller β would have allowed a firm to charge a higher price. However, this effect will be diminished by firm A's downward or firm B's upward product-line extension. As a result, if α is high relative to β, the price-competition-intensifying effect of such product-line extensions will be stronger than the consumer-segmentation effect, leading the firm to forgo the product-line extension to solely sell the product that is most differentiated from its competitor (as shown in Lemma 4, firm A will solely sell its higher-quality product if $\alpha > \hat{\beta}_A$ and firm B will solely sell its lower-quality product if $\alpha > \hat{\beta}_B$). In contrast, if α is low relative to β, the consumer-segmentation effect dominates the price-competition-intensifying effect, leading the firm to extend its product line by introducing a less differentiated product from its competitor than its original product (as indicated by Lemma 4, firm A is better off by choosing the downward product-line extension if $\alpha < \hat{\beta}_A$ and firm B is better off by choosing the upward product-line extension if $\alpha < \hat{\beta}_B$).

One can also interpret the results from another perspective. A firm can reinforce the effect of the consumer's social comparisons by solely selling a product that is most differentiated from its competitor, and can alleviate this effect by extending the product line. So whether this effect is positive or negative will determine the firm's optimal product-line design. Recall that this effect tends to be positive for the firm when the consumer's social-comparison benefit α is high relative to the consumer's social-comparison cost β. In this case, to reinforce the positive effect of the consumer's social comparison, the firm solely sells the product that is most differentiated from its competitor. However, if α is low relative to β, the effect of the consumer's social comparison tends to be negative for the firm, and to reduce this negative effect, the firm will introduce a less differentiated product. These results highlight that product-line extension is an effective way for firms to manage consumers' social comparisons.

As a remark, our results add new insights that complement Li (2019), who finds that in the absence of consumers' social comparisons, the higher-quality firm should choose upward rather than downward product-line extension, and the lower-quality firm should choose downward rather than upward product-line extension. Our result in Lemma 3 echoes Li (2019) under some circumstances. However, in Lemma 4, we additionally show that the presence of consumers' social comparisons can make downward product-line extension profitable for the higher-quality firm and upward product-line extension profitable for the lower-quality firm. These supplement the findings in Li (2019) and highlight the role played by social comparisons.

In Lemma 4 we give each firm's optimal product line. By considering the situation that each firm will choose its optimal product line, we derive the firms' equilibrium product lines in the following result.

Proposition 5. *If the firms can strategically choose their product lines, their equilibrium product-line strategies are as follows:*
When $\alpha < \min\{\hat{\beta}_{A1}, \hat{\beta}_{B2}\}$, the firms will sell both of their products, i.e., *(B, B) is in equilibrium;*
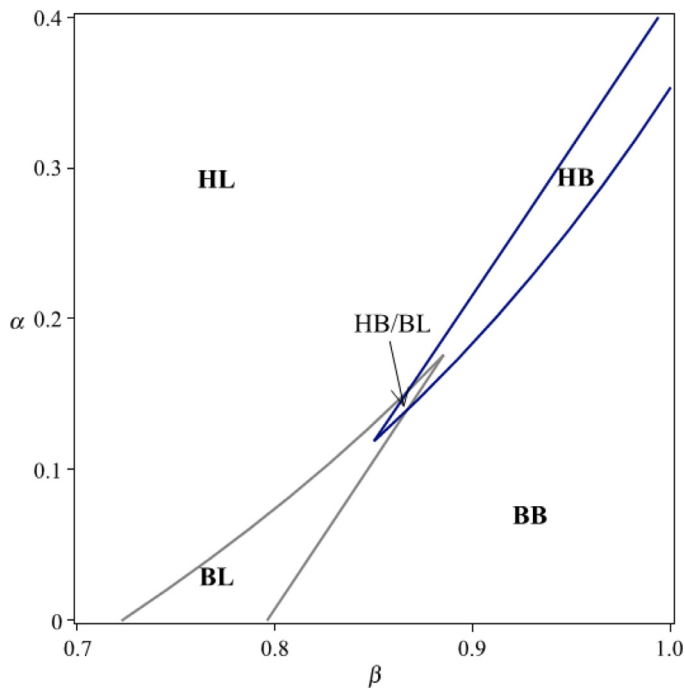
Fig. 5. The firms' equilibrium product-line strategies.[11]

When $\hat{\beta}_{B2} < \alpha < \hat{\beta}_{A2}$, firm A will sell both of its products and firm B will solely sell its lower-quality product, i.e., (B, L) is in equilibrium;

When $\hat{\beta}_{A1} < \alpha < \hat{\beta}_{B1}$, firm A will solely sell its higher-quality product and firm B will sell both of its products, i.e., (H, B) is in equilibrium;

When $\alpha > \max\{\hat{\beta}_{A2}, \hat{\beta}_{B1}\}$, firm A will solely sell its higher-quality product and firm B will solely sell its lower-quality product, i.e., (H, L) is in equilibrium.

Proposition 5 shows that the firms' equilibrium product lines depend on the consumer's social-comparison benefit α and the consumer's social-comparison cost β. Fig. 5 illustrates the result. To understand the intuition, recall that the firms' equilibrium product lines depend on whether the effect of the consumer's social comparisons is positive or negative for each firm.

In the parameter region HL where $\alpha > \max\{\hat{\beta}_2, \hat{\beta}_4\}$, i.e., when the consumer's social-comparison benefit is high and the consumer's social-comparison cost is low, the effect of the consumer's social comparisons tends to be positive for both firms. To reinforce this positive effect, firm A solely sells its product with the higher quality q_{AH} and firm B solely sells its product with the lower quality q_{BL} such that the quality difference between the two firms is very large. As such, some consumers will find that their products are very different from one another, yielding large magnitudes of social-comparison utilities.

However, in the parameter region BB with $\alpha < \min\{\hat{\beta}_3, \hat{\beta}_6\}$, i.e., when the consumer's social-comparison benefit is low and the consumer's social-comparison cost is high, the effect of the consumer's social comparisons tends to be negative for the firms. To reduce this effect, the firms will sell both of their products. The existence of so many products in the market cushions consumers'

social comparisons by leading some consumers to find that their products are not that different from the others'.

In the following we discuss the rest of the regions in which the consumer's social comparisons have reverse effects on the two firms such that they make asymmetric product-line-extension decisions. In regions HB and HB/BL where $\hat{\beta}_3 < \alpha < \hat{\beta}_4$, i.e., the consumer's social-comparison benefit and cost are high, and in regions BL and HB/BL where $\hat{\beta}_6 < \alpha < \hat{\beta}_2$, i.e., when the consumer's social-comparison benefit and cost are low, the effect of the consumer's social comparisons tends to be positive for firm A and negative for firm B. In regions HB and HB/BL, the effect of the consumer's social comparisons is strong such that firm A has an incentive to reinforce this effect by selling a single product and firm B has an incentive to reduce this effect by extending its product line. However, in regions BL and HB/BL, the effect of the consumer's social comparisons is weak such that firm A has no incentive to reinforce this effect and firm B has no incentive to reduce this effect. So, in regions BL and HB/BL, firm A will sell both of its products and firm B will sell its lower-quality product.

In Proposition 5 we discuss the firms' equilibrium product lines when the consumer's social-comparison benefit α and the consumer's social-comparison cost β are in different regions. Summarizing the findings, we have the following result.

Proposition 6. *As the consumer's social-comparison benefit α increases or as the consumer's social-comparison cost β decreases, in equilibrium, the firms' product lines tend to shrink.*

To understand Proposition 6, recall that product-line extension can reduce the effect of the consumers' social comparisons on the firms. As the consumers' social-comparison benefit α increases, the consumer's social comparisons tend to positively affect the firms, so the firms are more likely to reduce their product lines. However, as the consumer's social-comparison cost β increases, the consumer's social comparisons tend to negatively affect the firms, so the firms are more likely to extend their product lines.

In Proposition 5, we give the equilibrium outcome for the case where the firms can extend their product lines to sell two products. In the earlier Proposition 3, we provide the equilibrium outcome in the base model where the firms cannot extend their product lines, i.e., they can only sell a single product. By comparing the equilibrium outcomes for the two cases, we derive the effects of product-line extension in the following result.

Proposition 7. *If the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, i.e., when $\alpha < \min\{\frac{\beta}{2} + f_1(q_{BH}), 2\beta + f_2(q_{AL}), \hat{\beta}_{A1}, \hat{\beta}_{B2}\}$, both firms earn higher profits when they can extend their product lines than when they cannot extend their product lines.*

Proposition 7 shows that product-line extension can benefit both firms. If the consumer's social-comparison benefit α is low relative to the consumer's social-comparison cost β, the consumer's social comparisons tend to negatively affect the firms, for which product-line extension provides an additional countermeasure. When the firms cannot extend their product lines, they will reduce the negative effect of the consumer's social comparisons by reducing the quality difference between the two firms, so Proposition 3 shows that if $\alpha < \min\{\frac{\beta}{2} + f_1(q_{BH}), 2\beta + f_2(q_{AL})\}$, firm A will choose the lower quality and firm B will choose the higher quality. When the firms can extend their product lines, they will reduce the negative effect of the consumer's social comparisons by extending their product lines, so Proposition 5 shows that if $\alpha < \min\{\hat{\beta}_{A1}, \hat{\beta}_{B2}\}$, each firm will sell both of its products. If $\alpha < \min\{\frac{\beta}{2} + f_1(q_{BH}), 2\beta + f_2(q_{AL}), \hat{\beta}_{A1}, \hat{\beta}_{B2}\}$, the feasibility of product-line extension allows the firms to segment the consumers without intensifying the price competition between the two firms (recall

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that firm A's upward product-line extension and firm B's downward product-line extension will not lead the firms to reduce their prices). Thus, in this parameter region, the firms' profits when they can extend their product lines are strictly higher than those when they cannot extend their product lines. This indicates that compared with reducing quality differentiation, product-line extension is a more effective way for reducing the negative effect of the consumer's social comparisons on the firms.

6. Conclusions

6.1. Concluding remarks and managerial implications

Social comparisons are commonly seen in practice. In this paper we analytically study how consumers' social comparisons affect competing firms' product strategies. Consumers engage in social comparisons by comparing their product quality with that of others they meet, upon which they perceive a psychological gain from finding their product of superior quality and a psychological loss from finding their product of inferior quality. We measure this psychological gain (loss) with the consumer's social-comparison benefit (cost) and show how it would affect the firms' pricing, quality, and product-line strategies.

We examine the strategies using three models. First, in the base model in Section 3, we investigate the price competition between two quality-differentiated firms. We find that the consumer's social-comparison benefit leads to higher prices for both firms, reducing their price competition. However, the consumer's social-comparison cost leads to lower prices for both firms, intensifying their price competition. Thus, the consumer's social-comparison benefit can increase both firms' profits, and the consumer's social-comparison cost can decrease both firms' profits. We derive managerial implications of this result by recalling the motivation example in Section 1: If Audi uses the advertisement in Fig. 1(a) to increase the consumer's social-comparison benefit, then both Audi and its competitor can be better off, so it is a wise "all-win" strategy. However, if Rolex uses the advertisement in Fig. 1(b) to increase the consumer's social-comparison cost, both Rolex and its competitor may be worse off. We thus propose that even the higher-quality firm should be very much cautious about using advertisements such as Fig. 1(b).

Second, in the extended model in Section 4, we consider that the firms can strategically choose their products' quality before setting their prices. We find that as the consumer's social-comparison benefit increases, the higher-quality firm tends to improve its product quality and the lower-quality firm tends to reduce its product quality, leading to a larger quality difference between the two firms. This indicates that the consumer's social-comparison benefit not only directly reduces the firms' price competition by leading the firms to raise their prices but also indirectly reduces the firms' price competition by leading the firms to increase their quality difference. Both effects can increase the firms' profits. However, as the consumer's social-comparison cost increases, the higher-quality firm tends to reduce its product quality and the lower-quality firm tends to improve its product quality, leading to a smaller quality difference between the two firms. This indicates that the consumer's social-comparison cost not only directly intensifies the firms' price competition by leading the firms to reduce their prices but also indirectly intensifies the firms' price competition by leading the firms to reduce their quality difference. Both can decrease the firms' profits. This further highlights that the firms should be cautious about increasing the consumer's social-comparison cost with advertisements such as Fig. 1(b).

Third, in the extended model in Section 5, we study the firms' product-line strategies by allowing the firms to sell more than one product. We find that when the consumer's social-comparison ben-

efit is high relative to the consumer's social-comparison cost, the firm will extend its product line to sell both products; however, when the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, the firm will sell a single product that is most differentiated from its competitor. In equilibrium, the firms' product lines tend to shrink as the consumer's social-comparison benefit increases and expand as the consumer's social-comparison cost increases. Moreover, we find that if the consumer's social-comparison benefit is low relative to the consumer's social-comparison cost, both firms will earn higher profits when they can extend their product lines than when they cannot extend their product lines. This suggests that for the firms, compared with reducing their quality difference, product-line extension is a more effective way to reduce the negative effect of the consumer's social comparisons. For example, if advertisements like Fig. 1(b) are more common than those like Fig. 1(a) such that the consumer's social-comparison cost is high relative to the consumer's social-comparison benefit, firms may introduce products that are less differentiated from their competitor's (than their original products). However, the firms should not do so if advertisements like Fig. 1(a) are more common than those like Fig. 1(b). Thus, we argue that Audi's advertisement can be a wise one as it can benefit Audi and its competitors such as BMW.

Our results complement the findings of Iyer and Soberman (2016). Though both our paper and Iyer and Soberman (2016) show that the consumer's social-comparison benefit would mitigate the firms' price competition, and the consumer's social-comparison cost aggravates the firms' price competition, our paper provides some novel insights into the competing firms' quality choice and product-extension strategies. For example, as the consumer's social-comparison benefit increases, the competing firms tend to increase their quality difference or shrink their product lines; as the consumer's social-comparison cost increases, they tend to reduce their quality difference or expand their product lines. These are important new findings that can help explain some observed industrial practices in the real world (see our discussions above).

6.2. Limitations and future research

Our paper has some limitations, which provide opportunities for future research. First, similar to other operations management (OM) studies, we make some modeling assumptions to obtain tractable results. For example, we consider that the firm can choose from two discrete quality levels—a higher quality level and a lower quality level. Future research can extend our model to consider that the firm can choose from a continuum of quality levels to numerically test the robustness of our results. We also normalize the fixed costs to zero. Future research can relax these assumptions.

Second, our paper applies to the case where the higher-end firm A's alternative products have higher quality than the lower-end firm B's, i.e., $q_{AH} > q_{AL} > q_{BH} > q_{BL}$. Sometimes, the lower-end firm can launch a flagship product that has higher quality than its higher-end competitor. For example, consumers tend to consider Apple as a higher-end company than Xiaomi. In 2019, Xiaomi launched its flagship cellphone product, MIX Alpha, which is sold at ¥19,999. Some consumers may believe that Xiaomi's MIX Alpha has higher quality than Apple's iPhone. To study such cases, future studies may extend our model to consider the case where $q_{AH} > q_{BH} > q_{AL} > q_{BL}$, i.e., firm A's lower-quality product has lower quality than firm B's higher-quality product.

Last, we following the mainstream literature (e.g., Su and Zhang (2008) and Iyer and Soberman (2016)) by using the rational-expectation concept to analyze the consumers' purchase decisions. That is, in equilibrium, consumers' expectations on the products'

market shares equal the real ones. Future research can consider the consumers' bounded rational behaviours, see, for example, Huang and Liu (2015) and Huang and Yin (2021).

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ejor.2023.06.023.

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