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Product reviews by third parties are growing in popularity. This paper examines when and how a manufacturing firm should adapt its marketing strategies to such reviews. For example, should a firm receiving an unfavorable review reduce its price or adjust its advertising? Should a winning product of a product review (e.g., "editor's choice") boost its advertising expenditure to spread the good news? How should firms' strategic responses to product reviews differ across different types of product reviews (description vs. recommendation) and different advertising media (the reviewer's publication vs. other media)?

We develop a theory to address these issues and derive firms' optimal responses to product reviews under different product/market/review/media conditions. We show that firms should choose *advertising* rather than *price* as a strategic variable in response to product reviews when enough consumers value horizontal product attributes. Surprisingly, we find that using a review-endorsed *advertising format* (i.e., advertisements containing third-party award logos) to broadcast its victory can hurt the winning product of a product review. Also, it is not necessarily wise for the winning products to boost *advertising expenditures* to spread the good news. Data from two industries—printers and running shoes—are used to illustrate some of our findings.

Key words: pricing; advertising; third-party infomediaries; product review information; information asymmetry; competitive strategy
History: This paper was received February 24, 2003, and was with the authors 10 months for 2 revisions; processed by Z. John Zhang.

1. Introduction

Third-party product reviews based on independent laboratory tests or expert evaluations have grown increasingly popular in recent years. Various popular consumer magazines (e.g., *PC Magazine, PC World, Consumer Reports, Car and Driver, Scuba Diving Magazine, Runner's World, Entertainment Weekly, Gourmet*) regularly publish comprehensive reviews of products of interest to their readers. Moreover, the Internet and fast-developing information technology have significantly reduced reviewers' information-delivery cost and consumers' information-retrieval cost. As a result, a growing number of Websites (e.g., CNET.com, ZDNET.com, caranddriver.com, swiminfo.com, wirelessdesign.com, enjoythemusic.com, golfdigest.com) are offering online third-party product reviews. In addition, consumers can now easily access and compare product reviews by different sources via specialized product-review sites such as ConsumerSearch.com, which collects reviews on 170 product categories from trusted publications such as *Consumer Digest* and *PC Magazine*.

Market observations suggest that third-party product reviews have a significant effect on the success/failure of products. For example, *USA Today* reported that "[a] bad review in a computer magazine can kill a product and often does.... [A]fter *PC Magazine* panned one Northgate Computer Systems Inc. computer model in early 1988, sales all but dried up...." Moreover, "[a]fter Clarion Software was awarded an 'Editor's Choice' citation for its database program, Softsel—the USA's largest distributor of computer products—decided to carry the program, which Softsel had previously rejected, [and it] is now a best seller" (Lewyn 1989). Third-party reviews have played a very important role in consumers' purchasing decisions. A survey by the *Wall Street Journal* in 1994 showed that over a third of Americans sought the advice of critics when choosing a movie (Simmons 1994). And in a survey reported by *The Los Angeles Times*, 44% of online consumers said they consulted review websites before making a purchase (Riller 1999).

Recently, there has been growing interest among marketing scholars in studying the marketing implications of various third-party infomediaries, including third-party product reviewers (e.g., Eliashberg and Shugan 1997, Reddy et al. 1998, Chen et al. 2002,

Shaffer and Zettelmeyer 2002, Shugan and Winner 2003).[1] These recent studies have advanced our understanding of the impact of third-party review information on product success and firms' profits. However, an important but under-explored area is how manufacturing firms should adapt their marketing strategy in response to such reviews. For example, should a firm receiving an unfavorable product review reduce its price or adjust its advertising in response to the negative effect of the review on the demand for its product? Should a winning product of a product review (e.g., "editor's choice") boost its advertising expenditure to spread the news of its victory or reduce its advertising and enjoy the benefit of free advertising via the product review? It is important to develop a better understanding of when and how a manufacturing firm should vary its marketing strategy to maximize its benefit (or minimize its loss) from a third-party product review.

An early exploratory empirical study (Archibald et al. 1983) finds that, in the running shoes market, "[a]fter the (*Runner's World* review) ratings are published, firms adjust their advertising considerably...but they do not appear to adjust prices to any great degree." Given that price is a more flexible variable than advertising, one would expect a stronger impact of product review on price than on advertising. The observation that product review did not affect firms' prices is even more puzzling given the importance of *Runner's World* in the running shoes market. *Runner's World* was the dominant consumer magazine for runners and accounted for more than 70% market share (*Ayer Directory of Publications* 1981). The annual running shoes review from *Runner's World* had a significant impact on product demand. For instance, "the New Balance 320 was ranked No. 1 (by the review), and literally overnight the New Balance Company was flooded with orders" (*Runner's World* 1980, p. 37). Intuitively, one would expect price-cutting by the losing products after the publication of such an influential product review. It is important to provide a theory that helps us to understand the considerations underlying a manufacturing firm's decision on its choice of strategic variables. It is more important to understand how firms should adjust their advertising strategy when it is unprofitable to use price as a response variable.

In this paper, we consider two popular forms of product reviews: (1) a general description format that provides objective product information while avoiding explicit comparisons of competing products, and

(2) a recommendation format that selects winning products to recommend to consumers (e.g., "editor's choice," "best buy"). We consider two types of strategic responses to product review—pricing and advertising—but give special attention to firms' advertising strategy. We examine a manufacturing firm's advertising response in two different types of media: the reviewer's publication (e.g., *PC Magazine*), which publishes product reviews for printers, and the nonreviewer's publication (e.g., *PC World*). In addition, to vary the level of its advertising spending, we allow the winning product of a recommendation review to choose whether to use review-endorsed advertising (i.e., advertisements containing third-party award logos such as "editor's choice by *PC Magazine*"). We consider buyer heterogeneity in the importance of taste-related product attributes in buyer purchase decision as well as in buyer price sensitivity.

We address five specific research questions. First, under what conditions is it optimal for a manufacturing firm to vary its advertising strategy, but not its pricing strategy, in response to third-party product reviews? Second, how should a firm adjust its advertising spending when it is unprofitable to change price? Third, does a winning product of a recommendation review always gain by using review-endorsed advertising to broadcast its superiority? Fourth, how does the review format (description vs. recommendation) impact a firm's strategic response? Finally, should a firm's advertising response differ across different media (the reviewer's publication vs. other media)?

We find that when the number of consumers who value taste-related attributes is sufficiently large, it is best for firms to adjust advertising but not pricing strategy in response to the outcome of a third-party product review. We also discover the interaction effects between firms' price and advertising strategies. For example, in response to a recommendation review, whether the losing product will reduce its price might depend on whether the winning product adopts review-endorsed advertising. This is because the review-endorsed advertising can significantly increase a winning product's advertising effectiveness, which could force the losing product to aggressively compete on price in order to protect its market share. Therefore, broadcasting its superiority via review-endorsed advertising is not always beneficial for the review-winning product.

Our results reveal that a third-party review has two conceptually different effects on a firm's advertising function. First, a third-party product review generates a *substitutive* effect because it reduces consumers' need for advertising information. Second, a third-party review also generates a *complementary* effect because it can increase or decrease the effectiveness

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[1] A different but related research stream is product information provided by consumers, such as chartroom communication (e.g., Godes and Mayzlin 2004, Mayzlin 2005) and consumer-posted online product reviews (e.g., Chen and Xie 2004).

of a firm's advertising. While the two effects jointly determine a firm's optimal advertising response to a product review, their strength and direction are variously subject to various product/market/review/media conditions such as the quality of the products, the penetration level of the review information, the format of the product review, and the type of media. As a result, the outcome of a product review (i.e., winning vs. losing) is neither the only nor the most important factor in determining a firm's optimal advertising strategy. For example, we find that it is not always wise for the recommended products to boost advertising expenditures to spread the good news. We also show that firms' strategic response depends on review format. For example, description reviews have the same strategic impact on the products receiving favorable and unfavorable reviews, but recommendation reviews may have different strategic implications for winning and losing products. Finally, we suggest that firms adopt different advertising strategies in the reviewer's publication and other media because the impact of product review on readers differs across different media.

We conducted an exploratory empirical study based on data from two industries: printers and running shoes. The results provide preliminary support for our theoretical model.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature on third-party product reviews and discusses the two most popular review formats. Section 3 presents our model assumptions and setup. Sections 4 and 5 examine firms' strategic responses to a description and recommendation product review, respectively. Section 6 considers different types of advertising media. Section 7 discusses empirical results, and §8 presents our conclusions.

2. Third-Party Product Review

The emergence of third-party product reviews is a market phenomenon related to information asymmetry between sellers and buyers—sellers have product information that buyers may not share (e.g., Akerlof 1970, Nelson 1974). Marketing literature has examined how firms can communicate product information to consumers via various marketing strategies (e.g., Gerstner 1985, Wernerfelt 1994, Zhao 2000, Iyer and Soberman 2000, Villas-Boas 2004). Economics literature (e.g., Faulhaber and Yao 1989, Lizzeri 1999) has shown that the problem of information asymmetry can also be resolved or mitigated by having informed third parties (infomediaries) convey product information to potential buyers.

Several recent studies in the marketing literature have investigated the role of third-party product reviews. Eliashberg and Shugan (1997) show that film

critics predict rather than influence movie box office revenue. Reddy et al. (1998) find that newspaper critics have a significant impact on the success of Broadway shows. Shaffer and Zettelmeyer (2002) analyze how the provision of third-party information affects the division of profits in a multiproduct distribution channel. Shugan and Winner (2003) investigate the impact of firm advertising on third-party reviewer's policy. While these recent studies have advanced our understanding of the impact of third-party review information on product success and firms' profits, the interaction between third-party product review and firm marketing strategies, particularly the strategic response of manufacturing firms to third-party product reviews, remains a fascinating but under-explored area.

Third-party product reviews usually provide product information (e.g., basic features/functions and prices) based on lab testing or expert evaluation using one of several different review formats. Many third-party reviewers adopt a *description* format to provide detailed attribute facts about a product without making overall recommendations relative to its competing products. For example, *Audio*, the leading U.S. audio equipment consumer magazine, provides an exhaustive list of audio components available in the United States in its October issue. For each component, the magazine provides manufacturer's suggested retail price along with an extensive description of product characteristics but avoids subjective evaluation or recommendation. Other reviewers adopt a *recommendation* format that not only provides descriptive product attribute information but also selects winners to recommend to consumers based on overall product performance and prices. For example, *PC Magazine*, which regularly provides comparative product reviews on various PC-related products such as desktop and laptop computers, printers, scanners, digital cameras, and software, bestows its "editor's choice" seal of approval based on overall test scores and prices. *PC World* applies the phrase "best buy," *Scuba Diving Magazine* uses "tester's choice," and *Runner's World* awards its "five or four stars" to recommended products. Table 1 presents examples of consumer magazines and websites that provide comparative product reviews within various product categories and indicates which of them uses a recommendation format and which uses a description format.

3. Assumptions and Model Setting

In this section we specify assumptions and model setting. Key notations are summarized in the appendix.

3.1. Third-Party Product Reviewer

We make two assumptions about third-party product reviewers. First, we assume the third-party reviewer

Table 1   Examples of Third-Party Product Reviews

Third-party reviewer	Product category	Review format	Recommendation logo
Outdoor Photographer	Photographic Equipment	Recommendation	"Editor's Choice"
PC Magazine	Computer, Printer, Digital Camera, Software, Web Site, etc.	Recommendation	"Editor's Choice"
PC World	Computer, Printer, Digital Camera, Software, Web Site, etc.	Recommendation	"Best Buy"
Rodale's Scuba Diving Magazine	Scuba Diving Equipment	Recommendation	"Tester's Choice"
Runner's World	Running shoes	Recommendation	"Four & Five Star Shoes"
World Tennis	Tennis Shoes	Recommendation	"Best and Good Tennis Shoes"
CNET.com	Computer, Printer, Digital Camera, Software, etc.	Recommendation	"Editor's Choice"
Edutainingkids.com	Toys, Kids Learning Software and Games, etc.	Recommendation	"Top Pick"
ZDNET.com	Computer, Printer, Digital Camera, Software, etc.	Recommendation	"Editor's Choice"
Audio	CD Player	Description	N/A
Golf Magazine	Golf Equipment (Club tests)	Description	N/A
Runner's World	Running Shoes	Description	N/A

provides accurate product information. We do not consider cases in which the third-party reviewer might intentionally mislead readers by providing faulty information because we are interested in the impact of product reviews published by well-known publishers such as *PC Magazine* and *PC World,* each of which boasts millions of subscribers. Their reputation among readers is critical to these well-known publishers. Further, while advertising is often an important source of third-party reviewers' business revenue, a large reader base is crucial for attracting advertisers (Chaudhri 1998, Chen and Xie 2003). Hence, publishers have little incentive to favor larger advertisers at the cost of their credibility to readers. According to Lewis (1989), among most review publishers "[t]he editorial and advertising staffs are usually separate, and there is no evidence that any major publication has altered or withheld an unfavorable evaluation under pressure from the advertisers." While it is possible that a reviewer might provide faulty information with or without intention, we leave such cases to future research.

Second, we assume partial penetration of review information. Specifically, we assume that in the absence of other channels of information, such as advertising, nonreaders of the reviewer's publication will not be privy to the information contained in the review. Moreover, among readers of the publication, only λ percent of them read the review report. For ease of discussion, we call λ the *penetration rate* of the product review.

3.2. Firms
We consider two competing firms, H and L. First, we allow their products to differ in two mutually

independent attributes: quality (vertical) dimension, and taste (horizontal) dimension (e.g., Lancaster 1966, Liu et al. 2004). In the quality dimension, consumers agree on the preference order of the attributes. For instance, product reliability is an attribute in the quality dimension because all consumers agree that "the more, the better." In the taste dimension, however, different consumers may have very different preferences for the same attribute, such as design style or color (e.g., Anderson and de Palma 1992). In the quality dimension, product H has the high quality and L has the low quality. In the taste dimension, the two products offer horizontal attributes that match different consumers' tastes.

Second, we assume that the firms advertise their products in the reviewer's publication. (In §6, we allow firms to advertise in both the reviewer's publication and in other media and examine how firms' optimal advertising strategies differ across different types of media.)

Third, we assume an increasing convex function of advertising cost. Following Meurer and Stahl (1994), we use a cost function, $g(\alpha^j) = -\gamma \ln(1 - \alpha^j)$, where α^j is the reach level of firm j's advertising. Specifically, as defined by Meurer and Stahl (1994), α^j is the fraction of consumers who receive at least one advertisement from seller j. The parameter, α^j, can also be regarded as the probability that a consumer receives the advertisement from product j. The constant, γ, is a positive coefficient ensuring the interior choices of optimal advertising levels. This cost expression is derived by assuming that advertising technology resembles the classic statistical urn model (Butters 1977). It is in fact the mirror image of the typical

concave advertising-response function in advertising literature (e.g., Little 1979).

Finally, we allow the products to differ in production cost such that the high-quality product has a higher marginal cost than the low-quality product, $c^H \geq c^L$. Without loss of generality, let the marginal cost of L be normalized to 0 and the marginal cost of H be nonnegative, $c^H = c \geq 0$.

3.3. Consumers
We allow consumer heterogeneity in two dimensions. First, we allow consumers to differ in the importance of taste attributes in their purchase decision. Specifically, we assume that μ fraction of the consumers have a strong preference about taste-related attributes and make their purchase decisions mainly on the basis of these attributes. The remaining $1 - \mu$ consumers have little concern about the taste-related attribute and make their purchase decisions based mainly on the vertical product attributes. We call these two types of consumers "taste-driven" and "quality-driven" consumers, respectively. For instance, when making a purchasing decision for SUVs, quality-driven consumers are those who have strong preferences regarding quality attributes such as gas mileage, for which all consumers have the same preference order (i.e., high gas mileage is better). Taste-driven consumers are those who have strong preferences regarding taste attributes such as car design and size, for which different individuals might have different preferences. For example, many consumers strongly prefer Hummer because of its large size and special design, despite its poor gas mileage. Let τ denote the fraction of taste-driven consumers who have matched taste with L (i.e., $1 - \tau$ is the fraction of taste-driven consumers who have matched taste with H). Without loss of generality, the size of the whole consumers is normalized to 1. Note that the assumption about consumer heterogeneity in their types implies that if all consumers were fully informed, L would be the preferred product for $\mu\tau$ fraction of consumers and H would be the preferred product for $(1 - \mu) + \mu(1 - \tau)$ fraction of consumers.

Second, we allow consumers to differ in their price sensitivity. Assume that θ is the fraction of loyal consumers who are insensitive to price and buy only their preferred product (i.e., loyal consumers who prefer H will never buy L regardless of the price of L). $1 - \theta$ is then the fraction of switching consumers who are sensitive to price and would switch to a nonpreferred product if the price is sufficiently low. Let $\bar{v}$ denote consumers' reservation price for their preferred product and $\underline{v}$ denote the switchers' reservation price for their nonpreferred product. By definition, the loyal consumers' reservation price for their nonpreferred

product is zero. This heterogeneity can be interpreted as consumers differing in the marginal rate of substitution between income and product utility (Tirole 1990). We also assume that the high-quality firm's cost is sufficiently high ($c \geq \underline{v}$) that it is unprofitable for H to serve its least profitable segment: switchers who prefer L. This assumption ensures that the high-quality firm will not charge a price below $\underline{v}$ in the absence of product reviews, which allows us to focus on the more interesting cases and reduces the complexity of analysis. Relaxing this assumption will not alter our results qualitatively.

We assume that consumers enter the market with no information about products and that advertising and product reviews are the only two sources of information available to them. We also assume that advertising can convey full information on the taste attribute (e.g., design, color), but not necessarily on quality attributes (e.g., reliability) to consumers. In the absence of product reviews, consumers who receive advertising only from H are aware of the existence of H, but only q^H of them correctly identify H to be a high-quality product. Consumers who receive advertising only from L are aware of the existence of L, and q^L of them incorrectly identify L to be a high-quality product. Consumers who receive advertising from both firms become aware of the existence of both products, but only q of them correctly identify H as a high-quality and L as a low-quality product. Note that q can be a function of both firms' advertising effectiveness, $q = f(q^H, q^L)$, where $\partial q/\partial q^H > 0$, $\partial q/\partial q^L < 0$. Finally, because consumers who receive advertising from the high-quality firm alone are more likely to correctly identify H to be a high-quality product than consumers who receive advertising from both firms, we let $q < q^H$. Similarly, because consumers who receive advertising from the low-quality firm alone are more likely to incorrectly identify L to be a high-quality product than consumers who receive advertising from both firms, we let $1 - q < q^L$.

3.4. Model Setting
We allow firms to compete on both price and advertising. In practice, third-party reviewers often offer product reviews for products within a similar price range because buyer segments are often determined by price level. For instance, when providing reviews on PCs, CNET.com compares different products within three distinct segments: budget PC (low end), midrange PC (middle), and performance PC (high end). *Runner's World* reviews running shoes with categories such as under $50, $50 to $60, and above $60. Our data also revealed an insignificant price-quality correlation ($p = 0.673$) for all printer models when they were reviewed by *PC Magazine*. Given these market observations, we consider the situation in which the third party provides information

about products in the same price level. Specifically, our analysis focuses on the case in which both firms charge a high price (i.e., $\{P_0^H = P_0^L = \bar{v}\}$) in the absence of product reviews. We allow firms to choose whether to compete on price after the publication of the product review.

To provide some theoretical justification for the equal-price case, we offer a detailed equilibrium analysis (see the appendix) to show that $\{P_0^H = P_0^L = \bar{v}\}$ is an equilibrium as long as advertising alone cannot sufficiently convey product quality information to consumers. An equal-price equilibrium holds under this condition because when advertising is insufficient in conveying quality information, some consumers reached by advertising might not be able to correctly identify the high-quality product based on firms' advertising. When enough consumers fail to correctly identify the high-quality firm (or when enough consumers misidentify the low-quality firm), the low-quality firm has little incentive to charge a lower price. This condition is reasonable because third-party product reviews will be neither valuable to consumers nor influential to firms' strategy if advertising can fully convey product quality information. Note that we do allow both firms to adopt different prices in the presence of product reviews.

Let $t = 0, d, r$ denote the three cases we examine: in the absence of product review, in the presence of description product review, and in the presence of recommendation review, respectively. Let D_t^j, P_t^j, and π_t^j denote firm j's demand, price, and profit in case t, respectively ($j = H, L, t = 0, d, r$). Firm j's profit in case t is given by

$$\pi_t^j(\alpha_t^j, \alpha_t^i, P_t^j, P_t^i) = D_t^j(\alpha_t^j, \alpha_t^i, P_t^j, P_t^i)(P_t^j - c^j) - g(\alpha_t^j),$$

$$j = H, L, i = H, L, j \neq i. \quad (1)$$

Firm j's demand, $D_t^j(\alpha_t^j, \alpha_t^i, P_t^j, P_t^i)$, is determined not only by the firm's advertising and pricing but also by the availability of a product review.

In §4, we first examine firms' pricing and advertising strategies in the absence of a product review and then in the presence of a description review. In both cases we model competition with a two-stage game. Firms choose advertising reach levels in the first stage and prices in the second stage. We derive the subgame perfect Nash equilibrium (SPNE) of the two-stage game. Firms' optimal strategic responses to description product review are then derived by comparing the two cases ($t = 0$ and $t = d$).

We examine the recommendation review in §5. Different from the description product reviews, recommendation product reviews explicitly identify winning products, thus offering the high-quality firm an opportunity to increase its advertising effectiveness by including third-party award logos (e.g., "edi-

tor's choice by *PC Magazine*") in its ads. Dean and Biswas (2001) show that carrying third-party recommendation endorsements in the advertising can significantly increase consumers' perceived quality of the high-quality product and firm advertising effectiveness.[2] To allow the high-quality firm to use review-endorsed advertising as a strategic variable, we consider a three-stage game. In the first stage, firm H decides whether to use the review-endorsed advertising. In the second stage, each firm chooses its advertising reach level. In the third stage, firms make pricing decisions. We derive the SPNE of the three-stage game. Firms' optimal strategic responses to a recommendation product review are then derived by comparing the two cases ($t = 0$ and $t = r$).

4. Description Product Review
In this section, we first analyze the demand function in the absence of product reviews and then the demand in the presence of description reviews. Finally, we derive firms' optimal responses to third-party product reviews by comparing firms' competitive strategies in the two cases.

4.1. Analysis of Demand in the Absence of Product Review ($t = 0$)
First, firm j's demand is affected by the size of the informed consumers. In the absence of product review, consumers will make a purchase only when they are reached by a firm's advertising. There are three groups of informed consumers: (1) those reached only by L, (2) those reached only by H, and (3) those reached by both firms. Let E_0, A_0, and B_0 denote these three groups, respectively. The size of each group is

$$\text{Size:} \begin{cases} E_0 = \alpha_0^L(1 - \alpha_0^H) \\ \quad \text{reached only by } L\text{'s advertising,} \\ A_0 = \alpha_0^H(1 - \alpha_0^L) \\ \quad \text{reached only by } H\text{'s advertising,} \\ B_0 = \alpha_0^H \alpha_0^L \\ \quad \text{reached by both firms' advertising.} \end{cases} \quad (2)$$

Second, firm j's demand is also affected by whether informed consumers consider the advertised product(s) their preferred product(s) because consumers are willing to pay a higher price for their preferred product. For consumers in E_0 (reached only by L), L is a preferred product for all taste-driven consumers

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[2] While it is also possible to present the positive review information in firms' advertising in the case of description product review, as suggested by Dean and Biswas (2001), such endorsement by limited sentence is less striking and effective.

whose tastes match with L (i.e., $\mu\tau$) and for all quality-driven consumers who incorrectly identify L as a high-quality product (i.e., $(1-\mu)q^L$). Let ρ^L denote the fraction of consumers in E_0 who consider L to be a preferred product. It is easy to see that $\rho^L = \mu\tau + (1-\mu)q^L$. Similarly, let ρ^H denote the fraction of consumers in A_0 (reached only by H) who consider H to be a preferred product. H is a preferred product for all taste-driven consumers whose tastes match with H (i.e., $\mu(1-\tau)$) and for all quality-driven consumers who correctly identify H as a high-quality product (i.e., $(1-\mu)q^H$). Hence, $\rho^H = \mu(1-\tau) + (1-\mu)q^H$. Finally, let ρ denote the fraction of consumers in B_0 (reached by both products) who consider H to be a preferred product. It is easy to see that $\rho = \mu(1-\tau) + (1-\mu)q$. Because consumers in B_0 are aware of both products, the fraction of consumers who consider L to be a preferred product is $1-\rho$. We summarize consumers' preferences in (3):

$$\text{Preference:} \begin{cases} E_0: \rho^L \text{ consider } L \text{ to be preferred;} \\ A_0: \rho^H \text{ consider } H \text{ to be preferred;} \\ B_0: \rho \text{ consider } H \text{ to be preferred,} \\ \quad\ 1-\rho \text{ consider } L \text{ to be preferred;} \end{cases} \quad (3)$$

where $\rho^L = \mu\tau + (1-\mu)q^L$, $\rho^H = \mu(1-\tau) + (1-\mu)q^H$, $\rho = \mu(1-\tau) + (1-\mu)q$.

Finally, firm j's demand is affected by consumers' price sensitivity (see Table 2). For consumers reached only by L (E_0), both loyals and switchers will buy L if it is their preferred product and if $P^L \leq \bar{v}$, regardless of their price sensitivity. If L is not their preferred product, loyals will not buy but switchers will buy if $P^L \leq \underline{v}$. The consumers in E_0 will not buy H because they are not aware of H. The purchase behavior of consumers in A_0 about H is similar to the purchase behavior of consumers in E_0 about L. For consumers

reached by both firms (B_0), as shown in Table 2, loyals will buy their preferred product if its price is not higher than $\bar{v}$, and switchers will buy the product offering a higher positive surplus.

Firms' demand can be derived from Table 2, and the equilibrium of the two-stage game in the absence of product reviews ($t=0$) can be derived by maximizing the profit function (1).

4.2. Analysis of Demand in the Presence of a Description Product Review ($t = d$)

Unlike the case without review, in this case consumers can be informed not only by firms' advertising but also by third-party review information. Let R_d denote consumers who can directly access the description product review information. As defined in §3, the size of R_d is λ. Consumers in R_d can correctly identify their preferred product regardless of whether they receive firms' advertising. Let E_d, A_d, and B_d denote consumers who do not have access to product review information but are reached by advertising only from L, only from H, and from both firms, respectively. The sizes of the four informed consumer groups are

$$\text{Size:} \begin{cases} E_d = (1-\lambda)\alpha_d^L(1-\alpha_d^H) \\ \quad \text{reached only by } L\text{'s advertising,} \\ A_d = (1-\lambda)\alpha_d^H(1-\alpha_d^L) \\ \quad \text{reached only by } H\text{'s advertising,} \\ B_d = (1-\lambda)\alpha_d^H\alpha_d^L \\ \quad \text{reached only by both firms' advertising,} \\ R_d = \lambda \quad \text{reached by product review.} \end{cases} \quad (4)$$

Consumers in E_d, A_d, and B_d have the same preferences and reservation prices as consumers in E_0, A_0, and B_0 given in (3), respectively. Different from

Table 2   Consumer Purchase Decision

Informed consumer	Consumer preference	Consumer price sensitivity	Consumer purchase decision	
Reached by L only E_0	L is preferred (ρ^L)	Loyal (θ)	Buy L if $P^L \leq \bar{v}$	Case 1
		Switcher ($1-\theta$)		
	L is nonpreferred ($1-\rho^L$)	Loyal (θ)	No Purchase	Case 2
		Switcher ($1-\theta$)	Buy L if $P^L \leq \underline{v}$	Case 3
Reached by H only A_0	H is preferred (ρ^H)	Loyal (θ)	Buy H if $P^H \leq \bar{v}$	Case 4
		Switcher ($1-\theta$)		
	H is nonpreferred ($1-\rho^H$)	Loyal (θ)	No Purchase	Case 5
		Switcher ($1-\theta$)	Buy H if $P^H \leq \underline{v}$	Case 6
Reached by both B_0	H is preferred (ρ)	Loyal (θ)	Buy H if $P^H \leq \bar{v}$	Case 7
		Switcher ($1-\theta$)	Buy H if $P^H \leq \bar{v}$ and $\bar{v} - P^H \geq \underline{v} - P^L$ Buy L if $P^L \leq \underline{v}$ and $\underline{v} - P^L \geq \bar{v} - P^H$	Case 8
	L is preferred ($1-\rho$)	Loyal (θ)	Buy L if $P^L \leq \bar{v}$	Case 9
		Switcher ($1-\theta$)	Buy L if $P^L \leq \bar{v}$ and $\bar{v} - P^L \geq \underline{v} - P^H$ Buy H if $P^H \leq \underline{v}$ and $\underline{v} - P^H \geq \bar{v} - P^L$	Case 10

consumers reached only by advertising, consumers reached by product review are able to correctly identify product quality. Hence, for consumers in R_d, H is a preferred product for all taste-driven consumers whose tastes match with H (i.e., $\mu(1 - \tau)$) and all quality-driven consumers (i.e., $(1-\mu)$). Let η denote the fraction of consumers in R_d who consider H to be a preferred product, $\eta = \mu(1-\tau) + (1-\mu)$. We summarize consumers' preferences in the presence of a description review:

$$\text{Preference:} \begin{cases} E_d: & \rho^L \text{ consider } L \text{ to be preferred;} \\ A_d: & \rho^H \text{ consider } H \text{ to be preferred;} \\ B_d: & \rho \text{ consider } H \text{ to be preferred,} \\ & 1-\rho \text{ consider } L \text{ to be preferred;} \\ R_d: & \eta \text{ consider } H \text{ to be preferred,} \\ & 1-\eta \text{ consider } L \text{ to be preferred;} \end{cases} \quad (5)$$

where $\rho^L = \mu\tau + (1-\mu)q^L$, $\rho^H = \mu(1-\tau) + (1-\mu)q^H$, $\rho = \mu(1-\tau) + (1-\mu)q$, $\eta = \mu(1-\tau) + (1-\mu)$.

Consumers in E_d, A_d, and B_d have the same purchase behavior as consumers in E_0, A_0, and B_0 given in Table 2, respectively. Consumers in R_d who prefer product j have the same purchase behavior as consumers in B_d who prefer product j ($j = H, L$). The equilibrium of the two-stage game in the presence of description product reviews ($t = d$) can be derived by maximizing the profit function given in (1).

4.3. The Optimal Response to a Description Product Review

Comparing the equilibrium strategies in the two cases ($t = 0$ and $t = d$) allows us to derive firms' optimal strategic responses to the product review. Because market observations have suggested that third-party product reviews significantly affect a firm's advertising strategy but not its pricing strategy, as discussed earlier, we devote our attention to the equilibrium where firms do not adjust their price but vary their advertising. In Proposition 1, we derive conditions under which such an equilibrium occurs and discuss how to optimally vary one's advertising strategy when it is unprofitable to change price (see proofs of propositions in the appendix).

PROPOSITION 1 (DESCRIPTION REVIEW). *When the size of the taste-driven segment is sufficiently large ($\mu \geq \hat{\mu}_d$), both firms*

(i) *Adjust advertising strategy but not pricing strategy in response to a description product review, i.e., $P_d^{j*} = P_0^{j*}$;*

(ii) *Reduce their advertising spending, i.e., $g(\alpha_d^{j*}) < g(\alpha_0^{j*})$.*

Where P_t^{j*} and $g(\alpha_t^{j*})$ are firm j's optimal price and advertising expenditure in case t, and $\hat{\mu}_d$ is given in (A.18) in the appendix.

Proposition 1 reveals that price will not be used as a strategic variable in response to product review when there are enough consumers who value taste-related product attributes. This is because product reviews reveal information on product quality that often cannot be conveyed fully by firms' advertising. With the help of product reviews, more consumers can correctly identify H as a high-quality product. As a result, a product review decreases the number of consumers who are willing to pay a high price for L and motivates the low-quality firm to cut price in order to protect its market. Because only the quality-driven consumers have uncertainty about their preferred products, the impact of product review on a firm's pricing strategy depends on the relative size of the taste-driven vs. quality-driven consumers. When the segment of taste-driven consumers is very small, most consumers make purchase decisions based on product quality. Product review can significantly reduce the low-quality product's demand and motivate the low-quality firm to reduce price. However, if a sufficient number of consumers care about horizontal attributes, it will be more profitable for both firms to use advertising rather than price as a strategic variable in response to product review.

Proposition 1 also suggests that both high- and low-quality firms should reduce their advertising expenditure in the reviewer's publication. This is because a third-party product review is an alternative source of product information to the readers of the reviewer's publication that reduces the value of advertisement to these consumers. This *substitutive* effect of product review on firm advertising function has a negative impact on marginal advertising return. As a result, a product review reduces firms' advertising incentive, and all firms benefit from reducing advertising in the reviewer's publication.

5. Recommendation Product Review

As stated in §3, in the presence of recommendation product reviews, the high-quality firm might want to take advantage of the positive outcome of the product review by including third-party award logos (e.g., "Editor's Choice by *PC Magazine*") in its ads. To model this, we consider a three-stage game in which the high-quality firm decides whether to use review-endorsed advertising in stage 1, both firms choose their advertising reach levels in stage 2, and both firms make price decisions in stage 3.

5.1. Analysis of Demand in the Presence of a Recommendation Product Review ($t = r$)

Firms' demands under a recommendation reviews are the same as those under description reviews if the high-quality firm chooses not to use review-endorsed advertising. Therefore, we need only analyze the case

where the high-quality firm adopts review-endorsed advertising. Similar to the description review, in the presence of a recommendation review, there are four groups of informed consumers: $\{E_r, A_r, B_r, R_r\}$. Their definitions and sizes are

$$\text{Size:} \begin{cases} E_r = (1-\lambda)\alpha_r^L(1-\alpha_r^H) \\ \quad \text{reached only by } L\text{'s advertising,} \\ A_r = (1-\lambda)\alpha_r^H(1-\alpha_r^L) \\ \quad \text{reached only by } H\text{'s advertising,} \\ B_r = (1-\lambda)\alpha_r^H\alpha_r^L \\ \quad \text{reached only by both firms' advertising,} \\ R_r = \lambda \quad \text{reached by product review.} \end{cases} \quad (6)$$

The high-quality firm's decision to use review-endorsed advertising does not affect consumers reached only by the low-quality firm's advertising (E_r) because these consumers do not read the high-quality firm's ads. Such a decision also does not affect consumers reached by the product review (R_r) because these consumers are informed about quality attributes by reading product review and are not affected by advertising. Hence, consumers in E_r and R_r have the same purchase behavior as consumers in E_d and R_d, respectively. However, the high-quality firm's decision to use review-endorsed advertising will affect consumers reached by the high-quality firm's advertising (A_r and B_r) because review-endorsed advertising allows these consumers to learn the outcome of the product review. Hence, when review-endorsed advertising is used, all three groups, A_r, B_r, and R_r are aware of product quality. Consumers' preferences in the presence of a recommendation review and review-endorsed advertising are

$$\text{Preference:} \begin{cases} E_r: \ \rho^L \text{ consider } L \text{ to be preferred,} \\ A_r: \ \eta \text{ consider } H \text{ to be preferred,} \\ B_r: \ \eta \text{ consider } H \text{ to be preferred} \\ \quad 1-\eta \text{ consider } L \text{ to be preferred,} \\ R_r: \ \eta \text{ consider } H \text{ to be preferred} \\ \quad 1-\eta \text{ consider } L \text{ to be preferred,} \end{cases} \quad (7)$$

where $\rho^L = \mu\tau + (1-\mu)q^L$, $\eta = \mu(1-\tau) + (1-\mu)$.

Table 3 highlights the differences in the size of informed consumers and consumers' preference among the three cases ($t = 0, d, r$). Note that the case of recommendation review ($t = r$) without using review-endorsed format is the same as the case of description review ($t = d$) as shown in Table 3.

5.2. The Optimal Response to a Recommendation Product Review

In the presence of a recommendation review, the high-quality firm needs to decide whether to adopt review-endorsed advertising. Examination of firms' equilibrium strategies and profits when the high-quality firm adopts and does not adopt review-endorsed advertising leads to the following proposition regarding the review-endorsed advertising.

PROPOSITION 2 (REVIEW-ENDORSED ADVERTISING). (i) *There exists an interaction effect between firms' advertising and pricing strategies. Specifically, the low-quality firm is more likely to cut price if the high-quality firm adopts review-endorsed advertising than if the high-quality firm does not.*

(ii) *Adopting review-endorsed advertising can lead to a lower profit for the high-quality firm.*

Table 3   Consumer Information and Preference

Reached only by *L*'s ads		Reached only by *H*'s ads		Reached by *H*/*L*'s ads		Reached by review	
In the absence of product review ($t = 0$)							
$E_0 = \alpha_0^L(1-\alpha_0^H)$		$A_0 = \alpha_0^H(1-\alpha_0^L)$		$B_0 = \alpha_0^H\alpha_0^L$			
H is preferred	*L* is preferred	*H* is preferred	*L* is preferred	*H* is preferred	*L* is preferred		
N/A	ρ^L	ρ^H	N/A	ρ	$1-\rho$		
In the presence of a description review ($t = d$)							
$E_d = (1-\lambda)\alpha_d^L(1-\alpha_d^H)$		$A_d = (1-\lambda)\alpha_d^H(1-\alpha_d^L)$		$B_d = (1-\lambda)\alpha_d^H\alpha_d^L$		$R_d = \lambda$	
H is preferred	*L* is preferred	*H* is preferred	*L* is preferred	*H* is preferred	*L* is preferred	*H* is preferred	*L* is preferred
N/A	ρ^L	ρ^H	N/A	ρ	$1-\rho$	η	$1-\eta$
In the presence of a recommendation review ($t = r$) (with review-endorsed advertising)*							
$E_r = (1-\lambda)\alpha_r^L(1-\alpha_r^H)$		$A_r = (1-\lambda)\alpha_r^H(1-\alpha_r^L)$		$B_r = (1-\lambda)\alpha_r^H\alpha_r^L$		$R_r = \lambda$	
H is preferred	*L* is preferred	*H* is preferred	*L* is preferred	*H* is preferred	*L* is preferred	*H* is preferred	*L* is preferred
N/A	ρ^L	η	N/A	η	$1-\eta$	η	$1-\eta$

Note. $\rho^L = \mu\tau + (1-\mu)q^L$, $\rho^H = \mu(1-\tau) + (1-\mu)q^H$, $\rho = \mu(1-\tau) + (1-\mu)q$, $\eta = \mu(1-\tau) + (1-\mu)$.

*The case of the recommendation review is the same as that of the description product review if review-endorsed advertising is not adopted.

Proposition 2 reveals an interesting strategic inter-action between firms' advertising and pricing strat-egies—the low-quality firm is more likely to engage in price-cutting if the high-quality firm adopts review-endorsed advertising. This interaction is the result of the *complementary* effect of the recommenda-tion review on firm advertising function. A review endorsement has a significant impact on advertising effectiveness. This complementary effect can be posi-tive or negative, depending on whether the advertiser is a high- or low-quality firm.

As shown in Table 3, for consumers who do not have direct access to the review information but are reached by H's advertising (A_r and B_r), ρ^H (in A_r) and ρ (in B_r) prefer H when review-endorsed adver-tising is not used, but η (in both A_r and B_r) prefer H if such advertising is used. Because $\eta > \rho^H$ and $\eta > \rho$, review-endorsed advertising has a positive comple-mentary effect on a high-quality firm's advertising function. Furthermore, for consumers reached by both firms' advertising (B_r), $1 - \rho$ prefer L when review-endorsed advertising is not used, but $1 - \eta$ prefer L if such advertising is used. Because $1 - \rho > 1 - \eta$, review-endorsed advertising has a negative comple-mentary effect on a low-quality firm's advertising function.[3] The positive complementary effect on H's advertising implies that a larger number of consumers (including switchers who would buy L under a suf-ficiently low price) prefer H when review-endorsed advertising is used than when it is not used. For this reason, the benefit of price-cutting for the low-quality firm is higher in the former than in the latter case. The negative complementary effect on L's advertising implies that a smaller number of consumers (includ-ing loyals who are willing to pay a premium price for L) prefer L when review-endorsed advertising is used than when it is not used. For this reason, the cost of price-cutting for the low-quality firm is lower in the former case than in the latter. Therefore, price-cutting becomes a more profitable strategy for the low-quality firm when the high-quality firm adopts review-endorsed advertising.

The interaction effect between firms' advertising and pricing strategies leads to a surprising find-ing—the high-quality firm can be hurt by includ-ing a third-party endorsement in its advertisement. Review-endorsed advertising is a double-edged sword. On one hand, it increases the high-quality firm's advertising effectiveness and leads more con-sumers to prefer H. On the other hand, review-endorsed advertising increases the low-quality firm's

incentive to cut price. When the size of the taste-driven consumers is small, firm L may have to cut its price aggressively to compete for switchers who prefer H, which can significantly reduces H's profit.

By comparing the equilibrium strategies in the ab-sence of product review ($t = 0$) and in the presence of a recommendation product review ($t = r$), we derive the following proposition regarding firms' optimal responses to a recommendation product review.

PROPOSITION 3 (RECOMMENDATION REVIEW). *When the size of the taste-driven segment is sufficiently large* ($\mu \geq \hat{\mu}_r$),

(i) *Both firms adjust advertising strategy but not pric-ing strategy in response to a recommendation product review;*

(ii) *It is optimal for the high-quality firm to adopt review-endorsed advertising;*

(iii) *Firms adopt asymmetric advertising responses such that* (a) *the low-quality firm reduces its advertising expen-diture,* (b) *the high-quality firm increases its advertising expenditure if the review penetration rate is sufficiently low, but decreases its advertising expenditure, otherwise. Mathematically,*

$$
\begin{cases}
\text{Low-quality firm:} & g(\alpha_r^{L*}) < g(\alpha_0^{L*}); \\
\text{High-quality firm:} &
\begin{cases}
g(\alpha_r^{H*}) \geq g(\alpha_0^{H*}) \\
\quad \text{if } \lambda \leq \lambda^* = 1 - [(1 - \alpha_0^{L*})\rho^H \\
\qquad\qquad\qquad\qquad + \alpha_0^{L*}\rho]/\eta; \\
g(\alpha_r^{H*}) < g(\alpha_0^{H*}) \quad \text{otherwise;}
\end{cases}
\end{cases}
$$

where $g(\alpha_t^{j*})$ is firm j's optimal advertising expenditure in case t ($j = H, L$, $t = 0, r$), and $\hat{\mu}_r$ is given in (A.28) in the appendix.

Proposition 3 reveals that, similar to the case of the description review, if sufficient numbers of consumers care about horizontal product attributes ($\mu \geq \hat{\mu}_r$), it is optimal for firms to vary advertising but not price in response to a recommendation product review. In this case, because the low-quality firm has no incentive to cut price, the high-quality firm benefits from using review-endorsed advertising.

Proposition 3 also shows that, in contrast to the case of a description review, where both firms reduce their advertising expenditures in response to product review (see Proposition 1), in the presence of a recom-mendation review, the high- and low-quality firms may adopt different advertising strategies. Specifi-cally, in response to a recommendation review, while it is best for the low-quality firm to reduce its adver-tising, the high-quality firm may benefit from increas-ing or decreasing its advertising spending, depending on the review penetration rate.

The asymmetric impact of the recommendation product review on high- and low-quality firms can

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[3] Negative complementary effect on low-quality firm indirectly comes from the increased credibility and effectiveness of high-quality firm's advertising.

be explained by two effects: a *substitutive* effect and a *complementary* effect. On one hand, as an alternative source of product information, a recommendation review has the negative substitutive effect on a firm's advertising function. On the other hand, as discussed previously, a recommendation product review has a positive complementary effect on high-quality firms' advertising function and a negative complementary effect on low-quality firms' advertising function when the high-quality firm adopts review-endorsed advertising. It is interesting to note that the magnitude of the substitutive and complementary effects depends on the size of the review penetration rate, λ. This is because the substitutive effect applies only to the consumers who directly access review information, i.e., λ. These consumers learn about product quality from reading the product review and therefore do not need to rely on advertising information to make quality inferences. The complementary effect, however, applies to consumers who cannot directly access review information, $1 - \lambda$. Those consumers still rely on advertisements as their information source in making quality inferences. Hence, the size of λ affects both substitutive and complementary effects. A larger λ leads to a stronger substitutive effect and a weaker complementary effect.

Clearly, the overall effect of product review on firms' advertising function is determined by the combined impact of the substitutive and complementary effects. Proposition 3 shows that for low-quality firms, the optimal advertising response to the third-party review is to reduce advertising. This is because the low-quality firm suffers from both a negative substitutive effect and a negative complementary effect, and the product review reduces the low-quality firm's incentive to invest in advertising. Hence, the optimal advertising spending is lower in the presence than in the absence of product review.

For high-quality firms, the optimal advertising response depends on the penetration rate of the review information, λ. For high-quality firms, the substitutive and complementary effects take different directions, and λ is positively related to the strength of the substitutive effect but negatively related to the strength of the complementary effect. When the review penetration rate λ is sufficiently high, a large number of readers become aware of product quality and will not benefit from the high-quality firm's advertising. Although the product review can make a high-quality firm's advertising more persuasive for consumers, this positive complementary effect may be too weak to overcome the negative substitutive effect because the former applies to a very small $(1 - \lambda)$ and the latter a very large (λ) proportion of consumers. As a result, when a large number of consumers are aware of the review information, the high-quality

firm will benefit by reducing advertising spending. When the review penetration rate, λ, is sufficiently low, the high-quality firm's advertising can be very profitable because it will affect a large number of consumers and will have high credibility. In this case, the positive complementary effect can dominate the negative substitutive effect. Therefore, when the review penetration rate is very low, the high-quality firm will benefit by increasing advertising.

6. Other Advertising Media

In the preceding sections, we assume that the reviewer's publication is the firms' only advertising outlet. Now we allow the firms to advertise in two different types of media: the reviewer's publication and other publications. We also allow the firms to adopt different advertising strategies in response to a product review in these two types of media to determine whether it affects each type of media differently. We call the nonreviewer's publication "other media." Let σ be the percentage of consumers who read the reviewer's publication; hence, $1 - \sigma$ read the other media. To distinguish the cases without other media (discussed in previous sections), we use an "m" subscript to denote all the variables for the case with both the reviewer's publication and other media. For example, α_{tm}^{j} and ϕ_{tm}^{j} denote firm j's advertising reach levels in the reviewer's publication and in other media in case t $(t = 0, d, r)$, respectively.

Unlike the previous cases, consumers can now get product information via the firms' ads from both the reviewer's publication and other media. This will change the composition of different informed consumer groups. For instance, the proportion of consumers who can access review information directly was $R_t = \lambda$ in previous sections, but $R_{tm} = \sigma\lambda$ in this section, where $t = d, r$. As a result, the size of the consumers reached only by H's advertising in case t, A_{tm}, is

$$\text{Size:} \begin{cases} A_{0m} = \sigma\alpha_{0m}^{H}(1 - \alpha_{0m}^{L}) + (1 - \sigma)\phi_{0m}^{H}(1 - \phi_{0m}^{L}) \\ A_{dm} = \sigma(1 - \lambda)\alpha_{dm}^{H}(1 - \alpha_{dm}^{L}) + (1 - \sigma)\phi_{dm}^{H}(1 - \phi_{dm}^{L}) \\ A_{rm} = \sigma(1 - \lambda)\alpha_{rm}^{H}(1 - \alpha_{rm}^{L}) + (1 - \sigma)\phi_{rm}^{H}(1 - \phi_{rm}^{L}). \end{cases}$$

(8)

The size of the other groups of consumers in different cases also changes accordingly. (See the appendix for details.) Consumers' preferences and reservation prices in each group remain the same. Examining the firms' equilibrium strategies and profits leads to the following proposition regarding their advertising strategies in different media.

PROPOSITION 4 (OTHER ADVERTISING MEDIA). (i) *The existence of other media does not affect firms' advertising responses to product review in the reviewer's publication.*

(ii) *In the presence of a description review, firms do not adjust their advertising expenditure in other media.*

(iii) *In the presence of a recommendation review,* (a) *firms do not adjust their advertising expenditure in other media if the high-quality firm does not adopt review-endorsed advertising, and* (b) *the low-quality firm reduces but the high-quality firm increases advertising expenditure in other media if the high-quality firm adopts review-endorsed advertising.*

Taking Propositions 1, 3, and 4 together, we now are able to provide a summary of the firms' optimal advertising strategies (see Table 4) in the presence of different review formats (description vs. recommendation) and in different advertising media (reviewer's publication vs. other media). The upper part of Table 4 shows the impact of product review on advertising function in terms of substitutive and complementary effects, and the lower part of Table 4 shows the optimal advertising strategy in response to product review. Note that both description and recommendation reviews have the same effect on the firms' advertising strategies if the high-quality firm does not adopt review-endorsed advertising after the publication of a recommendation review. To focus on the differences between the two types of reviews, in the discussion below, a recommendation review refers to the case where the review is presented in a recommendation format and review-endorsed advertising is adopted.

As shown in Table 4, the substitutive effect depends on the type of media used. The negative substitutive effect applies only to advertising in the reviewer's publication and not to advertising in other media, because readers of the former have direct access to the review information whereas readers of the latter do not. The complementary effect depends on the type of review format used and the quality of the firm's product. It applies to the recommendation format but not to the description format. It is positive for high-quality firms but negative for low-quality firms. Table 4 shows that the description format has a symmetric effect such that it affects both firms in the same direction. Conversely, the recommendation format has an asymmetric effect such that it affects high- and low-quality sellers in different directions.

The combined impact of substitutive and complementary effects leads to the optimal advertising response shown in the lower part of Table 4. For example, firms should not change their advertising spending in other media after the publication of a description product review because such reviews have neither a substitutive nor a complementary effect on their advertising in other media. Firms should decrease their advertising in other media due to the negative substitutive effect of the description format. Firms' optimal advertising response to the recommendation format depends on the product's quality, the type of media, and the penetration rate (λ) of the review information. The optimal advertising response varies for firms with products of different quality because the complementary effect is positive for high-quality products but negative for low-quality products. Low-quality firms should reduce advertising in all media provided that both substitutive and complementary effects are negative. High-quality firms should increase advertising in other media due to a positive complementary effect. Their advertising strategy in the reviewer's publication depends on the review penetration rate which decreases the positive complementary effect and increases the negative substitutive effect. Increasing advertising is optimal when fewer people are aware of the review information, but decreasing advertising is optimal when most readers of the reviewer's publication are informed consumers.

Table 4   Advertising Response to the Third-Party Product Review

| | Recommendation format review (with review-endorsed advertising)* | | | | Description format review | | | |
| | High-quality firm | | Low-quality firm | | High-quality firm | | Low-quality firm | |
	Reviewer's publication	Other media	Reviewer's publication	Other media	Reviewer's publication	Other media	Reviewer's publication	Other media
Substitutive effect	Negative	None	Negative	None	Negative	None	Negative	None
Complementary effect	Positive	Positive	Negative	Negative	None	None	None	None
Optimal advertising response	Increase or Same (Low review penetration) Decrease (High review penetration)	Increase	Decrease	Decrease	Decrease	Same	Decrease	Same

*The optimal advertising strategy in the case of recommendation review is the same as that in the case of description product review if review-endorsed advertising is not adopted.

Substitutive effect: product review can reduce consumer's need for advertising information.
Complementary effect: product review can strengthen or weaken advertising effectiveness.

It is important to note that some third-party reviewers do not accept firms' advertising. Rather, they charge consumers for the product review information (e.g., *Consumer Reports*, Zagat). We call this type of third-party information *guidebooks*. Although guidebooks carry no ads, our model can be applied to this type of third-party reviewer by making two modifications. First, the fraction of informed consumers who receive advertising from the reviewer's publication is set to zero (i.e., σ is zero rather than positive). Second, by purchasing guidebooks, a fraction of readers of other media can directly access the review information (i.e., λ is defined as the percentage of readers of other media who can directly access the review information, rather than the percentage of readers of the reviewer's publication who can directly access the review information).

These minor modifications do not affect our results on firms' pricing strategy because firms still face the same trade-offs in deciding whether price should be a strategic variable in response to product review the benefit (cost) of using price as a response variable is low (high) when many consumers value horizontal product attributes. Because a guidebook does not accept advertising, firms need to consider their advertising strategy only in other media. Given the modified definition of λ, firms' advertising adjustments in other media in the guidebook case is the same as firms' advertising adjustments in the reviewer's publication shown in Table 4. In addition, some guidebooks such as *Consumer Reports* do not allow firms to carry the publications' award logos in advertising. Hence, review-endorsed advertising might not be possible. In this case, the impact of a recommendation review will be similar to that of a description review.

7. Empirical Evidence

To demonstrate some external validity for our theoretical model, we conduct an exploratory empirical study on the impact of third-party product reviews on firms' marketing strategies. In selecting product categories, the following criteria must be met.

(i) *Third-party product review.* (a) The category needs to have the third-party product reviews published by reputable consumer magazines; (b) the reviews must provide comprehensive information on all newly launched models in their respective markets; and (c) the reviews must use different formats in evaluating overall product performance.

(ii) *Media and advertising data.* (a) The category needs to have two dominating consumer magazines in the industry: the reviewer's publication and a representative of "other media"; and (b) advertising data for all the reviewed models must be available from both magazines before and after the review appears.

(iii) *Pricing data.* Pricing data for all the reviewed models must be available before and after the review appears.

We are able to find two product categories that met all these requirements: printers and running shoes. Although we were unable to obtain detailed price information for running shoes directly, Achibald et al. (1983) collected retailing price data on most of the running shoes models and reported the results of their examination of the impact of the review information on pricing in the running shoes market.

In the remainder of this section, we provide detailed information on the data collected from these two industries and discuss our empirical findings.

7.1. Data

Printer. In the printer industry, we collected review data from *PC Magazine*, which is considered one of the most influential computer consumer magazines in the world (Lohr 1993). *PC Magazine* was launched in 1982, and in 1999 it had a circulation of over 1.23 million and the highest advertising revenue among all U.S. consumer magazines (Fost 1999). Twenty-two issues of the magazine are published each year. Between 1984 and 1992, a special issue appeared every October or November in which all new models of printers were reviewed. These special issues presented detailed information on current price, print speed, graphics output, and text output for each model. Each of the special review issues also designated some models as "Editor's Choice" selections based on overall performance and price. We collected the printer review data from one of the special issues (November 14) published in 1989.[4] This issue reviewed 106 new models, designating 20 models an "Editor's Choice" selections. Among the models reviewed, 27 exited the market the following year. To rule out the impact of product strategy on advertising spending, we used the remaining 79 models for our analysis. Among these models, we classified the 16 "Editor's Choice" printers as high-quality products and the remaining 63 printers as low-quality products.

To examine the firms' advertising responses to product reviews, we collected advertising data in two magazines: the reviewer's publication, *PC Magazine*, and its leading rival, *PC World*. These two magazines were the dominant players in their market during the period we studied. According to the Fisher (1988), in 1988 the subscription size was 502,700 for *PC Magazine* and 475,000 for *PC World*, and the circulation of these two magazines accounts for 75% of overall

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[4] We used the review data from this issue because we were able to find complete advertising data for 12 months before and 12 months after the publication of this issue to complete our analysis.

circulation size of the top five computer magazines. Moreover, research showed that three-fourths of *PC World*'s readers did not read *PC Magazine* (Lohr 1993). We counted the number of advertising pages for all printers in both magazines one year before and one year after publication of the review issue of *PC Magazine*. Because sellers might advertise several models in one advertisement, when counting advertising pages we divided whole pages of this type of advertisement by the number of models and obtained the advertising level for each individual model.

In addition, in each year's review issue on printers, *PC Magazine* also provides the current prices for all printer models that were reviewed in previous years and are still available on the market. Therefore we were able to obtain price data for all 79 models before and after the review.

Running Shoes. In the running shoes industry, we collected review data from *Runner's World* magazine. *Runner's World* had a circulation of 410,000 in 1981, and since the 1980s it has had the highest circulation among U.S. runners' magazines. *Runner's World* published reviews of running shoes once a year in the October issue from 1975 to 1985 and twice a year in the April and October issue from 1986 to present. Before 1985, it employed a recommendation format with a five-star system to rate all shoes and recommended 5- and 4-star shoes to buyers. Since 1985, the magazine has adopted a description review format, providing only attribute facts on products without making recommendations. We collected recommendation review data from the October 1979 issue of *Runner's World*. Of 177 shoe models reviewed, 71 models were categorized as "5-star" and "4-star." We classified these models as high-quality and the remaining 106 models as low quality. We collected description review data on running shoes from the October 1985 issue of *Runner's World*. The review presented detailed product information and pictures of 52 models.

Advertising data were collected both from *Runner's World* and from its leading competitor *Runner*. According to *Ayer Directory of Publications*, in 1981 the circulation for *Runner's World* was about 410,000 while for *Runner* it was 85,000, and together these two magazines accounted for 90% of the market share in their market. For the recommendation review format, we collected advertising data by counting the number of advertising pages found in all issues of *Runner's World* for six months before the review issue (May 1980 to October 1980) and for six months after the review issue (November 1980 to April 1981). Likewise, we gathered advertising data from all issues of *Runner* for four months before and four months after the review (July 1980 to February 1981).[5] For the

description review, we collected advertising data from all issues of both magazines for six months before and six months after the reviews appeared (May 1985 to April 1986).

For the price data, we were unable to directly obtain the price data for the running shoe models after the review. However, Achibald et al. (1983) collected retailing price data on most of the running shoes models reviewed in the October 1979 issue both before and after the review issue and investigated the impact of the review information on pricing.

7.2. Empirical Findings

Impact of Product Review on Pricing. In the running shoes market, Archibald et al. (1983) report that the manufacturers of running shoes did not adjust prices to any significant degree after the publication of a review by *Runner's World.* In the printer market, our data reveal the same pattern. For example, we find that the publication of the product review by *PC Magazine* did not have a significant impact on the price-quality correlation ($p = 0.17$). In fact, the price-quality correlation is neither significant *before* nor *after* the publication of the review ($p = 0.85$ and $p = 0.95$). These observations are consistent with our theoretical results. In our basic model, we assume both high-quality and low-quality firms charge a high price and prove that firms will not adjust their pricing policy in response to third-party product review if the size of taste-driven consumer population is sufficiently large. This theoretical result predicts that, given the low price-quality correlation prior to the publication of the product review, the price-quality correlation will not increase after the publication of the product review when enough consumers value horizontal product attributes.

We use price-quality correlations instead of absolute price levels to evaluate the impact of the product review on the firms' pricing strategies also because the latter might be subject to a negative fixed time effect. A recent empirical study of the printer market (Melnikov 2000) provided evidence of such a negative fixed time effect on printer price. If product review had a significant impact on the firms' pricing strategy, we would expect an increase in the price-quality correlation after the publication of the product review. This is because a product review increases (decreases) the number of consumers who are willing to pay a high price for the high-quality (low-quality) products, provided that the product review is informative. The fact that the price-quality correlation did not change could suggest that the product review has an insignificant impact on the firms' pricing strategies.

Our model provides a possible explanation for this interesting observation. Our theoretical results suggest that if there are enough consumers who care

[5] The length of this time series is constrained by the availability of data.

about horizontal product attributes, it is unprofitable for firms to use price as a response variable in the presence of a product review. This is because when there are enough consumers whose purchase decisions are driven mainly by their idiosyncratic preferences, price competition is neither necessary (i.e., a product review does not pose a crucial threat to low-quality firms' demand) nor efficient (i.e., price-cutting offers little help in gaining market share).

When buying running shoes, for some consumers quality attributes such as flexibility, weight, sole traction, and injury prevention are critical to their purchase decision. For other consumers, taste attributes such as design style and fit with foot type (pronators, supinators, or normal) may play a dominant role in their purchase decisions. When making a purchase decision about printers, many consumers focus on quality attributes such as print speed, memory buffer size, and image resolution. However, other consumers may have a strong preference toward a particular brand due to personal taste, or concerns about horizontal attributes such as color, size, design, software compatibility, and special optional functions. Horizontal attributes such as software compatibility and special functions (e.g., Postscript compatibility, small computer system interface (SCSI), and special size paper handling) were important factors in consumers' purchase decisions in the early stage of the printer market we examined. We found that firms tended to emphasize these horizontal attributes in their advertisements, especially for products that were not designated an "Editor's Choice" selection. The observation that product reviews did not significantly affect firms' pricing strategies in both running shoes and printer markets may suggest that horizontal attributes were important to many consumers in these two markets, which weakened the benefit but increased the cost of using price as a response variable in the presence of product review.

Impact of Product Review on Advertising. We now examine the impact of product review on the advertising levels of firms in the two markets. Our model (see Table 4) suggests that advertising strategy in the presence of product review is determined by four factors: (1) review format, (2) type of media, (3) product quality, and (4) penetration rate of the review information. In our empirical study, we are able to measure the first three factors in both industries directly but unable to measure the last factor directly. The penetration rate of review information is defined as the percentage of those subscribers of the reviewer's publication who read the review information. Several factors may affect the review penetration rate. For example, due to limited time and search cost, a reader is more likely to learn the review information if (1) the reviewer publishes a small rather

than a large number of issues per year, (2) each issue has fewer rather than more pages, and (3) the annual review is published in a fixed issue (e.g., each October) rather than in different issues every year. Comparing the two third-party product reviewers, we find major differences in these factors. *PC Magazine* has 22 issues each year, while *Runner's World* is issued 12 times a year. Reviews of printers appeared in different issues of *PC Magazine* in different years, but reviews of running shoes appeared regularly in the October issue of *Runner's World*. Furthermore, *PC Magazine* runs almost 400 pages per issue, but *Runner's World* has fewer than 100 pages in each issue. These facts suggest that it is easier for readers of *Runner's World* to find and remember the review information than it is for readers of *PC Magazine*. In other words, *Runner's World* may have a higher review penetration rate, λ, than *PC Magazine*. Furthermore, our interviews with readers of *Runner's World* suggest that most readers of this magazine are serious runners who have sophisticated knowledge of running shoes and are capable of understanding the technical details of the review report. Given the single-product category focus of the magazine (running shoes), the ease of searching the product review information (fewer issues per year, fewer pages per issue, a fixed issue for product review), and the high degree of reader sophistication, we consider that *Runner's World* has a high penetration rate of product review information in developing our predictions for firms' advertising responses.

Based on Table 4, we provide 10 predictions about firms' advertising responses to the third-party product reviews in the two industries (P1a-P6), which are summarized in Table 5. We use "P#" to designate the number of our prediction in Table 5. We use the symbols, "+", "−", and "0" to indicate our predicted changes in advertising level (i.e., increase, decrease, or maintain the same level) after the publication of the review. For example, Prediction 1a implies that the advertising level of high-quality printers in *PC Magazine* (the reviewer's publication) is no lower after than before the recommendation review appeared in *PC Magazine*. Prediction 6 implies that there is no difference in the advertising level of running shoes in *Runner* (other media) before and after the description product review appeared in *Runner's World*. These predictions directly follow Table 4 (Predictions 1a and 1b assume *Runner's World* has a higher review penetration rate, $\lambda \geq \lambda_m^*$ and *PC Magazine* has a lower review penetration rate. Predictions based on recommendation review assume the use of review-endorsed advertising by the high-quality firms given that most winning products in our data did so).

Table 6 presents the empirical results (mean advertising levels before and after the publication of product reviews).

Table 5   Predictions of Advertising Response

		Recommendation format				Description format	
		High-quality products		Low-quality products			
Printers	Magazine	*PC Magazine* (Reviewer)	*PC World* (Other Media)	*PC Magazine* (Reviewer)	*PC World* (Other Media)		
	Prediction (P#)	+/0 (P1a)	+ (P2a)	− (P3a)	− (P4a)		
Running shoes	Magazine	*Runner's World* (Reviewer)	*Runner* (Other Media)	*Runner's World* (Reviewer)	*Runner* (Other Media)	*Runner's World* (Reviewer)	*Runner* (Other Media)
	Prediction (P#)	− (P1b)	+ (P2b)	− (P3b)	− (P4b)	− (P5)	0 (P6)

Recommendation Review Format. As predicted by Predictions 3a and 4a, the advertising levels of low-quality printers are significantly lower in both the reviewer's publication (*PC Magazine*, $p < 0.01$) and in the nonreviewer's publication (*PC World*, $p < 0.1$) after than before the printer review appeared. The same conclusion holds for running shoes. Makers of low-quality running shoes significantly reduced advertising levels in both *Runner's World* ($p < 0.01$) and *Runner* ($p < 0.01$), supporting Predictions 4a and 4b.

Proposition 3 suggests that, in the presence of a recommendation review, high-quality firms will respond differently than low-quality firms. Proposition 4 suggests that they may adopt different advertising adjustments for the reviewer's publication and other media. Consistent with Predictions 1b and 2b, high-quality running shoes significantly decreased their advertising levels in the reviewer's publication

(*Runner's World*, $p < 0.05$) but significantly increased their advertising levels in the nonreviewer's publication (*Runner*, $p < 0.01$). Also, as shown in Table 5, the change of high-quality printers' advertising in the nonreviewer's publication (*PC World*) is in the direction predicted (P2a), though not to a significant degree. It is possible that the insignificant result is due to the small sample size of the high-quality printers. The change in high-quality printers' advertising in the reviewer's publication (*PC Magazine*) is also in the direction predicted (P1a) but is insignificant. One possible reason for this insignificant result is that the penetration rate of the review is close to the threshold penetration level. If this is the case, then the insignificant result is consistent with Propositions 3 and 4, which suggest that the high-quality firms will not change their advertising levels in the reviewer's publication if the review penetration rate is in the threshold level.

Table 6   Empirical Results of Advertising Responses

	Recommendation format				Description format	
	High-quality products		Low-quality products			
Printer						
Magazine	*PC Magazine* (Reviewer)	*PC World* (Other Media)	*PC Magazine* (Reviewer)	*PC World* (Other Media)		
Before	1.91 (3.19)	0.69 (2.02)	0.67 (1.63)	0.25 (0.71)		
After	2.58 (4.84)	1.06 (2.54)	0.15 (0.55)	0.14 (0.53)		
T-statistic	1.04[ns]	0.49[ns]	−2.85***	−1.317*		
Conclusion	P1a: Support		P3a: Support	P4a: Support		
Running shoes						
Magazine	*Runner's World* (Reviewer)	*Runner* (Other Media)	*Runner's World* (Reviewer)	*Runner* (Other Media)	*Runner's World* (Reviewer)	*Runner* (Other Media)
Before	0.92 (1.37)	0.22 (0.55)	0.48 (1.27)	0.12 (0.39)	0.61 (0.98)	0.72 (0.99)
After	0.64 (0.87)	0.46 (0.83)	0.14 (0.43)	0.02 (0.10)	0.16 (0.42)	0.56 (1.17)
T-statistic	−1.86**	2.195***	−2.70***	−2.792***	−3.00***	−0.828[ns]
Conclusion	P1b: Support	P2b: Support	P3b: Support	P4b: Support	P5: Support	P6: Support

Note. Advertising level is measured by the number of advertising page.
    ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
    ns: not significant at 0.1 level.

Description Review Format. As shown in Table 6, the advertising levels of firms that make running shoes are significantly lower after the publication of the description review in the reviewer's publication (*Runner's World*, $p < 0.01$), supporting Prediction 5. Furthermore, there is no significant difference in advertising level before and after the publication of a description product review in the nonreviewer's publication (*Runner*), supporting Prediction 6.[6]

In summary, our empirical study based on data from two product categories provides some preliminary empirical support for our theoretical model. However, it is important for future research to provide more empirical evidence from a larger number of product categories.

8. Conclusion

In this paper, we investigate a new research area: firms' marketing strategies in response to third-party product reviews. Specifically, we study how firms should adapt their pricing and advertising strategies to third-party product reviews under different conditions. We develop a normative model to analyze firms' strategic responses to product reviews and illustrate our findings with data from computer printers and running shoes industries.

This paper contributes to the marketing literature by developing a normative theory that incorporates third-party product reviews into firms' marketing strategies. This theory explains the strategic impact of third-party product reviews on firms' pricing and advertising strategies, identifies key factors affecting firms' decisions, examines the interaction between pricing and advertising response, and derives the firms' optimal strategies in the presence of product reviews under various product/market/review/media conditions.

Our findings provide the following implications for firms' marketing strategies in the presence of third-party product reviews.

• Although price is generally considered to be more flexible than advertising, varying price in response to product review can be unprofitable if there are enough consumers who value horizontal product attributes. In such markets, the optimal response to product review is to adjust advertising rather than change price.

• Firms' strategic responses need to be review-format specific. For example, with review-endorsed ads, a recommendation product review generates a

complementary effect, which increases winners' but decreases losers' advertising effectiveness. Such a complementary effect does not apply to description product reviews because description product reviews do not explicitly distinguish winners from losers. As a result, the best advertising response to a product review depends not only on the outcome (i.e., winning vs. losing) but also on the format (i.e., recommendation vs. description).

• Firms need to be aware of the potential interaction between their pricing and advertising responses. For example, it is not always optimal for a winning product of a recommendation review to use review-endorsed advertising to spread the good news about its product. This is because review-endorsed advertising not only increases the winning products' advertising effectiveness, but it also motivates price-cutting by the losing products. As a result, using review-endorsed advertising could hurt winners due to intensified price competition.

• To design advertising response to third-party product review, firms need separate strategies for advertising in the reviewer's publication versus other media. This is because a product review generates a substitutive effect on advertising in the reviewer's publication but not (or to a lesser degree) on advertising in nonreviewers' publication.

• In responding to a recommendation product review, firms with winning products need to pay attention to the penetration rate of the review information. Increasing advertising to spread the good news is profitable for winning products only if the review information has a low penetration rate. When the review penetration rate is high, winners are better off taking the same strategy as losers: reducing advertising.

• In general, in the presence of a description review, both firms should reduce advertising spending in the reviewer's publication but not vary advertising spending in other media. In the presence of a recommendation review, the low-quality firm should reduce advertising spending across all media. However, the high-quality firm should increase advertising spending in other media, but should always reduce spending in the reviewer's publication unless the review penetration rate is sufficiently low.

While this research improves our understanding of third-party product review's impact on pricing and advertising strategy, many other interesting questions remain unanswered and require further investigation. One limitation of this paper is that we examine only two marketing strategies: pricing and advertising. Product review may also interact with other marketing strategies such as new product development, product line decisions, and the timing of new product launches.

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[6] Because the description review did not provide quality categorization, we also asked a 10-year amateur marathon runner and long-time subscriber to *Runner's World* as the judge to pick 20 out 52 models as high-quality models. The analysis based on this categorization is also consistent with our prediction.

Second, this paper does not consider the possible interaction between manufacturing firms' strategic responses and the reviewer's policy. For example, given manufacturing firms' responses to different types of product reviews (e.g., description or recommendation review), the third-party reviewer can strategically adopt different review formats to maximize its revenue income under different market and product conditions. Our static model limits our capability to address these issues considering the dynamic nature of such strategic interactions. Future research needs to develop dynamic models to examine these issues.

Third, one limitation of our empirical study is that it is based on only two product categories. More empirical evidences from more product categories are desirable to fully test our theory. Data from more product categories will not only test the generality of our theoretical findings but will also allow the examination of the impact of product characteristics on firms' advertising response to third-party product reviews. Furthermore, it is important to develop appropriate measurements for the degree to which consumers are taste driven vs. quality driven for a given product. Finally, it is desirable for future empirical studies to collect data on additional control variables such as the number of new products launched, the third-party reviewer's market share, and manufacturing firms' financial performance.

There are many other interesting questions that might be addressed in future research. For instance, what can a firm do to increase the chance of obtaining a favorable third-party review? How do consumers process information from multiple simultaneous product reviews? Finally, what are the strategic impacts of other types of independent product information, such as reviews posted by consumers?

Appendix

Summary of Notations

j Seller, $j = H, L$

t $t = 0, r, d$ (0: without review; r: recommendation format; d: description format).

α_t^j Advertising reach level of seller j in the reviewer's publication in t

ϕ_t^j Advertising reach level of seller j in other media in t

P_t^j Price of the seller j in t

π_t^j Profit of the seller j in t

D_t^j Demand of the seller j in t

c^L Marginal cost of seller L (c^L is normalized to 0)

c^H Marginal cost of seller H (c^H is normalized to c)

$g(\cdot)$ Advertising cost for an advertising reach level

γ Advertising cost coefficient

λ Penetration rate of the third-party product review

σ The percentage of the reviewer's publication subscribers

θ The percentage of price-insensitive consumers

$\bar{v}$ Consumers' evaluation on their preferred product

$\underline{v}$ Price-sensitive consumers' evaluation on their non-preferred product

μ The percentage of the taste-driven segment

τ The percentage of taste-driven consumers with matched taste with L

A_t The size of consumers who receive product information only from H's advertising in t

B_t The size of consumers who receive product information only from both firms' advertising in t

E_t The size of consumers who receive product information only from L's advertising in t

R_t The size of consumers who read review information in t

q^H The fraction of consumers who correctly identify H to be high quality among those receiving ads only from H in the absence of review

q^L The fraction of consumers who incorrectly identify L to be high quality among those receiving ads only from L in the absence of review

q The fraction of consumers who correctly identify H to be high quality among those receiving ads from both firms in the absence of review

ρ^H The fraction of consumers who consider H to be preferred among those receiving ads only from H in the absence of review

ρ^L The fraction of consumers who consider L to be preferred among those receiving ads only from L in the absence of review

ρ The fraction of consumers who consider H to be preferred among those receiving ads from both firms in the absence of review

η The fraction of consumers who consider H to be preferred among those read review

Equilibrium Analysis in the Absence of Product Review

In following, we derive conditions under which equal-price, $\{P_0^H = P_0^L = \bar{v}\}$, is an equilibrium.

In the absence of product reviews, firm H's potential demand comes from two segments: (1) the loyal consumers, l_0^H, who only buy H, and (2) the switchers, s_0^H, who will buy H if H provides a higher positive surplus than L. H's loyals, l_0^H, include price-insensitive consumers who receive advertising from both firms and consider H as the preferred product (case 7 in Table 2), and all consumers who receive advertising only from H and consider H as the preferred product (case 4 in Table 2). Note that $\underline{v} \leq c$, and

it is not profitable for H to cut its price to attract price-sensitive consumers who do not prefer H (case 6 and case 10 in Table 2). Hence, the switchers, s_0^H, are the price-sensitive consumers who receive advertising from both firms and consider H as the preferred product (case 8 in Table 2). From Table 2, l_0^H and s_0^H are given in the following equations:

$$l_0^H = \theta\rho B_0 + \rho^H A_0, \qquad (A.1)$$

$$s_0^H = (1-\theta)\rho B_0. \qquad (A.2)$$

There are three segments of consumers who might buy L: (1) all informed consumers who consider L as a preferred product, l_0^L (cases 1, 9, and 10 in Table 2), (2) price-sensitive consumers who receive advertising only from L but consider L as a nonpreferred product, $l_0^{L'}$ (case 3 in Table 2), and (3) the switchers, s_0^H (case 8 in Table 2). Similar to s_0^H, $l_0^{L'}$ will buy from L only when L's price is below $\underline{v}$. However, s_0^H might still choose H if they receive a higher from H than from L, while $l_0^{L'}$ will always choose L as long as L's price is below $\underline{v}$. From Table 2, l_0^L and $l_0^{L'}$ are given in the following equations:

$$l_0^L = (1-\rho)B_0 + \rho^L E_0, \qquad (A.3)$$

$$l_0^{L'} = (1-\theta)(1-\rho^L)E_0. \qquad (A.4)$$

When both firms charge a price of $\bar{v}$, their profits are

$$\pi_0^H(P_0^H = P_0^L = \bar{v}) = (l_0^H + s_0^H)(\bar{v}-c) - g(\alpha_0^H)$$
$$= (\rho B_0 + \rho^H A_0)(\bar{v}-c) - g(\alpha_0^H), \quad (A.5)$$

$$\pi_0^L(P_0^H = P_0^L = \bar{v}) = l_0^L\bar{v} - g(\alpha_0^L)$$
$$= [(1-\rho)B_0 + \rho^L E_0]\bar{v} - g(\alpha_0^L). \quad (A.6)$$

If L decides to cut its price below $\underline{v}$ to attract the switchers from H, the maximum of profit to gain is

Max $\pi_0^L(P_0^L \le \underline{v})$
$$= (l_0^L + s_0^H + l_0^{L'})\underline{v} - g(\alpha_0^L)$$
$$= ((1-\theta\rho)B_0 + [\rho^L + (1-\rho^L)(1-\theta)]E_0)\underline{v} - g(\alpha_0^L). \quad (A.7)$$

Note that q can be a function of both firms' advertising effectiveness, i.e., $q = f(q^H, q^L)$, where $\partial q/\partial q^H > 0$, $\partial q/\partial q^L < 0$, $q < q^H$, and $1-q < q^L$. From (A.6) and (A.7), when $q^H \le \hat{q}^H$ or $q^L \ge \hat{q}^L$, $\pi_0^L(P_0^H = P_0^L = \bar{v}) \ge$ Max $\pi_0^L(P_0^L \le \underline{v})$, and $P_0^{H*} = P_0^{L*} = \bar{v}$ is the unique price equilibrium, where $\hat{q}^H$ and $\hat{q}^L$ satisfy the following relationship:

$$f(q^H, q^L) - \frac{B_0(\bar{v}-\underline{v}) - E_0(1-\theta)\underline{v}}{(1-\mu)B_0(\bar{v}-\theta\underline{v})} - \frac{E_0}{B_0}q^L$$
$$- \frac{\mu}{1-\mu}\left[\tau\frac{E_0}{B_0} - (1-\tau)\right] = 0. \qquad (A.8)$$

Both sellers maximize their profits with respect to advertising. According to (A.5) and (A.6), the first-order conditions are

$$\partial\pi_0^H/\partial\alpha_0^H = 0 \Rightarrow ((1-\alpha_0^L)\rho^H + \alpha_0^L\rho)(\bar{v}-c) - \gamma/(1-\alpha_0^H) = 0, \qquad (A.9)$$

$$\partial\pi_0^L/\partial\alpha_0^L = 0 \Rightarrow ((1-\alpha_0^H)\rho^L + \alpha_0^H(1-\rho))\bar{v} - \gamma/(1-\alpha_0^L) = 0. \qquad (A.10)$$

It is straightforward that both second-order conditions are negative. Solutions of Equations (A.9) and (A.10), α_0^{H*} and α_0^{L*}, are the equilibrium advertising reach levels when $q^H \le \hat{q}^H$ or $q^L \ge \hat{q}^L$.

Therefore, when $q^H \le \hat{q}^H$ or $q^L \ge \hat{q}^L$, i.e., when the high-quality firm's advertising cannot sufficiently convey quality information to consumers, or when the low-quality firm's advertising is sufficiently misleading, $(\alpha_0^{H*}, \alpha_0^{L*}; P_0^{H*} = P_0^{L*} = \bar{v})$ is the SPNE for the model. $\square$

Proof of Proposition 1
Similar to the case in the absence of reviews, firm H's potential demand comes from two segments: (1) the loyals, l_d^H, who will buy only H, and (2) the switchers, s_d^H, who will buy H only if H's price is low enough. From Equations (4) and (5) in the paper, l_d^H and s_d^H are given in the following equations:

$$l_d^H = \theta\eta\lambda + \theta\rho B_d + \rho^H A_d, \qquad (A.11)$$

$$s_d^H = (1-\theta)(\eta\lambda + \rho B_d). \qquad (A.12)$$

Similarly, firm L's potential demand comes from three segments: (1) all informed consumers who prefer L, l_d^L, (2) price-sensitive consumers who receive advertising only from L but do not prefer L, $l_d^{L'}$, and (3) the switchers, s_d^H. l_d^L and $l_d^{L'}$ are given in the following equations:

$$l_d^L = (1-\eta)\lambda + (1-\rho)B_d + \rho^L E_d, \qquad (A.13)$$

$$l_d^{L'} = (1-\theta)(1-\rho^L)E_d. \qquad (A.14)$$

Firms' profits, when charging a price of $\bar{v}$, are

$$\pi_d^H(P_d^H = P_d^L = \bar{v}) = (l_d^H + s_d^H)(\bar{v}-c) - g(\alpha_d^H)$$
$$= (\eta\lambda + \rho B_d + \rho^H A_d)(\bar{v}-c)$$
$$- g(\alpha_d^H); \qquad (A.15)$$

$$\pi_d^L(P_d^H = P_d^L = \bar{v}) = l_d^L\bar{v} - g(\alpha_d^L)$$
$$= [(1-\eta)\lambda + (1-\rho)B_d + \rho^L E_d]\bar{v}$$
$$- g(\alpha_d^L). \qquad (A.16)$$

If firm L decides to cut its price below $\underline{v}$ to attract the switchers from firm H, the maximum of profit to gain is

$$\text{Max } \pi_d^L(P_d^L \le \underline{v}) = (l_d^L + s_d^H + l_d^{L'})\underline{v} - g(\alpha_d^L)$$
$$= ((1-\theta\eta)\lambda + (1-\theta\rho)B_d$$
$$+ [\rho^L + (1-\rho^L)(1-\theta)]E_d)\underline{v}$$
$$- g(\alpha_d^L). \qquad (A.17)$$

Therefore, Max $\pi_d^L(P_d^L \le \underline{v}) \le \pi_d^L(P_d^H = P_d^L = \bar{v})$ when $\mu \ge \hat{\mu}_d$, where

$$\hat{\mu}_d = 1 - \frac{\frac{\bar{v}-\underline{v}}{\bar{v}-\theta\underline{v}} + \frac{B_d(\bar{v}-\underline{v}) + E_d[\tau\bar{v} - (1-\theta+\tau\theta)\underline{v}]}{\lambda(\bar{v}-\theta\underline{v})} + \frac{B_d(1-\tau)}{\lambda} - (1-\tau)}{\tau - (B_d(q+\tau-1) + E_d[q^L - \tau])/\lambda}. \qquad (A.18)$$

The firm L has no incentive to undercut to attract switcher from firm H. The pricing equilibrium is $P_d^{H*} = P_d^{L*} = \bar{v}$. Hence, both firms do not adjust pricing when $\mu \ge \hat{\mu}_d$.

According to (A.15) and (A.16), the first-order conditions are

$$\partial \pi_d^H / \partial \alpha_d^H = 0 \Rightarrow (1-\lambda)((1-\alpha_d^L)\rho^H + \alpha_d^L \rho)(\bar{v}-c)$$
$$- \gamma/(1-\alpha_d^H) = 0, \qquad (A.19)$$

$$\partial \pi_d^L / \partial \alpha_d^L = 0 \Rightarrow (1-\lambda)((1-\alpha_d^H)\rho^L + \alpha_d^H(1-\rho))\bar{v}$$
$$- \gamma/(1-\alpha_d^L) = 0. \qquad (A.20)$$

From (A.9), (A.10), (A.19), and (A.20), we find that α_0^{H*} and α_d^{H*} are the solutions of the function $a(\alpha^H)^2 + b\alpha^H + e = 0$, where $a = \Omega(\bar{v}-c)\bar{v}[1-(\rho^H-\rho)][\rho^L-(1-\rho)]$, $b = -\gamma(\rho^H-\rho)(\bar{v}-c) - \Omega(\bar{v}-c)\bar{v}[1-(\rho^H-\rho)](\rho^L+\rho) + \gamma[\rho^L-(1-\rho)]\bar{v}$, and $e = \Omega(\bar{v}-c)\bar{v}[1-(\rho^H-\rho)] + \gamma(\bar{v}-c) \cdot (\rho^H-\rho) - \gamma\bar{v}$. Let $\Delta = b^2 - 4ae$. Then $\alpha^{H*} = (-b-\sqrt{\Delta})/2a$. $\alpha_0^{H*} = \alpha^{H*}|_{\Omega=1}$ and $\alpha_d^{H*} = \alpha^{H*}|_{\Omega=1-\lambda}$. Notice $\partial \alpha^{H*}/\partial\Omega = [(\bar{v}-c)[1-(\rho^H-\rho)](1-[\rho^L-(1-\rho)]\alpha^{H*})(1-\alpha^{H*})]/\sqrt{\Delta} > 0$. Because $1-\lambda < 1$, $\alpha_d^{H*} < \alpha_0^{H*}$. Also note that advertising cost function $g(\alpha_t^j)$ is increasing in α_t^j. Hence $g(\alpha_d^{H*}) < g(\alpha_0^{H*})$. Similarly, we can show $\alpha_d^{L*} < \alpha_0^{L*}$ and $g(\alpha_d^{L*}) < g(\alpha_0^{L*})$. Proposition 1 holds. $\square$

Proof of Propositions 2 and 3

In the presence of the recommendation review, in the subgame where H does not use review-endorsed advertising, the pricing and advertising equilibria are the same as those in the description review case.

In the presence of the recommendation review, in the subgame where H adopts review-endorsed advertising, similarly to previous cases, firm H's potential demand comes from two segments: (1) the loyals, l_r^H, and (2) the switchers, s_r^H. From Equations (6) and (7) in the paper, l_r^H and s_r^H are given in the following equations:

$$l_r^H = \theta\eta(\lambda + B_r) + \eta A_r, \qquad (A.21)$$

$$s_r^H = (1-\theta)\eta(\lambda + B_r). \qquad (A.22)$$

Firm L's possible demand comes from three segments: (1) informed consumers who prefer L, l_r^L, (2) price-sensitive consumers who receive advertising only from L but do not prefer L, $l_r^{L\prime}$, and (3) switchers s_r^H. l_r^L and $l_r^{L\prime}$ are given in the following equations:

$$l_r^L = (1-\eta)(\lambda + B_r) + \rho^L E_r, \qquad (A.23)$$

$$l_r^{L\prime} = (1-\theta)(1-\rho^L)E_r. \qquad (A.24)$$

Firms' profits, when charging a price of $\bar{v}$, are

$$\pi_r^H(P_r^H = P_r^L = \bar{v}) = (l_r^H + s_r^H)(\bar{v}-c) - g(\alpha_r^H)$$
$$= \eta(\lambda + B_r + A_r)(\bar{v}-c) - g(\alpha_r^H), \qquad (A.25)$$

$$\pi_r^L(P_r^H = P_r^L = \bar{v}) = \bar{v}l_r^L - g(\alpha_r^L)$$
$$= [(1-\eta)(\lambda + B_r) + \rho^L E_r]\bar{v} - g(\alpha_r^L). \qquad (A.26)$$

Firm L's maximum profit when cutting its price is

$$\text{Max } \pi_r^L(P_r^L \leq \underline{v}) = \underline{v}(l_r^L + l_r^{L\prime} + s_r^H) - g(\alpha_r^L). \qquad (A.27)$$

From (A.26) and (A.27), when $\mu \geq \hat{\mu}_r$, $\pi_r^L(P_r^H = P_r^L = \bar{v}) \geq \text{Max } \pi_r^L(P_r^L = \underline{v})$, where

$$\hat{\mu}_r = 1 - \frac{\frac{\bar{v}-\underline{v}}{\bar{v}-\theta\underline{v}} + \frac{E_r[\tau\bar{v}-(1-\theta+\tau\theta)\underline{v}]}{(\lambda + B_r)(\bar{v}-\theta\underline{v})} - (1-\tau)}{\tau - (E_r[q^L - \tau])/(\lambda + B_r)}. \qquad (A.28)$$

Therefore, both firms maintain the same price of $\bar{v}$ when $\mu \geq \hat{\mu}_r$, provided that firm H adopts review-endorsed advertising.

According to (A.25) and (A.26), the first-order conditions are

$$\partial \pi_r^H / \partial \alpha_r^H = 0 \Rightarrow (1-\lambda)\eta(\bar{v}-c) - \gamma/(1-\alpha_r^H) = 0, \quad (A.29)$$

$$\partial \pi_r^L / \partial \alpha_r^L = 0 \Rightarrow (1-\lambda)[(1-\alpha_r^H)\rho^L + \alpha_r^H(1-\eta)]\bar{v}$$
$$- \gamma/(1-\alpha_r^L) = 0. \qquad (A.30)$$

Both second-order conditions are negative. Firms' optimal advertising reach levels after the publication of the recommendation format review are given in the following equations:

$$\alpha_r^{H*} = 1 - \gamma/((1-\lambda)\eta(\bar{v}-c)), \qquad (A.31)$$

$$\alpha_r^{L*} = 1 - \gamma \bigg/ \left((1-\eta)(1-\lambda) + \frac{\gamma(\rho^L - 1 + \eta)}{\eta(\bar{v}-c)}\right)\bar{v}. \qquad (A.32)$$

From (A.9) and (A.29), we have $\alpha_r^{H*} \geq \alpha_0^{H*}$ and $g(\alpha_r^{H*}) \geq g(\alpha_0^{H*})$ if $\lambda \leq \lambda^*$, and $\alpha_r^{H*} < \alpha_0^{H*}$; and $g(\alpha_r^{H*}) < g(\alpha_0^{H*})$ otherwise, where $\lambda^* = 1 - [(1-\alpha_0^{L*})\rho^H + \alpha_0^{L*}\rho]/\eta$. From (A.32), we know $\partial\alpha_r^{L*}/\partial\lambda < 0$. The maximum of α_r^{L*}, $\bar{\alpha}_r^{L*} = \alpha_r^{L*}|_{\lambda=0}$. Notice $\alpha_r^{H*}|_{\lambda=0} > \alpha_0^{H*}$ because $\lambda = 0 \leq \lambda^*$. From (A.10) and (A.30), given $\partial\pi_r^L/\partial\alpha_r^L|_{\alpha_r^H=\alpha_r^{H*}|_{\lambda=0}, \alpha_r^L=\bar{\alpha}_r^{L*}} = 0$, we know $\partial\pi_0^L/\partial\alpha_0^L|_{\alpha_0^L=\bar{\alpha}_r^{L*}} = \partial\pi_0^L/\partial\alpha_0^L|_{\alpha_0^L=\bar{\alpha}_r^{L*}} - \partial\pi_r^L/\partial\alpha_r^L|_{\alpha_r^H=\alpha_r^{H*}|_{\lambda=0}, \alpha_r^L=\bar{\alpha}_r^{L*}} = \bar{v}[(\alpha_r^{H*}|_{\lambda=0}[\rho^L-(1-\eta)] - \alpha_0^{H*}[\rho^L-(1-\rho)])] > 0$. Notice $\partial\pi_0^L/\partial\alpha_0^L|_{\alpha_0^L=\alpha_0^{L*}} = 0$. Hence, $\partial\pi_0^L/\partial\alpha_0^L|_{\alpha_0^L=\alpha_0^{L*}} = 0 < \partial\pi_0^L/\partial\alpha_0^L|_{\alpha_0^L=\bar{\alpha}_r^{L*}}$. Because $\partial^2\pi_0^L/\partial(\alpha_0^L)^2 < 0$, we have $\alpha_0^{L*} > \bar{\alpha}_r^{L*} \geq \alpha_r^{L*}$. Therefore, $g(\alpha_r^{L*}) < g(\alpha_0^{L*})$; hence Proposition 3(iii) holds.

Given equilibrium levels α_r^{j*}, from (A.18) and (A.28) we find $\hat{\mu}_r^* = \hat{\mu}_r|_{\alpha_r^j=\alpha_r^{j*}} \geq \hat{\mu}_d|_{\alpha_d^j=\alpha_r^{j*}}$. Hence $\Delta\pi_d^L|_{\mu=\hat{\mu}_r^*, \alpha_d^j=\alpha_r^{j*}} = \pi_d^L(P_d^H = P_d^L = \bar{v})|_{\mu=\hat{\mu}_r^*, \alpha_d^j=\alpha_r^{j*}} - \text{Max } \pi_d^L(P_d^L \leq \underline{v})|_{\mu=\hat{\mu}_r^*, \alpha_d^j=\alpha_r^{j*}} > 0$. Notice $\partial B_d/\partial\alpha_d^L > 0$, $\partial B_d/\partial\alpha_d^H > 0$, $\partial E_d/\partial\alpha_d^L > 0$, and $\partial E_d/\partial\alpha_d^H < 0$. Therefore, $\partial\Delta\pi_d^L/\partial\alpha_d^L > 0$, and $\partial\Delta\pi_d^L/\partial\alpha_d^H = (1-\lambda)\alpha_d^L(1-\rho-\rho^L)(1-\theta)(\bar{v}-\underline{v}) < 0$. From (A.19) and (A.29) we find the marginal advertising cost $g'(\cdot)|_{\alpha_r^{H*}} > g'(\cdot)|_{\alpha_d^{H*}}$ noticing $\eta > (1-\alpha_d^L)\rho^H + \alpha_d^L\rho$. Because $g''(\cdot) > 0$, we have $\alpha_r^{H*} > \alpha_d^{H*}$. Similarly, from (A.20) and (A.30), we have $\alpha_r^{L*} < \alpha_d^{L*}$. Therefore, $\Delta\pi_d^L|_{\mu=\hat{\mu}_r^*, \alpha_d^j=\alpha_d^{j*}} > \Delta\pi_d^L|_{\mu=\hat{\mu}_r^*, \alpha_d^j=\alpha_r^{j*}} > 0$. Hence $\text{Max } \pi_d^L(P_d^L \leq \underline{v})|_{\mu=\hat{\mu}_r^*, \alpha_d^j=\alpha_d^{j*}} < \pi_d^L(P_d^H = P_d^L = \bar{v})|_{\mu=\hat{\mu}_r^*, \alpha_d^j=\alpha_d^{j*}}$. Therefore, the threshold level for L's price cut is higher if H adopts the review-endorsed ads than if H does not adopt (i.e., $\hat{\mu}_r \geq \hat{\mu}_d$ in the equilibrium). Hence Proposition 2(i) holds.

Note $\hat{\mu}_r \geq \hat{\mu}_d$. Therefore, when $\mu \geq \hat{\mu}_r$, $P_r^{H*} = P_r^{L*} = \bar{v}$ is the SPNE pricing equilibrium of the three-stage game; hence Proposition 3(i) holds.

From (A.15) and (A.25) it is straightforward that $\pi_r^H(P_r^H = P_r^L = \bar{v})|_{\alpha_r^H=\alpha_d^{H*}} \geq \pi_d^H(P_d^H = P_d^L = \bar{v})|_{\alpha_d^H=\alpha_d^{H*}}$. Note $\pi_r^{H*} = \pi_r^H(P_r^H = P_r^L = \bar{v})|_{\alpha_r^H=\alpha_r^{H*}} \geq \pi_r^H(P_r^H = P_r^L = \bar{v})|_{\alpha_r^H=\alpha_d^{H*}}$. We have $\pi_r^{H*} = \pi_r^H(P_r^H = P_r^L = \bar{v})|_{\alpha_r^H=\alpha_d^{H*}} \geq \pi_d^H(P_d^H = P_d^L = \bar{v})|_{\alpha_d^H=\alpha_d^{H*}} = \pi_d^{H*}$. Therefore, when $\mu \geq \hat{\mu}_r$, H always adopts review-endorsed advertising. Proposition 3(ii) holds.

In the following, we prove Proposition 2(ii) by showing a sufficient condition for the case when firm H is less profitable to adopt the review-endorsed advertising, i.e., $\pi_r^{H*} \leq \pi_d^{H*}$.

In the absence of product review, it is reasonable to assume that if all consumers receive advertising from both firms, there is enough uncertainty about product quality and L's advertising is sufficiently persuasive such that a significant number of quality-driven consumers would misperceive L as the high-quality product. Specifically, in the absence of product review, ρ^L is sufficiently high, i.e., $\rho^L > (1-\theta)\underline{v}/(\bar{v}-\theta\underline{v})$, such that it is more profitable for firm L to charge a high price $\bar{v}$ than to cut price to $\underline{v}$ to attract switchers, i.e., $\rho^L\bar{v} > [\rho^L + (1-\rho^L)(1-\theta)]\underline{v}$.

In the subgame where firm H adopts the review-endorsed advertising, when $\mu < \hat{\mu}_r$, firm L has incentive to cut price to attract switchers from firm H. We find $(l_r^L + l_r^{L'})\underline{v} = ((1-\eta)(\lambda + B_r) + \rho^L E_r + (1-\rho^L)(1-\theta)E_r)\underline{v} \leq (1-\eta)(\lambda + B_r)\underline{v} + \rho^L E_r\bar{v} < ((1-\eta)(\lambda + B_r) + \rho^L E_r)\bar{v} = l_r^L\bar{v}$. Hence, when $\mu \geq \hat{\mu}_r$, firm L makes trade-offs between pricing at $\bar{v}$ to capture the surplus from its loyal segment of l_r^L and pricing below $\underline{v}$ to sell to $l_r^L + l_r^{L'} + s_r^H$ consumers. The lower boundary $(\hat{P}_r^L)$ for L's price support happens when $\hat{P}_r^L(l_r^L + l_r^{L'} + s_r^H) = l_r^L\bar{v}$, i.e., $\hat{P}_r^L = l_r^L\bar{v}/(l_r^L + l_r^{L'} + s_r^H)$. Firm H makes trade-offs between pricing at $\bar{v}$ to capture the surplus from its loyal segment of l_r^H and pricing below $\bar{v}$ to sell to $l_r^H + s_r^H$ consumers. The lower boundary $(\hat{P}_r^H)$ for H's price support happens when $(\hat{P}_r^H - c)(l_r^H + s_r^H) = l_r^H(\bar{v} - c)$, i.e., $\hat{P}_r^H = l_r^H(\bar{v} - c)/(l_r^H + s_r^H) + c$.

When $\bar{\mu}_r \leq \mu < \hat{\mu}_r$, $\underline{v} - \hat{P}_r^L \leq \bar{v} - \hat{P}_r^H$, i.e., $\hat{P}_r^H \leq \tilde{P}_r^H = \hat{P}_r^L + (\bar{v} - \underline{v})$, where

$$\bar{\mu}_r = 1 - \frac{(\lambda + B_r)\frac{\bar{v} - \hat{P}_r^L}{\bar{v} - \theta\hat{P}_r^L} - \frac{E_r(1-\theta)\hat{P}_r^L}{\bar{v} - \theta\hat{P}_r^L} + E_r\tau - (1-\tau)(\lambda + B_r)}{(\lambda + B_r)\tau - (E_r[q^L - \tau])}. \quad \text{(A.33)}$$

Firm H can price a little bit below $\tilde{P}_r^H$ to undercut firm L's price $\hat{P}_r^L$ and obtain the entire segment of s_r^H, for a total profit of $(\tilde{P}_r^H - c)(l_r^H + s_r^H)$. Note that prices $P_r^L \in (\underline{v}, \bar{v})$ attract only loyal consumers and hence are inferior to $\bar{v}$. Firm L randomizes its prices in the strategy set $[\hat{P}_r^L, \underline{v}] \cup \bar{v}$ to achieve the equilibrium expected profit (before advertising cost) $l_r^L\bar{v}$. Firm H randomizes its prices in the strategy set $[\tilde{P}_r^H, \bar{v}]$ to achieve the equilibrium expected profit (before advertising cost) $(\tilde{P}_r^H - c)(l_r^H + s_r^H)$.

The equilibrium expected profits for both firms are

$$E\hat{\pi}_r^H = (\tilde{P}_r^H - c)(l_r^H + s_r^H) - g(\alpha_r^H), \quad \text{(A.34)}$$

$$E\hat{\pi}_r^L = \bar{v}l_r^L - g(\alpha_r^L). \quad \text{(A.35)}$$

For $\bar{\mu}_r \leq \mu < \hat{\mu}_r$, from (A.15) and (A.34) we find when $\mu' < \mu \leq \mu_0$, $\pi_r^{H*} = E\hat{\pi}_r^{H*} > \pi_d^{H*}$. When $\mu > \mu_0$ or $\bar{\mu}_r < \mu \leq \mu'$, $\pi_r^{H*} = E\hat{\pi}_r^{H*} \leq \pi_d^{H*}$, where $\mu_0 = 1 - (b_\eta - \sqrt{\Delta_\eta})/2a_\eta$, and

$$\mu' = 1 - \left(b_\eta + \sqrt{\Delta_\eta}\right)/2a_\eta, \quad \text{(A.36)}$$

where $a_\eta = N_2\tau[\bar{v}(E_r q^L - \tau N_1) + (\bar{v} - \underline{v} - c)\theta[q^L E_r - \tau N_1]] - \theta[q^L E_r - \tau N_1](\bar{v} - c)(\lambda + B_d q + A_d q^H - (1-\tau)N_3)$, $b_\eta = \bar{v}[(E_r q^L - \tau N_1)N_2(1-\tau) + \tau^2 N_1 N_2] + (\bar{v} - \underline{v} - c)(N_1(1 - \theta(1-\tau))N_2\tau + \theta[q^L E_r - \tau N_1]N_2(1-\tau)) - \theta[q^L E_r - \tau N_1]((1-\tau) \cdot N_3(\bar{v} - c) - g(\alpha_d^H) + g(\alpha_r^H)) - N_1(1 - \theta(1-\tau))(\bar{v} - c)(\lambda + B_d q + A_d q^H - (1-\tau)N_3)$, $e_\eta = N_2(1-\tau)[\bar{v}\tau N_1 + (\bar{v} - \underline{v} - c)N_1(1 - \theta + \theta\tau)] - N_1(1 - \theta + \theta\tau)((1-\tau)N_3(\bar{v} - c) - g(\alpha_r^L) + g(\alpha_r^H))$, $\Delta_\eta = b_\eta^2 - 4a_\eta e_\eta$, $N_0 = (\bar{v} - \underline{v} - c)$, $N_1 = \lambda + B_r + E_r$, $N_2 = \lambda + B_r + A_r$, $N_3 = \lambda + B_d + A_d$. When $\mu = \hat{\mu}_r$, $\pi_d^{H*} < E\hat{\pi}_r^H = \pi_r^H(P_r^H = P_r^L =$

$\bar{v})$. Therefore $\mu_0 > \hat{\mu}_r$. Hence for $\bar{\mu}_r \leq \mu \leq \mu'$, $\pi_r^{H*} = E\hat{\pi}_r^H \leq \pi_d^{H*}$, and it is less profitable for firm H to adopt the review-endorsed advertising. Proposition 2(ii) holds. $\square$

Proof of Proposition 4
In the absence of product review, the sizes of informed consumer groups are

$$\text{Size:} \begin{cases} E_{0m} = \sigma\alpha_{0m}^L(1 - \alpha_{0m}^H) + (1-\sigma)\phi_{0m}^L(1 - \phi_{0m}^H) \\ \quad \text{reached only by } L\text{'s advertising,} \\ A_{0m} = \sigma\alpha_{0m}^H(1 - \alpha_{0m}^L) + (1-\sigma)\phi_{0m}^H(1 - \phi_{0m}^L) \\ \quad \text{reached only by } H\text{'s advertising,} \\ B_{0m} = \sigma\alpha_{0m}^H\alpha_{0m}^L + (1-\sigma)\phi_{0m}^H\phi_{0m}^L \\ \quad \text{reached by both firms' advertising.} \end{cases} \quad \text{(A.37)}$$

Similar to the proof of the Proposition 1, the profits of firm H and L when they charge prices at $\bar{v}$ are

$$\pi_{0m}^H(P_{0m}^H = P_{0m}^L = \bar{v})$$
$$= (l_{0m}^H + s_{0m}^H)(\bar{v} - c) - g(\alpha_{0m}^H) - g(\phi_{0m}^H)$$
$$= (\rho B_{0m} + \rho^H A_{0m})(\bar{v} - c) - g(\alpha_{0m}^H) - g(\phi_{0m}^H), \quad \text{(A.38)}$$
$$\pi_{0m}^L(P_{0m}^H = P_{0m}^L = \bar{v})$$
$$= l_{0m}^L\bar{v} - g(\alpha_{0m}^L) - g(\phi_{0m}^L)$$
$$= [(1-\rho)B_{0m} + \rho^L E_{0m}]\bar{v} - g(\alpha_{0m}^L) - g(\phi_{0m}^L). \quad \text{(A.39)}$$

The first-order conditions are

$$\partial\pi_{0m}^H/\partial\alpha_{0m}^H = 0 \Rightarrow \sigma((1 - \alpha_{0m}^L)\rho^H + \alpha_{0m}^L\rho)(\bar{v} - c)$$
$$- \gamma/(1 - \alpha_{0m}^H) = 0, \quad \text{(A.40)}$$
$$\partial\pi_{0m}^L/\partial\alpha_{0m}^L = 0 \Rightarrow \sigma((1 - \alpha_{0m}^H)\rho^L + \alpha_{0m}^H(1 - \rho))\bar{v}$$
$$- \gamma/(1 - \alpha_{0m}^L) = 0, \quad \text{(A.41)}$$
$$\partial\pi_{0m}^H/\partial\phi_{0m}^H = 0 \Rightarrow (1-\sigma)((1 - \phi_{0m}^L)\rho^H + \phi_{0m}^L\rho)(\bar{v} - c)$$
$$- \gamma/(1 - \phi_{0m}^H) = 0, \quad \text{(A.42)}$$
$$\partial\pi_{0m}^L/\partial\phi_{0m}^L = 0 \Rightarrow (1-\sigma)((1 - \phi_{0m}^H)\rho^L + \phi_{0m}^H(1 - \rho))\bar{v}$$
$$- \gamma/(1 - \phi_{0m}^L) = 0. \quad \text{(A.43)}$$

It is straightforward that all second-order conditions are negative. Solutions of Equations (A.40), (A.41), (A.42), and (A.43), α_{0m}^{H*}, α_{0m}^{L*}, ϕ_{0m}^{H*}, and ϕ_{0m}^{L*}, are the equilibrium advertising reach levels.

In the presence of the description review, the sizes of informed consumer groups are

$$\text{Size:} \begin{cases} E_{dm} = \sigma(1 - \lambda)\alpha_{dm}^L(1 - \alpha_{dm}^H) + (1-\sigma)\phi_{dm}^L(1 - \phi_{dm}^H) \\ \quad \text{reached only by } L\text{'s advertising,} \\ A_{dm} = \sigma(1 - \lambda)\alpha_{dm}^H(1 - \alpha_{dm}^L) + (1-\sigma)\phi_{dm}^H(1 - \phi_{dm}^L) \\ \quad \text{reached only by } H\text{'s advertising,} \\ B_{dm} = \sigma(1 - \lambda)\alpha_{dm}^H\alpha_{dm}^L + (1-\sigma)\phi_{dm}^H\phi_{dm}^L \\ \quad \text{reached only by both firms' advertising,} \\ R_{dm} = \sigma\lambda \quad \text{reached by product review.} \end{cases} \quad \text{(A.44)}$$

Similar to the proof of Proposition 1, the profits of H and L, when both firms charge the same price at $\bar{v}$, are

$$\pi_{dm}^H(P_{dm}^H = P_{dm}^L = \bar{v})$$
$$= (l_{dm}^H + s_{dm}^H)(\bar{v} - c) - g(\alpha_{dm}^H) - g(\phi_{dm}^H)$$
$$= (\eta\sigma\lambda + \rho B_{dm} + \rho^H A_{dm})(\bar{v} - c)$$
$$- g(\alpha_{dm}^H) - g(\phi_{dm}^H), \qquad (A.45)$$

$$\pi_{dm}^L(P_{dm}^H = P_{dm}^L = \bar{v})$$
$$= l_{dm}^L \bar{v} - g(\alpha_{dm}^L) - g(\phi_{dm}^L)$$
$$= [(1-\eta)\sigma\lambda + (1-\rho)B_{dm} + \rho^L E_{dm}]\bar{v}$$
$$- g(\alpha_{dm}^L) - g(\phi_{dm}^L). \qquad (A.46)$$

According to (A.45) and (A.46), the first-order conditions are

$$\partial\pi_{dm}^H/\partial\alpha_{dm}^H = 0 \Rightarrow \sigma(1-\lambda)((1-\alpha_{dm}^L)\rho^H + \alpha_{dm}^L\rho)(\bar{v}-c)$$
$$- \gamma/(1-\alpha_{dm}^H) = 0, \qquad (A.47)$$
$$\partial\pi_{dm}^L/\partial\alpha_{dm}^L = 0 \Rightarrow \sigma(1-\lambda)((1-\alpha_{dm}^H)\rho^L + \alpha_{dm}^H(1-\rho))\bar{v}$$
$$- \gamma/(1-\alpha_{dm}^L) = 0, \qquad (A.48)$$
$$\partial\pi_{dm}^H/\partial\phi_{dm}^H = 0 \Rightarrow (1-\sigma)((1-\phi_{dm}^L)\rho^H + \phi_{dm}^L\rho)(\bar{v}-c)$$
$$- \gamma/(1-\phi_{dm}^H) = 0, \qquad (A.49)$$
$$\partial\pi_{dm}^L/\partial\phi_{dm}^L = 0 \Rightarrow (1-\sigma)((1-\phi_{dm}^H)\rho^L + \phi_{dm}^H(1-\rho))\bar{v}$$
$$- \gamma/(1-\phi_{dm}^L) = 0. \qquad (A.50)$$

From (A.42), (A.43), (A.49), and (A.50), it is straightforward that $\phi_{0m}^{H*} = \phi_{dm}^{H*}$ and $\phi_{0m}^{L*} = \phi_{dm}^{L*}$; hence, $g(\phi_{0m}^{H*}) = g(\phi_{dm}^{H*})$ and $g(\phi_{0m}^{L*}) = g(\phi_{dm}^{L*})$. Similar to the proof of Proposition 1, we can show $g(\alpha_{dm}^{H*}) < g(\alpha_{0m}^{H*})$ and $g(\alpha_{dm}^{L*}) < g(\alpha_{0m}^{L*})$.

In the presence of the recommendation review, in the subgame where H does not adopt review-endorsed advertising, the pricing and advertising equilibria are the same as those in the description review case.

In the presence of the recommendation review, in the subgame where H adopts review-endorsed advertising, the sizes of informed consumer groups are

$$\text{Size:}\begin{cases} E_{rm} = \sigma(1-\lambda)\alpha_{rm}^L(1-\alpha_{rm}^H) + (1-\sigma)\phi_{rm}^L(1-\phi_{rm}^H) \\ \quad\quad \text{reached only by } L\text{'s advertising,} \\ A_{rm} = \sigma(1-\lambda)\alpha_{rm}^H(1-\alpha_{rm}^L) + (1-\sigma)\phi_{rm}^H(1-\phi_{rm}^L) \\ \quad\quad \text{reached only by } H\text{'s advertising,} \\ B_{rm} = \sigma(1-\lambda)\alpha_{rm}^H\alpha_{rm}^L + (1-\sigma)\phi_{rm}^H\phi_{rm}^L \\ \quad\quad \text{reached only by both firms' advertising,} \\ R_{rm} = \sigma\lambda \quad \text{reached by product review.} \end{cases}$$
$$(A.51)$$

Similar to the proof of Propositions 2 and 3, the profits for both firms when they maintain their prices at $\bar{v}$ are

$$\pi_{rm}^H(P_{rm}^H = P_{rm}^L = \bar{v})$$
$$= (l_{rm}^H + s_{rm}^H)(\bar{v} - c) - g(\alpha_{rm}^H) - g(\phi_{rm}^H)$$
$$= \eta(\sigma\lambda + B_{rm} + A_{rm})(\bar{v} - c) - g(\alpha_{rm}^H) - g(\phi_{rm}^H), \quad (A.52)$$

$$\pi_{rm}^L(P_{rm}^H = P_{rm}^L = \bar{v})$$
$$= \bar{v} l_{rm}^L - g(\alpha_{rm}^L) - g(\phi_{rm}^L)$$
$$= [(1-\eta)(\sigma\lambda + B_{rm}) + \rho^L E_{rm}]\bar{v} - g(\alpha_{rm}^L) - g(\phi_{rm}^L). \quad (A.53)$$

According to (A.52) and (A.53), the first-order conditions are

$$\partial\pi_{rm}^H/\partial\alpha_{rm}^H = 0 \Rightarrow \sigma(1-\lambda)\eta(\bar{v}-c) - \gamma/(1-\alpha_{rm}^H) = 0, \quad (A.54)$$
$$\partial\pi_{rm}^L/\partial\alpha_{rm}^L = 0 \Rightarrow \sigma(1-\lambda)[(1-\alpha_{rm}^H)\rho^L + \alpha_{rm}^H(1-\eta)]\bar{v}$$
$$- \gamma/(1-\alpha_{rm}^L) = 0, \quad (A.55)$$
$$\partial\pi_{rm}^H/\partial\phi_{rm}^H = 0 \Rightarrow (1-\sigma)\eta(\bar{v}-c) - \gamma/(1-\phi_{rm}^H) = 0, \quad (A.56)$$
$$\partial\pi_{rm}^L/\partial\phi_{rm}^L = 0 \Rightarrow (1-\sigma)[(1-\phi_{rm}^H)\rho^L + \phi_{rm}^H(1-\eta)]\bar{v}$$
$$- \gamma/(1-\phi_{rm}^L) = 0. \quad (A.57)$$

All second-order conditions are negative.
From (A.42) and (A.56), we know

$$\frac{\partial\pi_{0m}^H}{\partial\phi_{0m}^H}\bigg|_{\phi_{0m}^H = \phi_{rm}^{H*}} = (1-\sigma)(\bar{v}-c)((1-\phi_{0m}^L)\rho^H + \phi_{0m}^L\rho - \eta) < 0$$
$$= \frac{\partial\pi_{0m}^H}{\partial\phi_{0m}^H}\bigg|_{\phi_{0m}^H = \phi_{0m}^{H*}}$$

noticing $\eta > \rho^H \geq \rho$. Because $\partial^2\pi_{0m}^H/\partial(\phi_{0m}^H)^2 < 0$, we have $\partial\pi_{0m}^L/\partial\phi_{0m}^L|_{\phi_{0m}^L = \phi_{0m}^{L*}}\phi_{rm}^{H*} > \phi_{0m}^{H*}$ and $g(\phi_{rm}^{H*}) > g(\phi_{0m}^{H*})$.

From (A.43) and (A.57),

$$\frac{\partial\pi_{0m}^L}{\partial\phi_{0m}^L}\bigg|_{\phi_{0m}^L = \phi_{rm}^{L*}}$$
$$= (1-\sigma)(\bar{v}-c)(\phi_{rm}^{H*}(\rho^L - 1 + \eta) - \phi_{0m}^{H*}(\rho^L - 1 + \rho)) > 0$$
$$= \frac{\partial\pi_{0m}^L}{\partial\phi_{0m}^L}\bigg|_{\phi_{0m}^L = \phi_{0m}^{L*}}.$$

Because $\partial^2\pi_{0m}^L/\partial(\phi_{0m}^L)^2 < 0$, we have $\phi_{rm}^{L*} < \phi_{0m}^{L*}$ and $g(\phi_{rm}^{L*}) < g(\phi_{0m}^{L*})$.

Similar to the proof of Proposition 3, we can show (i) $g(\alpha_{rm}^{L*}) < g(\alpha_{0m}^{L*})$, and (ii) $g(\alpha_{rm}^{H*}) \geq g(\alpha_{0m}^{H*})$ if $\lambda \leq \lambda_m^*$, and $\alpha_{rm}^{H*} < \alpha_{0m}^{H*}$ otherwise, where

$$\lambda_m^* = 1 - [(1-\alpha_{0m}^{L*})\rho^H + \alpha_{0m}^{L*}\rho]/\eta. \quad (A.58)$$

Proposition 4 holds. $\square$

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