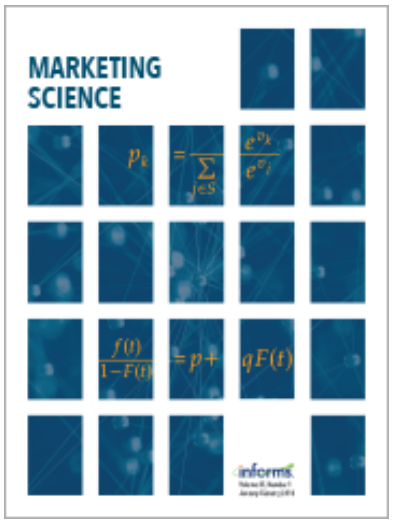

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Information Provision in a Vertically Differentiated Competitive Marketplace

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This paper examines the interaction of information provision, product quality, and pricing decisions by competitive firms to explore the following question: in a competitive market where consumers face uncertainty about product quality and/or their preference for quality, which firms—those that sell higher- or lower-quality products—have the higher incentive to provide what type of information? We find that while the higher-quality firm should always provide information resolving consumer uncertainty on product quality, the lower-quality firm under certain conditions will have the higher incentive to and will be the one to provide information resolving consumer uncertainty about their quality preferences. In the analysis, we trace the latter result to competition and to free-riding on the information provision. Specifically, in a monopoly market or when consumer free-riding is restricted by the costliness of store visits, the lower-quality firm would have a lower incentive to provide information resolving consumer preference uncertainty than otherwise. The model is also adapted to examine product returns as a possible strategy of information provision.

Key words: uncertainty; information; competitive strategy; service; free-riding; game theory; product returns
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1. Introduction

Consumer uncertainty about product valuation is an important feature of many markets. In response, competing firms may want to invest in providing information to consumers. In this paper, we analyze the general economic issue of which kind of firm, with the higher- or lower-quality products, would provide what type of information.

Consider the following motivating example. Imagine a soccer mom considering a digital camera purchase. After some research she identifies several options, among which there is a more expensive camera with 4× optical zoom and a CMOS (complementary metal oxide semiconductor) element and a cheaper camera with 3× optical zoom and a CCD (charge-coupled device) element. One can think of the following two dimensions of the uncertainty that the soccer mom is still facing in her choice. First, is a CMOS or a CCD sensor an objectively better attribute? Second, even if it is clear which camera has a better attribute, as is the case with 3× versus 4× optical zoom, how much should she desire the better option? In this example, what zoom would be useful for her to take good pictures of the soccer games (specifically, is 4× zoom better than 3× zoom by $100 for this specific use)? Whereas the first type of uncertainty is about the physical quality of a product, the second one is about the weight a consumer should place on each attribute. Resolving each type of the above uncertainty may affect the consumer's choice and, hence, a firm's profits.

If one of the sellers of the above digital cameras invests in marketing activities such as informative advertising or expert reviews that show the consumer how realistic the color reproduction and what the energy efficiency of its sensor component is, the consumer will have better knowledge of the physical quality of this seller's camera. However, this kind of information might not help her resolve uncertainty about what zoom is really needed for her to take good pictures from her regular distance to the field. If a seller offers a flexible return policy, the soccer mom would have an opportunity to use the camera to take pictures from her regular distance to the field and thus resolve her preference uncertainty. However, profit implications are not straightforward, because the consumer may either learn that the low-end camera is good enough for her, or she may be even more willing to buy the high-end product on learning her high-quality preference. Note that looking at each consumer's utility of two given products, the value of extra quality may be indistinguishable from the

quality difference. However, the difference is important in the case of heterogeneous consumers or when a consumer is learning.[1]

As noted above, a seller may either try to resolve consumer uncertainty about the features and quality of the product, e.g., through employing salespeople to show the product use, advertise certain features of the product, print clear explanations of the product's features, or use expert testimonials and provide free samples to an opinion leader. Alternatively, the seller may encourage individual consumer assessment of the product through at-home trials and other forms of direct experience.[2] Note that although trials and easy returns may also resolve uncertainty about quality, they could be more costly than revealing such uncertainty through advertising or expert reviews. The research question this paper analyzes is which firm—the one selling the higher- or lower-quality product—has a higher incentive to provide information to resolve which type of the above uncertainty. To provide managerial guidance, it is also important to understand how the decision about information provision is related to demand and competitive effects, and how information provision interacts with the firm's product and pricing decisions.

It may be fairly straightforward that the seller of the higher-quality product will try to provide information about the quality level. It is also easy to find examples of high-end firms concentrating on promotional brochures and displays that tout the objective quality of their products.[3] The strategy is less clear about helping consumers understand how much they should value quality. Returning to the example of digital cameras, Table 1 shows that the lower-end retailers, such as Target, OfficeMax, and Walmart, may actually be allowing more flexible returns of digital cameras than the higher-end retailers, such as Best Buy and Circuit City.[4] As Messinger and Qiu (2007) argue, a seller may use a flexible product-return policy, rentals, or used markets for the purpose of resolving the idiosyncratic consumer preference uncertainty.[5]

Table 1 Digital Camera Return Terms Across Major Consumer Electronics Firms

Name	Return deadline	Restocking fee (%)
Best Buy	14 days	15
Circuit City	14 days	15
RadioShack	30 days	0
OfficeMax	14 days	0
Target	90 days	15
Walmart	30 days	0

Notes. In this category, Best Buy has the highest market share and, among the retailers in the table, the highest average quality in the U.S. market. Circuit City has the second-highest market share. This table is current as of May 2008.

To answer these questions, we develop a model of a competitive market with two firms competing for consumers heterogeneous in their preference for quality and having uncertainty about the product quality, their preference for quality, or both. Firms can provide relevant information to resolve one or both types of consumer uncertainty (for example, consumer returns to resolve uncertainty about quality preference, informative advertising to determine uncertainty about physical product quality).

As expected, we find that the high-end firm should always provide information resolving consumer

[1] In an empirical setting, the difference between quality and preference-for-quality uncertainty and consumer learning has been explored as uncertainty about the intercept and slope parameters (see, e.g., Bradlow et al. 2004).

[2] For example, ease of use is a common concern of consumers, and its objective level may be judged by consumer report experts as well as demonstrated by a (trained) salesperson. However, there is also consumer heterogeneity in how important the ease of use is for each consumer. Some consumers find it easy to use even sophisticated controls, and some find it confusing if there are more than a couple controls on a device. Hands-on experience may help an individual consumer better determine which type she is. Even if we restrict our attention to advertising, some advertisements featuring performance in extreme situations may speak to the objective quality of the product, while advertising featuring more common everyday use may speak to the weight an individual consumer should be placing on a given value of quality. Consumer research about the effect of direct versus indirect product experience on consumer preferences (e.g., Dahan and Srinivasan 2000, Thompson et al. 2005) also finds that direct product experience is more likely to result in heterogeneous consumer responses to the experience.

[3] An example is BMW's production of DVD "For Hire" with short films featuring fictional BMW driving experiences similar to those in the movie *Transporter*. It is common for auto manufacturers to pay movie studios to use the latest high-end cars in action movies, such as the "*007*" series.

[4] In the retail context, one can think of the products the retailer sells as the "overall quality" of the retailer. Although a retailer does not set the quality of a product, the retailer chooses which products to stock and promote. In the digital camera category context, Best Buy and Circuit City sell more high-end cameras than OfficeMax, Target, or Walmart.

[5] From April 15 to July 22, 2003, GM allowed overnight test drives on most of its automobiles during which consumers could leave their own car at any GM dealership and take home a GM car for a full day or a weekend test drive. In September 2007, GM made it possible for consumers coming to its Saturn and Chevrolet dealerships to test drive Toyota cars (without an option to buy). In 2005, Maytag allowed consumers to try out its washing machines with a load of their dirty laundry at some stores (Daily 2005). Ikea gives a three-week full buyback guarantee to allow customers to assess whether the product fits with their décor (Messinger and Qiu 2007). These are some examples that are consistent with the idea that some firms with products valued relatively lower by the average consumer may invest more than the higher-quality firms in marketing activities providing information that helps consumers understand whether they value the quality difference or if the cheaper option has good-enough quality for them.

uncertainty about the product quality. However, we show that the lower-quality firm will have the higher incentive to and will be the one to provide information resolving consumer uncertainty about quality preference when the marginal cost of the high-quality product is not very high compared to that of the low-quality product. The intuition for this comes from the fact that this kind of information always sways some consumers toward the high-quality product and some toward the low-quality product. When the cost of quality is low, the high-quality firm is in a better position to compete. On the other hand, the lower-quality firm has to seek ways of attracting at least some consumers. Therefore, it has a greater incentive to provide information about consumer preference for quality. Given the dependence on the cost of quality, one could also reformulate the information provision result in a more intuitive way so that the niche firm (i.e., the firm with the lower market share) will be the one providing information resolving consumers' preference uncertainty. In the analysis, we trace the results for different types of information provided by different kinds of firms to the competitive factor and to consumer free-riding on store information provision. When only one firm is present in the market or when consumer free-riding is restricted by the cost of a store visit, the lower-quality firm will have less incentive to provide information resolving consumer preference uncertainty.

2. Related Literature

This paper is mainly in the nexus of two streams of literature: the literature on the product and price competition, and the literature on firms' decisions about information provision. We now discuss how this paper borrows from and contributes to these streams.

2.1. Product and Price Competition

Studies in strategic product choice under price competition generally support the idea that a firm must differentiate its product from competitors when faced with consumers of heterogeneous preferences (see, e.g., d'Aspremont et al. 1979, Hauser and Shugan 1983, Hauser 1988, Moorthy 1988). Prior literature also considered how price competition is affected by consumer shopping costs in the presence of consumer heterogeneity (see, e.g., Lal and Mattutes 1994, Bergen et al. 1996, Lal and Rao 1997, Bell et al. 1998, Iyer 1998, Anderson and Renault 1999, Lal and Sarvary 1999, Iyer and Pazgal 2003, Kuksov 2004). We build on this literature stream by considering consumer utility from purchasing *vertically* differentiated products in the presence of consumer heterogeneity, consumer *uncertainty*, and *information provision* decisions by the firm, and we also allow for shopping to be costly. The possibility that consumers have uncertainty about product quality and/or their valuation of quality may be particularly likely in such categories as consumer electronics, where products are evolving so fast that technologies appear confusing to many consumers.[6]

2.2. Information Provision

There is extensive research on firms' information provision and communication with consumers through informative advertising (see, e.g., Butters 1977, Lal and Mattutes 1994, Stahl 1994, Rajiv et al. 2002, Soberman 2004, Villas-Boas 2004, Bass et al. 2005, Iyer et al. 2005), sales assistance (see, e.g., Wernerfelt 1994, Krishnan et al. 2002), and money-back guarantee (see, e.g., Davis et al. 1995, Heiman et al. 2002, Messinger and Qiu 2007). Lewis and Sappington (1994) consider incentives for a seller to provide information to subsequently use second-degree price discrimination. In Davis et al. (1995), the seller facilitates purchasing and consumer learning by allowing product returns. The choice of advance and spot selling (Shugan and Xie 2000, 2001) can also be considered as a firm's choice of information environment. We study vertically differentiated competitive markets where the information free-riding possibly exists and derive the conditions under which the high- and low-quality firms should provide what type of information. We thus contribute to the literature by comparing multiple types of information provision and the interaction with product and pricing decisions, and highlight the trade-offs a firm faces in information provision in the presence of consumer heterogeneity.

The free-riding concern refers to the possibility that firms that provide information to consumers may not necessarily be the ones that realize the potential demand.[7] Existing literature suggests that incentive-of-service provision will then be reduced because of this concern (see, e.g., Telser 1960, Mittelstaedt 1986, Singley and Williams 1995, Tang and Xing 2001). There are, however, recent marketing studies suggesting that the incentive to provide truthful informational assistance may be sustained when considering the firm reputation (Wernerfelt 1994), the effect of softening competition (Strauss 2002, Shin 2007), or the effect of increasing differentiation (Wu et al. 2004, Shin 2005). This paper, in particular, suggests that differentiated product competition may actually increase information provision, and it investigates the interaction of product quality-price decisions with information provision.

[6] *Retail Forward* (2004).

[7] According to the IU/KPMG consumer shopping survey (IU/KPMG 2000), multiple channels are used by 82% of survey respondents to learn about new products, by 77% to search for product information, by 74% to compare and evaluate alternatives, and by 63% to purchase and pay for products.

The remainder of the paper is organized as follows. Section 3 presents the main model, which is solved in §4 and further analyzed in §5 through several model extensions that establish the driving factors for and the robustness of the results. Section 6 concludes with a summary and further discussion of the results.

3. Model Setup

We consider a vertically differentiated market with two firms, A and B, also denoted by 1 and 2, serving consumers of unit total mass. Similar to past literature, we make the following assumptions about the demand and supply side in our model.

3.1. Consumers

Each consumer has utility only for a single unit of the product. This utility is $U = V + \theta q - p$, where q is the product quality, p is the price paid, and θ is the consumer's valuation for quality.[8] We assume that θ is distributed uniformly on $[0, 1]$ across consumers. Parameter V in this setup captures the reservation value of a consumer who does not need more than a basic product of minimal quality. We allow V to be equal to zero.

3.2. Firms

The two firms in the market decide on their respective quality levels, on whether or not to provide information of either type which allows consumers to resolve uncertainty in purchase, and on the prices of their products. There could be two types of information: one (denoted by I_q) allows consumers to learn about the product quality (q) and the other (denoted by I_θ) allows consumers to learn their preference (θ) for a particular level of quality. For simplicity, we assume the decisions of quality and information provision are discrete. In particular, we assume there are two quality levels to choose from: the low quality q_1 (≥ 0) and the high quality q_2 ($> q_1$), and a firm either offers (I_q and/or I_θ) or does not offer (NI) each type of information. The marginal cost of q_1 is normalized to zero, and the marginal cost of q_2 is denoted by δ (≥ 0). The quality-revealing information has a fixed cost $c_{Iq} > 0$, and the preference-for-quality-revealing information has a fixed cost $c_{I\theta} > 0$ (this assumption is relaxed in §§5.3 and 5.6). All other costs are normalized to zero.

3.3. Information Structure

Prior to any purchase decisions, consumers observe the firms' prices and information-provision decisions. Consumers may be uncertain about their utility of a product either because they are uncertain about the quality of the product or are uncertain about their preference level (θ) for the quality or both. A consumer can learn the quality level of the product or the value of her θ by visiting the firm that provides the relevant type of information, if such a firm exists. We first assume that consumers have zero shopping cost, and therefore, if a firm provides any information, all consumers obtain this information before making their purchase decisions (§5.2 relaxes this assumption by introducing a positive consumer shopping cost t). If a firm does not provide information, consumers use their priors and rational expectations of the behavior of the firm to infer it.

3.4. Game Structure and the Sequence of Moves

The timing of the game is as follows:

Stage 1. The two firms simultaneously decide on the quality of their respective products, as well as whether to offer each type of information.[9]

Stage 2. The two firms simultaneously set prices for their products.

Stage 3. Consumers make purchase decisions and profits are realized.

Firms observe each other's choices after each stage and consumers observe prices and information-provision decisions by the firms.[10] Note also that we do not allow firms to commit to prices before deciding on the quality and information provision. Allowing firms to commit to prices at or before stage 1, say, through a price-matching guarantee, could change the results because this could restrict the strategic effect of quality and information provision of one firm on the price of the other firm. We look for a perfect Bayesian equilibrium of this game.

4. Solution

The model is a multistage game. We therefore follow the standard idea of backward induction to look for the equilibria. In the following subsections, we first look at the two cases that involve consumers having only one dimension of uncertainty. After exploring firms' strategic trade-offs in the situation where

[8] The quality index q is a summary measure of all more-is-better attributes of the product. For example, in the case of the digital camera, q can be a composite of resolution, optical zoom, digital zoom, etc.

[9] The results of the model will not change if the quality and information provision are modeled as sequential (see the electronic companion, available as part of the online version that can be found at http://mktsci.pubs.informs.org). The implications about the quality and information provision link also remain the same if the quality is not a decision variable, but rather, firms are exogenously differentiated in quality before stage 1. However, such an assumption does not simplify the model results.

[10] When the zero shopping cost assumption is relaxed, consumers have to make the decision on which store to visit first and then whether to buy at that store or go to the other one. We elaborate on this sequence in §5.2. When shopping is costless, consumers might as well learn everything there is to learn before making any decisions.

consumers have uncertainty on preference or quality alone, we then present the results for the game where consumers have uncertainty on both dimensions. Note that looking at the Nash equilibrium implies looking at outcomes where each firm behaves optimally given the correct expectations of the other firm's actions. Given our research question, we are specifically interested in the classification of outcomes that involve firms differentiated in the product quality they offer so that we can analyze the connection between quality and the information provision of each type. We also derive explicit conditions under which quality differentiation is the unique equilibrium outcome.[11]

4.1. Consumer Uncertainty About Their Preference (θ) Only

We start with the analysis of firms' pricing decisions given any possible combination of the quality and information provision decisions. As a convention, if firms turn out to be differentiated in their quality choices, so that one firm chooses q_1 and the other one chooses q_2, we will denote the firm that chooses the low-quality product (q_1) by firm 1 and the firm that chooses the high-quality product (q_2) by firm 2. As we will argue below, a pure-in-quality-choice strategy equilibrium will always have quality-differentiated firms unless the marginal cost (δ) of high quality is prohibitively high. Such equilibrium implies that while the two firms are initially symmetric, they hold different expectations of each other's behavior, so that as they choose different actions in quality and information provision, they have correct expectations about the other firm's choice of actions. For simplicity, we start by considering the case when V is high enough, so the market is fully covered, and consumer valuation (the individual rationality constraint) is not binding.[12] The appendix shows that a sufficient condition for this to hold is that $V > (\Delta + \delta)/3$, where $\Delta = q_2 - q_1$. Lemma 1 states the price competition results. The corresponding price competition results for smaller V, when the market may not be fully covered, are reported in the electronic companion.

Lemma 1 ($V > (\Delta + \delta)/3$). *If the firms are not differentiated in quality, the profit of a firm not providing information is zero and the profit of a firm providing information is negative. When firms are differentiated in quality choices, their profits depending on the information provision are presented in Table* 2.

[11] Considering exogenously differentiated firms would save us from this last step but would not simplify the results about the connection between quality and information provision.

[12] We also show in the electronic companion that the qualitative implications remain the same for smaller V, including, for $V = 0$.

Table 2 Payoffs for Differentiated-Product Firms, Zero Shopping Costs ($V > (\Delta + \delta)/3$)

Firm 1\2	(q_2, NI)	(q_2, I_θ)
When $0 \le \delta < \frac{\Delta}{2}$		
(q_1, NI)	$\left(0, \frac{\Delta}{2} - \delta\right)$	$\left(\frac{(\Delta+\delta)^2}{9\Delta}, \frac{(2\Delta-\delta)^2}{9\Delta} - c_{I\theta}\right)$
(q_1, I_θ)	$\left(\frac{(\Delta+\delta)^2}{9\Delta} - c_{I\theta}, \frac{(2\Delta-\delta)^2}{9\Delta}\right)$	$\left(\frac{(\Delta+\delta)^2}{9\Delta} - c_{I\theta}, \frac{(2\Delta-\delta)^2}{9\Delta} - c_{I\theta}\right)$
When $\frac{\Delta}{2} < \delta < 2\Delta$		
(q_1, NI)	$\left(\delta - \frac{\Delta}{2}, 0\right)$	$\left(\frac{(\Delta+\delta)^2}{9\Delta}, \frac{(2\Delta-\delta)^2}{9\Delta} - c_{I\theta}\right)$
(q_1, I_θ)	$\left(\frac{(\Delta+\delta)^2}{9\Delta} - c_{I\theta}, \frac{(2\Delta-\delta)^2}{9\Delta}\right)$	$\left(\frac{(\Delta+\delta)^2}{9\Delta} - c_{I\theta}, \frac{(2\Delta-\delta)^2}{9\Delta} - c_{I\theta}\right)$
When $\delta > 2\Delta$		
(q_1, NI)	$\left(\delta - \frac{\Delta}{2}, 0\right)$	$(\delta - \Delta, -c_{I\theta})$
(q_1, I_θ)	$(\delta - \Delta - c_{I\theta}, 0)$	$(\delta - \Delta - c_{I\theta}, -c_{I\theta})$

Proof. See the appendix for the proof and the complete outcome specification. □

We now come to the central question of this subsection: when firms are differentiated in the quality dimension, will the low- or the high-quality firm (or neither) provide preference-revealing information? Note that although we model the quality and information provision as a simultaneous choice (i.e., during the same stage), these decisions within a firm are interdependent. Considering how the information provision is related to the quality decision, we can therefore consider what information the firm should provide when it chooses a certain quality level. Before we state the formal results, it may be beneficial to consider the following to gain some insight from Lemma 1.

A common observation can be drawn from both the case of high V presented above and the case of low V presented in the electronic companion with respect to the profit difference between the high- and the low-quality firms as the marginal cost of quality (δ) changes and consumers make purchase decisions under uncertainty about their preference. When δ is sufficiently small and no preference information is available, given the equilibrium prices charged by the firms, every consumer purchases a high-quality product as if she were an average consumer (with $\theta = 1/2$). In this case (i.e., for low δ), the high-quality firm in fact benefits from the product differentiation more than in the case of perfect information where some consumers (with $0 < \theta < 1/2$) realize that their quality preferences are low. Consequently, the direct effect of providing preference-revealing information (keeping all other decisions, i.e., price and quality, constant) is negative for the high-quality firm's profit and positive for the

low-quality firm. However, as explained below, preference information provision (by either firm) results in both firms increasing their prices, and therefore the strategic effect of preference-information provision on either firm's profit is positive. This observation provides insight for why the low-quality firm could have a higher incentive to provide preference-revealing information. To get a positive market share and profit, the low-quality firm in the case of low δ has to provide the type of information that allows the low-end consumers to realize that the low-quality product is in fact more appealing to their preferences (given its lower price).

The above-discussed forces act in the reverse direction when δ is sufficiently large so that the consumers in the case of preference uncertainty (i.e., when neither firm provides information) would choose a product of low quality, and the direct effect of providing preference-revealing information is then positive for the high-quality firm and negative for the low-quality firm, while the strategic effects are positive for both as before. The following proposition summarizes the above discussion.

Proposition 1. *Assume one of the firms chooses the high-quality product* (*and is expected to do so by the other firm*) *and the other firm chooses the low-quality product* (*and is expected to do so by the first firm*). *Then if* $\delta < \Delta/2$, *the firm choosing the low-quality product has a higher incentive than the firm choosing the high-quality product to provide information to consumers that will allow them to learn their preference* (θ) *for quality. On the other hand, if* $\delta > \Delta/2$ (*but still such that the high-quality firm stays in the market; i.e.,* $\delta < 2\Delta$), *the firm choosing the high-quality product has a higher incentive to provide this type of information.*

Proof. See the appendix. □

To better understand the condition under which the low-quality firm has a higher incentive to provide preference information, note that the condition $\delta = \Delta/2$ is the condition where the average consumer (who has $\theta = 1/2$) is indifferent between the high- and the low-quality product if the price difference between them represents the cost difference. The implication of this is that if $\delta < \Delta/2$, the high-quality firm will have the higher market share (with or without information provision), while if $\delta > \Delta/2$, the low-quality firm will have the higher market share. This leads to the following corollary.

Corollary 1. *The firm with the lower market share has the higher incentive to provide preference-revealing information.*

Proof. See the appendix. □

We will now state the equilibrium results driven by the above-discussed incentives for firms to provide preference-revealing information. We will make use of the following condition:

$$0 \le \delta < 2\Delta \quad \text{and}$$
$$0 < c_{I\theta} < \min\left\{\frac{(\Delta+\delta)^2}{9\Delta}, \frac{(2\Delta-\delta)^2}{9\Delta}\right\}, \tag{1}$$

in which the upper bound on δ is a necessary condition for the high-quality product to be offered and to have positive sales in the equilibrium, and the upper bound on $c_{I\theta}$ is a necessary condition for information to be provided in the equilibrium (see the appendix). The following proposition reports the equilibrium quality-information combinations when V is high (again, the corresponding results when V is low are similar and are provided in the electronic companion):

Proposition 2 ($V > (\Delta+\delta)/3$). *If condition* (1) *is satisfied, in equilibrium, the firms are differentiated in quality and exactly one of them provides preference-revealing information.*[13] *Furthermore, when* $\delta < \Delta/2$,

(1) *If* $0 < c_{I\theta} \le (2\delta^2 + 10\delta\Delta - \Delta^2)/18\Delta$ (*which is never true if* $\delta < (3\sqrt{3}-5)\Delta/2$), *in equilibrium, either the high- or the low-quality firm may provide preference-revealing information.*

(2) *Otherwise, the unique quality-information equilibrium combination is when the low-quality firm provides preference-revealing information, but the high-quality firm does not.*

Alternatively, when $\delta > \Delta/2$,

(1) *If* $0 < c_{I\theta} \le (11\Delta^2 - 14\Delta\delta + 2\delta^2)/18\Delta$ (*which is never true if* $\delta > (7-3\sqrt{3})\Delta/2$), *in equilibrium, either the high- or the low-quality firm may provide preference-revealing information.*

(2) *Otherwise, the unique quality-information equilibrium combination is when the high-quality firm provides preference-revealing information, but the low-quality firm does not.*

If the upper bounds of condition (1) *are not satisfied with a strict inequality, no preference-revealing information is provided in the equilibrium.*

Proof. See the appendix. □

To illustrate the above proposition, let us consider what it implies when the cost of additional quality (δ) is sufficiently small (e.g., when $\delta = 0$). In this case, the condition on $c_{I\theta}$ cannot be satisfied because $2\delta^2 + 10\delta\Delta - \Delta^2 < 0$, and hence, the above proposition implies that in equilibrium, the low-quality firm

[13] As is common in quality choice literature (e.g., Shaked and Sutton 1982, Moorthy 1988), we only consider equilibria with pure strategy in quality choice. There is also a mixed (in quality and information choices) strategy equilibrium, the result of which could be an undifferentiated outcome. However, if Proposition 2 predicts a unique quality-information combination, it is still the unique combination in the mixed-strategy equilibrium (see the appendix).

and only that firm will provide preference-revealing information:

Corollary 2. *If $\delta = 0$, the information about consumer preference for quality will never be provided by the high-quality firm, but will be provided by the low-quality firm unless $c_{1\theta} \geq 4\Delta/9$.*

More generally, the above proposition identifies additional conditions under which the unique prediction is that the low-quality firm would be the only one to provide preference-revealing information: when δ is low enough, or when the cost of preference-information provision is high enough and $\delta < \Delta/2$. On the flip side, when δ is high enough, or when it is relatively high ($\delta > \Delta/2$) and the cost of preference-information provision is high enough, the unique equilibrium is for the high-quality firm to provide this type of information. There are also regions of multiple equilibria where either the high-quality or the low-quality firm could be the provider of this type of information, but the range of this regime shrinks as the cost of quality (δ) goes either down or up from the value $\Delta/2$.[14] The interpretation of the above critical value $\delta = \Delta/2$ is that this is the cost under which the average consumer (i.e., the consumer with $\theta = 1/2$) or a consumer who does not know her θ would think that the higher cost is justified by the higher value (therefore, it is also the critical value that makes the monopolist or the social planner not providing preference-revealing information switch from producing the low-quality to the high-quality product).

4.2. Consumer Uncertainty About Product Quality (q)

Suppose now that consumers do not know if a firm's product is of high or low quality. To avoid the problem of multiple equilibria, assume that it is at least marginally cheaper to produce the low-quality rather than the high-quality product (i.e., assume $\delta > 0$). Through the quality-revealing information provision, a firm can convey to the consumers the exact quality of its product. Given that the uncertainty is product-specific, consumers receiving quality information from one firm may still not know the quality level of the other firm unless the other firm provides this type of information as well. We then have the following proposition.

Proposition 3. *When consumers face uncertainty about product quality (q), in equilibrium, only the high-quality firm may provide quality-revealing information, while the low-quality firm never provides quality-revealing information. Furthermore, the firm offering high-quality product always provides quality-revealing information if it expects positive sales.*

Proof. See the appendix. □

Note that this proposition holds both when consumers face uncertainty about their preferences for quality and when they do not, and regardless of whether either firm ends up providing preference-revealing information.

The insight for Proposition 3 comes from the fact that on receiving quality-revealing information, *all* consumers, as opposed to only a proportion, increase the value they expect to receive from the firm if it is high quality and decrease the expected value from the firm if it is low quality. Furthermore, if $\delta > 0$ and the high-quality firm expects positive sales, if it were not to provide quality-revealing information, its decision to offer high-quality product would be strictly dominated by the possibility of a less costly option of selling the lower-quality product at the same price, because consumers, unaware of the product quality, would not alter their purchase decisions. Note that in the setting of this model, the high-quality firm cannot signal its high quality by raising its price because if consumers were to believe that high price signals high quality, the low-quality firm would have at least as high incentive to raise price as the high-quality firm. Therefore, within the model setup, the only way to show high quality is through the information provision in forms such as informative advertising. The comparison with Propositions 1 and 2 illustrates that the nature of consumer uncertainty is an important factor affecting firms' strategic choice of quality and information provision in competition. With the results from §§4.1 and 4.2, we are now ready to present the equilibrium outcome for the full model where consumers may have uncertainty on both dimensions.

4.3. Consumer Uncertainty About Both Quality (q) and Preference (θ)

In the case when consumers are uncertain about both the product quality and their preference for a given product quality, §4.2 already shows that if the firms are differentiated in their quality choice and have positive profits, then the high-quality firm and only that firm may provide information about the product quality. Furthermore, providing a low-quality product is a dominant strategy if $\delta > 0$ for a firm that decides not to provide information about quality and expects positive sales. To avoid multiple equilibria, let us assume that $\delta > 0$, but it could be arbitrarily small. In this case, rational consumers will infer that a firm not providing information about quality is selling a low-quality product. Of course, if the cost of quality information provision is prohibitively high, neither firm will provide the quality-revealing information, and undifferentiated competition will result in zero

[14] The region of the parameter values resulting in the possibility of multiple equilibria can be reduced by introducing positive consumer shopping costs. This possibility is considered in §5.2.

profits for both firms. Therefore, we will assume the following condition binding the cost of quality information provision from above:

$$0 < c_{Iq} < \frac{(2\Delta-\delta)^2}{9\Delta} \quad \text{if } \delta < \frac{\Delta}{2} \quad \text{and}$$
$$0 < c_{Iq} < \frac{(2\Delta-\delta)^2}{9\Delta} - c_{I\theta} \quad \text{if } \delta \geq \frac{\Delta}{2}. \tag{2}$$

This condition makes the profits of the higher-quality firm positive in a differentiated equilibrium with information about consumer preference for quality provided by the firm who has a higher incentive to do so and with the quality-revealing information provided by the high-quality firm. We then have the following proposition:

Proposition 4 ($V > (\Delta+\delta)/3$). *If conditions* (1) *and* (2) *are satisfied, in equilibrium, the firms are differentiated in quality, the high-quality firm provides quality-revealing information, and exactly one of the firms provides preference-revealing information. Furthermore, the enumerated results of Proposition* 2 *about who provides preference-revealing information hold.*

Proof. See the appendix. □

Proposition 4 helps us understand why it is difficult to find examples where only the low-quality firm provides information and the high-quality firm provides no information at all. In fact, what one could expect is not that the general level of information provision from the low-quality firm is higher, but that the information provided by the two quality-differentiated firms are qualitatively different, with the low-quality firm concentrating on providing information explaining to consumers the value of quality, while the information provided by the high-quality firm explains to consumers that this firm has the high quality level.

For illustration, it could again be useful to consider what type of information would be provided by which firm in the case where δ is small. In this case, we have the following:

Corollary 3. *Assume* $\delta < (3\sqrt{3}-5)\Delta/2$. *Then if* $c_{I\theta} < (\Delta+\delta)^2/9\Delta$ *and* $c_{Iq} < (2\Delta-\delta)^2/9\Delta$, *in equilibrium, the firms are differentiated in quality, and the low-quality firm provides preference-revealing information, while the high-quality firm provides quality-revealing information. If* $c_{Iq} > (2\Delta-\delta)^2/9\Delta$, *then neither firm provides any information. Finally, if* $c_{I\theta} > (\Delta+\delta)^2/9\Delta$, *then if* $c_{Iq} < \Delta/2-\delta$, *the firms are differentiated in quality and the only information provided is the quality-revealing type by the high-quality firm, while if* $c_{Iq} > \Delta/2-\delta$, *neither type of information is provided.*

Proof. See the appendix. □

In particular, the above corollary shows that the constraints on the cost of information provision about quality are weaker than the constraints on the cost of providing preference-revealing information.

5. Extentions and Further Discussion

This section considers several modifications and extensions to the main model to better understand the driving factors behind the results and the robustness of those results about when the high- or low-quality firm becomes the provider of preference-for-quality-revealing information.

We start by exploring the qualifiers for the possibility that the low-quality firm has the higher incentive to provide preference-revealing information. Thus, we focus the model extensions on this dimension of consumer uncertainty alone. We first link the above possibility to the competitiveness of the market by comparing the outcome in §4.1 with decisions of a monopoly. Next, we consider an extension where consumers have a positive shopping cost if they receive information at one place and buy from the other relative to the case when both are done at the same place. Consumer shopping costs limit the ability of one firm to free-ride on the other firm's information provision. We show that when shopping costs are positive, the high-quality firm is more likely to provide preference-revealing information relative to the above-considered case with zero shopping costs.

Furthermore, we consider several extensions relaxing the assumptions on the cost and information structure and introduce an explicit model of product returns as a possible tool to provide information to consumers.

5.1. Monopoly

When there is no competition as opposed to the duopoly case we considered above, how would a firm's decision on information provision change when it faces consumers who have uncertainty on preference (θ) as in §4.1? The answer is provided in the following proposition.

Proposition 5.

(1) *When* $0 < \delta < V + (q_2/2)$, *it is optimal for the monopolist to choose* q_2. *The monopolist will also provide preference-revealing information to the consumers if*

$$\max\{0, \delta - q_2\} < V < \delta + q_2 \quad \textit{and}$$
$$0 < c_{I\theta} < \frac{(V-\delta)^2 - 2q_2(V-\delta) - q_2^2}{4q_2}.$$

Otherwise, the monopolist will not provide preference-revealing information.

(2) *When* $\delta > V + (q_2/2)$, *it is optimal for the monopolist to choose* q_2 *and provide preference-revealing information if*

$$\max\{0, \delta - q_2\} < V < \delta + q_2 \quad \textit{and}$$
$$0 < c_{I\theta} < \frac{(V-\delta)^2 - 2q_2(V+\delta+q_1) + q_2^2}{4q_2}.$$

Otherwise, the monopolist will choose q_1 *and will not provide preference-revealing information.*

Proof. See the electronic companion. □

A comparison between Proposition 5 and the results of the competitive model (Proposition 2 and its modification for low V reported in the electronic companion), leads to the following two implications. First, competition increases a firm's incentive to provide preference-revealing information to consumers, because in a monopoly, no preference-revealing information will be offered when V is sufficiently large (such that the market is fully covered). Furthermore, the equilibrium outcome of the low-quality firm providing information resolving consumers' uncertainty on preference is partially driven by competition, because, according to Proposition 5, a monopoly never chooses to provide this type of information when it provides the low-quality product.

5.2. Positive Consumer Shopping Costs

In the main model, we assumed that if either of the firms provides information that helps consumers learn about their preference for quality, all consumers know their preference. In reality, it may be that the purchase is separated in time from the information-gathering stage of consumer behavior. However, consumers may also be uncertain about their preferences and seek relevant information at the time of purchase decision making. In this latter case, the store providing information may have an advantage because consumers coming to it to resolve uncertainty have already incurred the travel cost to this store but would have to incur an extra travel cost if they were to decide to buy from the other store. Whereas the main model applied to this situation assumes that the travel costs are zero, it may be interesting to consider how the consumer behavior and the payoffs to information provision change when consumers have a positive shopping cost. To do this, we now examine the following extension to the main model. Because it is more applicable when firms actually represent (physically or online) stores, rather than when manufacturers sell through a retailer, we will refer to the firms in this subsection as stores.

As opposed to the main model, we assume that each consumer faces a per-visit cost t of visiting a store and that if a store provides preference-revealing information, then any consumer can learn her θ by visiting that store. For simplicity, we consider t to be the same across consumers. In other words, the consumer decision process and information structure are modified:

- As before, prior to any decisions, consumers learn the quality, price, and the information-provision decision by each of the two firms;
- Whether any store is providing preference information or not, a consumer only knows the prior distribution of θ prior to the store visit;
- The consumer cost of each store visit for information acquisition or product purchase is t.

To simplify the model analysis, we again concentrate on the case where V is high enough, so that the market exists and product valuations are not a constraint. For example, $V > (\Delta + \delta)/3 + t$ is a sufficient condition for this to hold. Under this assumption, by elimination of strictly dominated strategies, the consumer decision process can be simplified to the following:

1. Decide which store to visit first and go to the chosen store, at which point if the store provides preference-revealing information, the consumer learns her preference θ;
2. Decide whether to buy at the current store or go to the other store and buy there.

Note that if a consumer decided to first visit a store that does not provide preference information, the consumer must intend to buy at that store, because no new information is learned following the visit. If consumers, in equilibrium, do not abstain from shopping, the consumers' cost of the first visit is inconsequential for the model predictions. Therefore, the assumption that the first visit costs as much as the second is inconsequential. Furthermore, because the consumer has no reason to visit more than twice, the cost of the third visit (e.g., coming back to the first store a second time) is also inconsequential.

Just as in the main model, the interesting quality-information subgame of this model is when stores are differentiated in quality, because otherwise (whether they provide preference information or not), they are engaged in undifferentiated Bertrand competition and earn zero or negative profits. Following the same solution sequence as in the main model, we first derive the payoffs of the quality-differentiated stores when none, one, or both stores provide preference-revealing information. We will further concentrate on the case where $0 < \delta < \Delta/2$ and assume that t is low enough. The following lemma summarizes these results:

Lemma 2. *When* $V > (\Delta + \delta)/3 + t$, $0 < \delta < \Delta/2$, *and* t *is such that there is a pure-strategy equilibrium, Table* 3 *states the profits of the stores* 1 *and* 2, *depending on their information provision decision, in case they are differentiated in quality.*

Table 3 Payoffs for Differentiated-Product Firms When Consumers Have a Positive Shopping Cost (Assuming $V > (\Delta+\delta)/3+t$, $0<\delta<\Delta/2$, and $t \le (\Delta/16)(3\sqrt{17+60\partial+68\partial^2}-13\partial-11)$)

Firm 1\2	(q_2, NI)	(q_2, I_θ)
(q_1, NI)	$\left(0, \frac{\Delta}{2}-\delta\right)$	$\left(\frac{(\Delta+\delta-t)^2}{9\Delta}, \frac{(2\Delta-\delta+t)^2}{9\Delta}-c_{I\theta}\right)$
(q_1, I_θ)	$\left(\frac{(\Delta+\delta+t)^2}{9\Delta}-c_{I\theta}, \frac{(2\Delta-\delta-t)^2}{9\Delta}\right)$	$\left(\frac{(\Delta+\delta-t)^2}{9\Delta}-c_{I\theta}, \frac{(2\Delta-\delta+t)^2}{9\Delta}-c_{I\theta}\right)$

Proof. See the electronic companion for the proof and the complete outcome specification. □

Although the complete proof is provided in the electronic companion, it could be worthwhile to summarize the consumer behavior and the intuition for the effect of the positive shopping costs on profits. If one of the stores provides preference-revealing information, consumers go to that store to learn their preference for quality. If this is the low-quality store, a consumer buys there if her preference for quality is low enough; if it is the high-quality store, the consumer buys there if her preference for quality is high enough. Otherwise, the consumer goes to the other store. Because doing so requires spending an extra t, the store attracting consumers to visit it first gains the benefit of having consumers valuing the "convenience of not going to the other store." Thus, consumer shopping costs increase the incentive to provide information. If both stores provide this type of information, it turns out that in the equilibrium, consumers go to the high-quality store first. This is because the high-quality store has a higher incentive to increase its demand (because it has higher margins), and therefore it wins in the competition for the first consumer visit. Therefore, if the high-quality store provides preference-revealing information, the low-quality store has no incentives to do so.

An implication of Lemma 2 is that stores are now not indifferent to who provides the preference-revealing information (if it is provided by at least one of the stores). In particular, if only one store provides preference-revealing information and the cost of doing so is low enough, each store prefers to be the one providing it. Therefore, consumer shopping costs increase the incentive to provide information. Furthermore, if this type of information is going to be provided in the equilibrium by the low-quality store and the cost of doing so is low enough, the high-quality store prefers to be the information provider. In other words, we have the following proposition:

Proposition 6. *Let $\partial = \delta/\Delta$, and assume $\partial < 1/2$ and $t \le (\Delta/16)(3\sqrt{17+60\partial+68\partial^2}-13\partial-11)$.*

Denote $c^*_{I\theta} \equiv ((2\partial^2+10\partial-1+(2-\partial)\tau+\tau^2)/18)\Delta$, $c^{**}_{I\theta} \equiv ((1+\partial+\tau)^2/9)\Delta$, and $\tau \equiv t/\Delta$. Then, in equilibrium:

(1) *If $c_{I\theta} < c^*_{I\theta}$, only the high-quality store provides preference-revealing information*;

(2) *If $c^*_{I\theta} < c_{I\theta} < c^{**}_{I\theta}$, there is no equilibrium in pure strategies in the information provision*;

(3) *If $c_{I\theta} > c^{**}_{I\theta}$, neither store provides preference-revealing information*.

Proof. See the electronic companion. □

Note that under the conditions of part (2) of Proposition 6, although both stores provide preference-revealing information with a positive probability, the purpose of doing so is different for each store: store 2 provides preference-revealing information to prevent store 1 from being the information provider, whereas store 1 wants the information to be offered but wants to save the cost of doing so if it is provided by store 2.

To compare the Proposition 6 with Proposition 2, note that as t goes to zero, the condition $c_{I\theta} < c^*_{I\theta}$ becomes the condition of multiple equilibria region in Proposition 2, and the condition $c^*_{I\theta} < c_{I\theta} < c^{**}_{I\theta}$ becomes the condition for only low-quality stores providing preference-revealing information in the equilibrium. Hence, consumer shopping costs partly determine the multiple equilibria in favor of the high-quality store and the high-quality store provides preference-revealing information sometimes even when the unique equilibrium was that the low-quality store does so. The intuition for that is that when consumers have positive shopping costs, providing preference information increases demand, which is more beneficial to the high-quality store that has a higher margin. Furthermore, both $c^*_{I\theta}$ and $c^{**}_{I\theta}$ increase when t increases (note that $c_{I\theta} < c^*_{I\theta}$ is still never satisfied when $\delta < \tau + (3\sqrt{3-4\tau}-5)/2$). Therefore, consumer shopping costs also increase the range of parameters $c_{I\theta}$, δ, and Δ, for which one of the stores provides preference-revealing information in the equilibrium. In other words, consumer shopping costs increase the incentives of the preference-information provision.

5.3. Marginal Cost of Information Provision and Partial Resolution of Uncertainty

Although some information provision activities, such as advertising, product display, and facilitating expert

reviews, may have only a fixed cost to the firm, others may have variable cost. It is then a natural question whether the model predictions will be different if the cost of information is modeled as a marginal cost. Obviously, there is no difference if the cost is zero. If the cost is positive, it turns out that the predictions of our model are strengthened: Propositions 1, 3, and 4 hold without changes and the ranges of single equilibria in Proposition 2 are expanded (see the electronic companion). It is also possible that the cost of providing information depends on quality. Of course, if the cost of information to the low-quality firm is sufficiently high, then the range of multiple equilibria may instead lead to the high-quality firm providing information.

Another interesting consideration is when the firm does not have to provide full information or information to all potential consumers. In this case, it is also natural to think of the cost of information as marginal to the amount of information provided. To explore this possibility of information provision, consider the following modification of the main model. To consider the robustness of the preference-for-quality information provision, let us restrict consideration to the case when the quality level itself is known.[15] Assume that each firm j decides on the amount $I_j \in [0, 1]$ of (preference-for-quality) information to provide. Given the information provision, consumer distribution of the expected θ becomes uniform on $[1/2 - a, 1/2 + a]$, where $a = f(I_1, I_2)$ is an increasing function in each argument such that $f(0, 0) = 0$ (i.e., no uncertainty is resolved if neither firm provides any information), and $f(1, 0) = f(0, 1) = 1/2$ (i.e., all uncertainty is resolved if either firm provides full information). For analytical tractability and to concentrate on the incentives to provide information, rather than have cost-driven results, assume that the costs of providing information are zero. Given this, without loss of generality, we can assume that $f(I_1, I_2) = \max\{1, (I_1 + I_2)/2\}$. The question we then ask is what incentives does each firm have to provide a given level of information and how much information will be provided by each firm in equilibrium?

It turns out (see the electronic companion) that when $\delta < \Delta/2$ (as in the main case; the results are symmetrically opposite when $\delta > \Delta/2$), the profits of the low-quality firm will never decrease if more rather than less information is provided, whereas the high-quality firm marginally benefits from extra information provision if $a > (\Delta - 2\delta)/6\Delta$ and is marginally worse off with lower a. As a result, the high-quality firm is strictly worse off with any positive a lower than $\partial/3 - 1/6 + (2 - 4\partial)^{1/2}/2$ than with $a = 0$ where $\partial = \delta/\Delta$. Furthermore, the low-quality firm always benefits strictly more than the high-quality firm from any level of information provided. It turns out that the equilibrium information is any combination (I_1, I_2) such that $I_1 + I_2 = 1$ and $I_1 \geq (1 - 10\partial - 2\partial^2)/18$. In other words, in equilibrium, either firm or both provide information to resolve all uncertainty, but when δ is small, the high-quality firm never provides full information, while the low-quality firm always provides some information. To some extent, the above results show that our main finding is robust to allow partial information provision. It would be interesting to further investigate, possibly through a dynamic model, the process of information provision with consumer learning over time.

5.4. Correlated Uncertainty

In the main model, we assumed that the firms have instruments of providing quality-related information and preference-for-quality-related information. In practice, some information that resolves one uncertainty may resolve the other uncertainty as well. When one of the uncertainties is not present, the results of the model will still apply in this case. At the opposite end, when both uncertainties are perfectly correlated and without information provision, products appear to be the same, the higher-quality firm will always have a higher incentive to provide information when $\delta < \Delta/2$. This is because in this case, if no information is provided, firms are in undifferentiated competition and have zero profits. On the other hand, if all uncertainty is resolved, the high-quality firm will have a higher profit than the low-quality firm when $\delta < \Delta/2$.

A more realistic situation may be that either it is possible to provide information about quality without fully resolving uncertainty about preference-for-quality, or that at the beginning, consumers have better information about quality than about their exact preference for quality. For example, some features, such as the optical zoom, size, weight, or memory capacity are easily interpreted as to which is better, but how much value they have is more uncertain. In this situation, the results of the main model will still hold if consumers know which product is of higher quality and they have good enough information about how big this quality difference is.

5.5. Robustness to Asymmetric Distribution of the Preference for Quality

One of the simplifying assumptions in the main model is that the consumer preference-for-quality (θ) distribution is uniform. One may wonder how robust

[15] It is fairly straightforward to check that only the high-quality firm will have an incentive to provide quality-related information. Furthermore, if the cost of quality information is sufficiently low, the high-quality firm will choose to provide full information about quality.

the results are to asymmetric distributions of θ when there are more consumers with preferences closer to the high- or low-quality product. As an example, let us consider what happens when there are more consumers who should value quality a lot. This will have the following two effects on consumer beliefs and valuation updating: First, an uninformed consumer will expect that θ is more likely to be high; i.e., in the absence of information, she will be more likely to purchase a higher quality product all else being equal. Second, resolving uncertainty will more likely lead to consumer updating her belief favorably to the lower-quality firm, because in a skewed-to-the-right distribution, the mass to the left of the mean is lower than the mass to the right. However, it is not completely clear how these forces will play out when prices are set competitively.

To further explore the possibility of skewed consumer distribution, let us consider the distribution of θ with probability density function $f(x) = a + (b-a)\cdot x$ for $0 < a < 2$ and the case when only the preference-for-quality is uncertain to consumers.[16] Normalization of the total mass of consumers to one implies $b = 2$. In this set of distributions, $a < 1$ corresponds to more consumers valuing quality highly, whereas $a > 1$ corresponds to more consumers valuing quality less.

It turns out that in this case, regardless of a, the low-quality firm will have a higher incentive to provide information when it has lower market share (but not always when δ is close to $\Delta/2$). Also, when δ is close to 0, the low-quality firm strictly benefits from providing information, and the high-quality firm is strictly worse off if the information is provided. See Figure 1 for some example graphs of the incentives to provide information for each firm as a function of a for different values of δ (see the electronic companion for the derivations). Thus, the results are robust to this extension (except for δ close to $\Delta/2$).[17]

5.6. A Model of Product Returns as Information Provision

As we have discussed above, a flexible product return policy can be used to allow consumers to see how much they value quality. In this section, we will show how to explicitly incorporate product returns as information provision. This explicit modeling will allow us to better understand the cost structure of information provision and thus see how the results may change when the cost of product returns is not negligible for the firms.

[16] It is easy to check that the high-quality firm will provide information about the quality unless the cost is prohibitively high.

[17] However, it is possible that the results could be affected by some more extreme cases of skewed distribution.

As an extension to the main model with no quality uncertainty, let us consider that at the stage of information provision, the firms set the return policy. Naturally, the cost of returns to the firm is marginal to the number of the products returned. Denote by c_R^j the cost of each product return to firm j. Assume that the cost of returns to consumers is zero. Assume that the consumer preference-for-quality uncertainty is resolved after buying a product. Therefore, if a firm offers free product returns to consumers, all consumers can buy from this firm, learn their θ, and if it turns out that they would be better off buying the other product, return the first one and buy the second. As a tie-breaking rule, assume that if both firms offer product returns, half of the consumers buy first from one firm and half from the other. Thus, in this model, if one of the firms offers free product returns, consumers end up being informed about their θ before the final purchase decision. Furthermore, if only one firm offers the product return, the total cost of product returns to the firm will be proportional to one minus the realized final demand. Note that because the higher-quality product is also more costly to the firm, the cost of one product return, c_R^j, could be higher to the high-quality firm. However, the total cost of product returns could be lower to the high-quality firm, because it may end up with a smaller number of returns. To keep the number of parameters to a minimum and to test the robustness of the model, assume $c_R^j = c_R$; i.e., the higher-quality firm does not have higher per-product return cost. This increases the incentive for the high-quality firm to offer product returns relative to the incentive of the low-quality firm. For returns to be provided in equilibrium, we need the following condition:

$$0 \le \delta < 2\Delta \quad \text{and}$$
$$0 < c_R < \min\left\{\frac{7\Delta - 2\delta - 3\sqrt{\Delta(5\Delta - 4\delta)}}{2},\ \frac{5\Delta + 2\delta - 3\sqrt{\Delta(\Delta + \delta)}}{2}\right\}. \tag{3}$$

Proposition 7 ($V > (\Delta + \delta - C_R)/3$). *Assume that condition* (3) *is satisfied. When* $\delta < \Delta/2$,

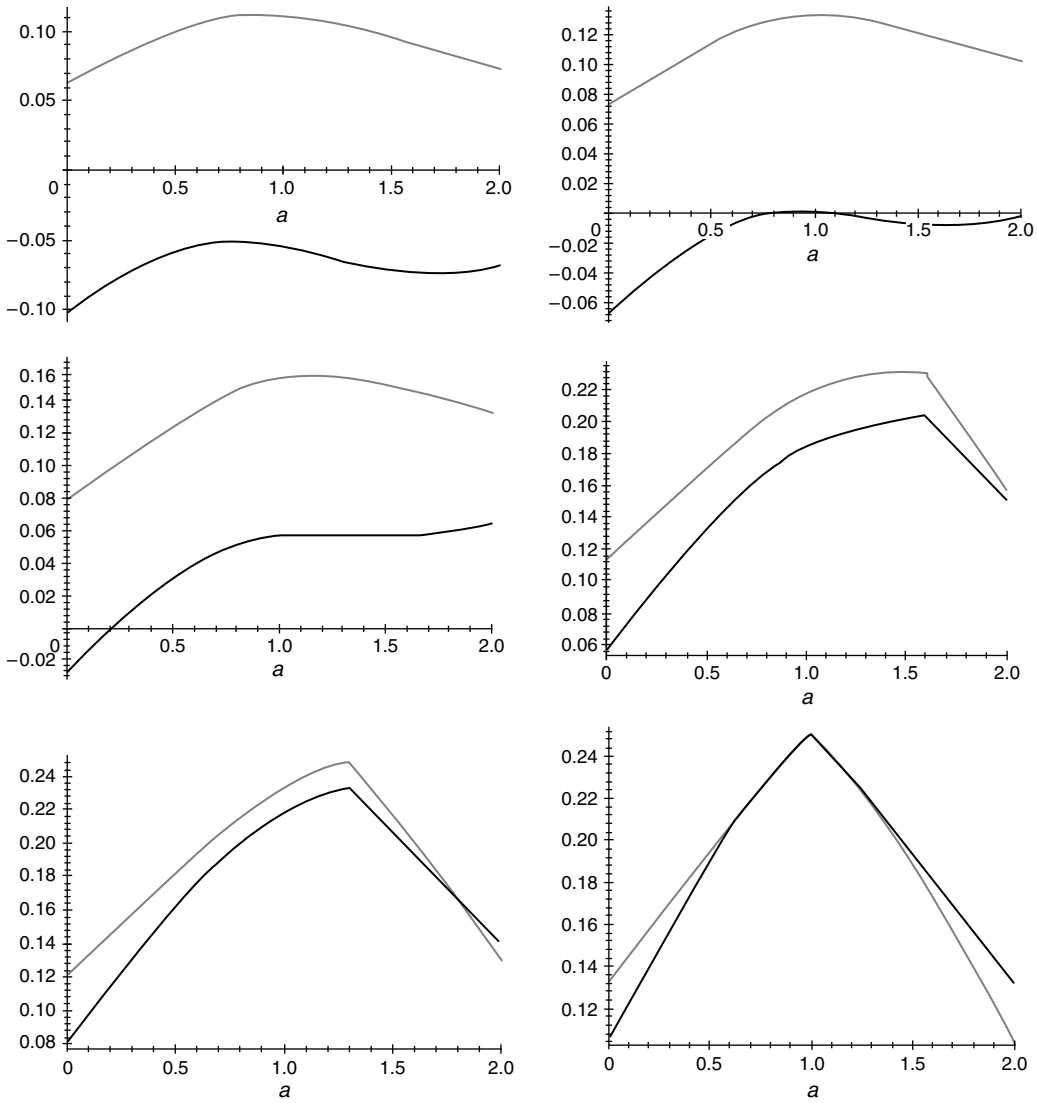
(1) *If* $0 < c_R \le ((5 - 3\sqrt{3})\Delta - 2\delta)/2$ (*which is never true if* $\delta < (3\sqrt{3} - 5)\Delta/2$), *in equilibrium, either the high- or the low-quality firm may provide preference-revealing information.*

(2) *Otherwise, the unique quality-information equilibrium combination is when the low-quality firm provides preference-revealing information, but the high-quality firm does not.*

Alternatively, when $\delta > \Delta/2$,

(1) *If* $0 < c_R \le ((7 - 3\sqrt{3})\Delta - 2\delta)/2$ (*which is never true if* $\delta > (7 - 3\sqrt{3})\Delta/2$), *in equilibrium, either the high-*

Figure 1 **Incentives for Low- (Grey) and High-Quality (Black) Firms to Provide Information for $\delta = 0, 0.1, 0.2, 0.3, 0.4$, and 0.5 with Skewed Consumer Distribution**



Note. Horizontal axis: a.

or the low-quality firm may provide preference-revealing information.

(2) *Otherwise, the unique quality-information equilibrium combination is when the high-quality firm provides preference-revealing information, but the low-quality firm does not*.

Proof. See the electronic companion. □

As one can see, the results are qualitatively the same as in the main model.

6. Conclusion

In this paper, we model a firm's quality, information provision, and pricing decisions with the focus on how the firms' incentives of information provision interact with their quality (or quality choice). Through the main model and its natural extensions, we find that the information provision is closely linked to product decision. Besides the straightforward cost concern, we demonstrate that the adoption of a specific quality-information combination is affected by the competitive pressure, the nature of uncertainty, the consumers' heterogeneity in preference, and the consumer shopping costs. In particular, we show that although the high-quality firm always wants to provide information showing to consumers that it has high-quality products, the low-quality firm has the higher incentive and should want to invest in marketing activities that help provide information to consumers explaining to them the value of quality. Our study thus provides important managerial implications to firms when it comes to the consideration of information provision as an additional strategic tool along with product design and pricing to

achieve a competitive advantage. Our model may be more applicable to the durable-product categories such as household appliances and consumer electronics where either the rapid technological innovation or the complicated, but seemingly important, product options lead to greater consumer uncertainty about the extent of usefulness of different product features.

Note that we only consider the role of information provision for various marketing activities adopted by firms rather than the value-adding functions of those marketing activities that directly enter the consumer utility function. Furthermore, we assume that information provision is such that the firm cannot distort information in its favor, and thus, consumers believe it. Although in some cases this may be a reasonable assumption (e.g., when the consumer is allowed to directly experience the product), one may argue that the firm could find ways of distorting the information or consumer perception of the information provided. The implications of such incentives and the resulting question of the credibility of the information provided by the firm is an interesting area of future research. Another interesting consideration is how information provision not only affects the realized demand, but also the initial market size. If this effect exists, it would lead to a higher incentive for the firm with higher market share, i.e., the category leader, to provide information.

Although the objective of this paper is to investigate the firms' incentives to provide information, peer-to-peer diffusion of information is also very important as a consumer information source (Godes and Mayzlin 2005). In this context, this paper can be viewed as showing the incentives for different firms to facilitate or hinder peer-to-peer communication. How the firm can affect the peer-to-peer information diffusion is also a very interesting topic out of the scope of this paper (see, e.g., Kuksov and Xie 2008). Abstracting from how the firm can affect peer-to-peer communication, we can consider the demand and consumer uncertainty model as an outcome of this communication, which can then be considered as exogenous to the firm's actions. Because word-of-mouth effects may be smaller and uncertainty larger for new products (Manchanda et al. 2008), this model may be especially applicable to relatively new products.

7. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mktsci.pubs.informs.org/.

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Appendix

Proof of Lemma 1. First consider the case *when both firms choose the same quality q* and at least one firm also provides preference-revealing information at the first stage. Upon discovering her exact quality valuation, consumer i derives the following utilities from purchasing firm 1's or firm 2's product, respectively,

$$\mu_1 = V + \theta_i q - p_1, \quad \mu_2 = V + \theta_i q - p_2. \tag{4}$$

Because $\mu_1 = \mu_2$ at equal price levels, the undifferentiated Bertrand price competition at the second stage of the game results in zero profit gross of information-provision cost. Hence, the profit of the firm that did not provide preference information is zero, and the profit of the firm providing service is $-c_{I\theta}$. If neither firm provides preference information, the profit results are the same because in that case, we also have $E\mu_1 = E\mu_2$. This proves the first half of Lemma 1.

Next, consider the case *when the two firms differentiated their quality choice* at the first stage. As in the main text, without loss of generality, we denote the firm choosing the low-quality product (q_1) by firm 1 and the other firm by firm 2. If at the same time *neither firm provides preference information*, each consumer derives the following expected utilities from purchasing firm 1's or firm 2's product, respectively,

$$\mu_1 = V + q_1/2 - p_1, \quad \mu_2 = V + q_1/2 + \Delta/2 - p_2, \quad \text{where } \Delta = q_2 - q_1. \tag{5}$$

In this case, the price competition at the second stage results in

$$\begin{aligned} &p_1 = 0,\ p_2 = \Delta/2; \quad \pi_1 = 0,\ \pi_2 = \Delta/2 - \delta; \quad \text{if } 0 \le \delta < \Delta/2; \\ &\quad p_1 = 0,\ p_2 = \delta; \quad \pi_1 = 0,\ \pi_2 = 0; \quad \text{if } \delta = \Delta/2; \\ &p_1 = \delta - \Delta/2,\ p_2 = \delta; \quad \pi_1 = \delta - \Delta/2;\ \pi_2 = 0; \quad \text{if } \delta > \Delta/2. \end{aligned} \tag{6}$$

Note that if $0 \le \delta < \Delta/2$, firm 1 has zero market share, and if $\delta > \Delta/2$, firm 2 has zero market share.

Finally, consider the case when *at least one firm provides preference information* (*still within the case of firms providing different qualities*). We will derive the result for the case when firm 1 provides preference information. The case where firm 2 or both firms provide preference information immediately follows by adjusting the profit outcomes by the cost of information provision. After learning her preferences, consumer i derives the following utilities from purchasing firm 1's or firm 2's product, respectively,

$$\mu_1 = V + \theta_i q_1 - p_1, \quad \mu_2 = V + \theta_i q_2 - p_2. \tag{7}$$

The consumer who is indifferent between buying from firm 1 or firm 2 has the marginal willingness to pay for quality equal to

$$\theta^* = (p_2 - p_1)/\Delta. \tag{8}$$

Consumers having $\theta \in [0, \min\{\theta^*, 1\}]$ buy from firm 1, and those with $\theta \in [\theta^*, 1]$ buy from firm 2 (when the market is fully covered—the condition that we check below). The profits of firm 1 and firm 2 are, respectively,

$$\pi_1 = p_1 \min\{1, \theta^*\} - c_{I\theta}, \quad \pi_2 = (p_2 - \delta)(1 - \min\{\theta^*, 1\}). \quad (9)$$

One obtains the equilibrium prices from simultaneously solving the first-order conditions of the above profit functions and checking that the second-order Hessian matrix is negatively semidefinite. The unique solution to the first-order conditions yields the following equilibrium prices:

$$\begin{aligned} p_1 = (\Delta + \delta)/3, \ \ p_2 = 2(\Delta + \delta)/3, \quad & \text{if } 0 \le \delta \le 2\Delta, \\ p_1 = \delta - \Delta, \ \ p_2 = \delta, \quad & \text{if } \delta > 2\Delta, \end{aligned} \quad (10)$$

and the equilibrium profits are

$$\begin{aligned} \pi_1 = (\Delta+\delta)^2/9\Delta - c_{I\theta}, \ \ \pi_2 = (2\Delta-\delta)^2/9\Delta, \quad & \text{if } 0 \le \delta \le 2\Delta, \\ \pi_1 = \delta - \Delta - c_{I\theta}, \ \ \pi_2 = 0, \quad & \text{if } \delta > 2\Delta. \end{aligned} \quad (11)$$

Table 2 is now immediately obtained by rearranging the above results under different ranges of δ. Finally, the full market coverage condition is checked by ensuring that the lowest-valuation consumer ($\theta = 0$) prefers buying q_1 to not buying anything. Substituting the equilibrium price into $V - p_1 > 0$ yields that the assumed condition $V > (\Delta + \delta)/3$ is the condition for the market being fully covered. This completes the proof. □

Proof of Proposition 1. If $\delta < \Delta/2$, using the corresponding part of Table 2, we have that if neither firm provides preference information, the firm choosing the low-quality product has profit $\pi_{1,NI} = 0$. On the other hand, if the firm choosing the low-quality product provides preference information, it obtains a profit $\pi_{1,I_\theta} = (\Delta + \delta)^2/9\Delta$ gross of the information cost. Thus the benefit of providing preference information to the low-quality firm is

$$\pi_{1,I_\theta} - \pi_{1,NI} = (\Delta + \delta)^2/9\Delta > 0. \quad (12)$$

Similarly, the benefit of providing preference information to the firm choosing high quality is given by

$$\pi_{2,I_\theta} - \pi_{2,NI} = (2\Delta - \delta)^2/9\Delta - (\Delta/2 - \delta). \quad (13)$$

Comparing (12) and (13), we find that if $\delta < \Delta/2$, the low-quality firm's incentive to provide preference information is higher than that of the high-quality firm by $(\Delta - 2\delta)/6 > 0$. On the other hand, in the case $\delta > \Delta/2$, the above steps result in that the high-quality firm's incentive to provide preference information is higher than that of the low-quality firm by $(2\delta - \Delta)/6 > 0$. This completes the proof. □

Proof of Corollary 1. According to Proposition 1, the low-quality firm has a higher incentive to provide preference information when $\delta < \Delta/2$. According to the results in the proof of Lemma 1, when $\delta < \Delta/2$, if neither firm provides preference information, the price competition results in the low-quality firm having zero market share. If the low-quality firm provides information to help consumers resolve their uncertainty on quality preference, the resulting equilibrium prices and profits are as shown in the first line of Equation (10). Substituting the equilibrium price expression into Equation (8), we find that the demand for the low-quality firm is coming from consumers with $\theta \in [0, \theta^*]$, where

$$\theta^* = (p_2 - p_1)/\Delta = (\Delta + \delta)/3, \quad (14)$$

which is positive but smaller than 1/2 when $\delta < \Delta/2$. In other words, whether preference information is provided or not, the low-quality firm has a smaller market share than the high-quality firm when $\delta < \Delta/2$.

Similarly, the high-quality firm is the one with the lower market share (with or without the preference-information provision) when $\delta > \Delta/2$. In the case where $\delta = \Delta/2$, firms have equal market share and equal incentive to provide preference-revealing information. This completes the proof. □

Proof of Proposition 2. We first show that if the upper bounds in condition (1) are not satisfied, no preference information is provided in the equilibrium. To see this, note that if $\delta > 2\Delta$, the high-quality product is not chosen by either firm. Therefore the equilibrium profits before taking the cost of information into consideration are zero regardless of the information-provision decision, and hence, neither firm has an incentive to provide preference information at any positive cost. When $\delta < 2\Delta$, it is straightforward to check that the incentive by either firm to provide preference information is bounded from above by the upper bound on $c_{I\theta}$ in condition (1).

We now derive the quality and service choice of the firms given the pricing subgame results reported in Lemma 1. Each firm has four possible actions at stage 1 of the game corresponding to the choice of offering high- or low-quality product, with or without providing preference information. It thus generates 16 strategic profiles in total. If condition (1) is satisfied, the subset of strategic profiles where two firms choose product of the same quality $\{(q_j, NI); (q_j, NI)\}$, $\{(q_j, NI); (q_j, I_\theta)\}$, and $\{(q_j, I_\theta); (q_j, I_\theta)\}$ with $j = 1, 2$ are strictly dominated because according to Table 2, the unilateral deviation by one firm to choose different quality and offer preference information results in positive profits for both firms. Hence, under condition (1), in a pure-strategy equilibrium, firms choose different quality levels. Furthermore, because consumers will learn their quality preference as long as one of the two firms provides preference information, and information provision is costly, it cannot be an equilibrium outcome in a pure-strategy equilibrium for both firms to provide preference information. Therefore, given condition (1), in a pure-strategy equilibrium, firms are differentiated in quality and *exactly* one of them provides preference-revealing information in equilibrium.

If $\delta < \Delta/2$, profits in the pricing subgame for the two differentiated-quality firms are given by the first matrix in Table 2. Comparing the top left with the top right boxes of the matrix, we find that if neither firm provides preference information, the high-quality firm wants to do so if and only if

$$\pi_2((q_1, NI); (q_2, I_\theta)) - \pi_2((q_1, NI); (q_2, NI)) \ge 0, \quad (15)$$

which yields the following parameter condition on information-provision cost:

$$c_{I\theta} \le \frac{2\delta^2 + 10\delta\Delta - \Delta^2}{18\Delta}. \quad (16)$$

Comparing the top right with the bottom right boxes of the same matrix in Table 2, we see that the low-quality firm will not provide preference information when the high-quality firm chooses to do so. Comparing the top left with the bottom left boxes of the first matrix in Table 2, we find that the low-quality firm wants to provide preference information when the high-quality firm does not if and only if

$$\pi_1((q_1, I_\theta); (q_2, NI)) - \pi_1((q_1, NI); (q_2, NI)) \geq 0, \tag{17}$$

which yields the following parameter condition on information-provision cost:

$$c_{I\theta} \leq \frac{(\Delta+\delta)^2}{9\Delta}. \tag{18}$$

Comparing the bottom left and the bottom right boxes of the same matrix in Table 2, it is straightforward to see that the high-quality firm has no incentive to deviate and provide preference information as well when the low-quality firm chooses to do so. Note that $(2\delta^2 + 10\delta\Delta - \Delta^2)/18\Delta < (\Delta + \delta)^2/9\Delta$ when $\delta < \Delta/2$, which leads to the range of unique equilibrium results shown in the first part of Proposition 2. The verification for the case of $\delta > \Delta/2$ follows similar logic and procedure. This completes the proof. □

Claim (Stated in Footnote 13). *In the mixed-strategy equilibrium of the model in* §4.1, *if Proposition* 2 *implies a unique equilibrium correspondence between preference-information provision and quality level* (*i.e., the pure-strategy equilibrium is unique up to renaming the firms*), *the quality-information outcome combinations in the unique mixed-strategy equilibrium are the same as in the pure-strategy equilibrium.*

Proof (Includes the Mixed-Strategy Derivation). Let us first consider the case when the unique pure-strategy equilibrium results in choices of (q_1, I_θ) and (q_2, NI). According to Proposition 2, this means that

$$\frac{2\delta^2 + 10\delta\Delta - \Delta^2}{18\Delta} < c_{I\theta} < \frac{(\Delta+\delta)^2}{9\Delta}. \tag{19}$$

First, note that the mixed strategy in quality and information provision has to be mixed in the quality choice (by mixed in this proof, we will always mean nondegenerately mixed). This is because otherwise undifferentiated Bertrand competition results in nonpositive profits, and according to Lemma 1, either firm will want to deviate to the other quality choice. Consider now the information provision decision of the firm that offers q_2. If the firm provides preference information, then the lower bound on the information cost in condition (19) guarantees that this firm has negative profits, whether the other firm chose the high- or the low-quality product. Therefore, (q_2, I_θ) is never a part of an equilibrium strategy.

Let us now look for an equilibrium in which the firm mixes between (q_2, NI) and (q_1, I_θ), and then rule out (q_1, NI) as a part of a mixed strategy. Denote the probability of offering (q_2, NI) by r. Then the indifference between the strategies (q_2, NI) and (q_1, I_θ) implies

$$\begin{aligned} 0\cdot r + \frac{(2\Delta-\delta)^2}{9\Delta}(1-r) &\equiv \mathrm{E}\pi(q_2, NI) = \mathrm{E}\pi(q_1, I_\theta) \\ &\equiv -c_{I\theta}(1-r) + \left(\frac{(\Delta+\delta)^2}{9\Delta} - c_{I\theta}\right) r, \end{aligned} \tag{20}$$

from which we have

$$\begin{aligned} r &= \frac{(2\Delta-\delta)^2 + 9c_{I\theta}\Delta}{(2\Delta-\delta)^2 + (\Delta+\delta)^2} \quad \text{and} \\ \mathrm{E}\pi &= \frac{(2\Delta-\delta)^2((2\Delta-\delta)^2 - 9c_{I\theta}\Delta)}{9\Delta((2\Delta-\delta)^2 + (\Delta+\delta)^2)} > 0. \end{aligned} \tag{21}$$

This defines an equilibrium in mixed strategies in q and I_θ, which has the same quality-information combinations as in the pure-strategy equilibrium. It remains to show that (q_1, NI) cannot be a part of an equilibrium. To see this, assume the contrary. Then the choice of (q_1, NI) yields zero equilibrium profit, because any choice of the other firm (q_1, NI), (q_1, I_θ), or (q_2, I_θ) leads to zero profit to this firm. From the indifference, we must also have that (q_2, NI) results in zero profit as well. However, note that if a firm chooses (q_2, NI), according to Lemma 1, it will have positive profits unless the other firm chooses the same strategy, in which case it will have zero profits. Therefore, the expected profit under the choice of (q_2, NI) is positive as far as the probability of either of the strategies (q_1, NI) or (q_1, I_θ) is positive. This is a contradiction with the existence of the mixed strategy involving (q_1, NI).

The case of when the unique pure-strategy equilibrium results in choices of (q_2, I_θ) and (q_1, NI) follows exactly the same steps as above by switching q_2 and q_1. The proof is complete. □

Proof of Proposition 3. If a firm does not provide quality-revealing information, consumers do not know the quality of its product. Therefore, it is the strictly dominant strategy for a firm to offer low-quality product if it does not provide quality information but expects positive sales. Therefore, consumers expect the quality to be low if this type of information is not offered. A low-quality firm then does not change consumer perceptions at all by providing quality information, but spends a fixed cost c_{Iq}. Hence, it is a dominant strategy for the low-quality firm to not provide this type of information. The proof is complete. □

Proof of Proposition 4. Given condition (2), and the results of Proposition 2 and Lemma 2, the high-quality seller is guaranteed a positive profit if it offers high quality, provides quality-revealing information, and if $\delta > \Delta/2$, and then provides preference-for-quality revealing information, whereas the other firm does not provide quality-revealing information. Therefore, one of the firms will choose the higher quality and provide information about quality (otherwise, there would be zero profits for both firms), whereas the other one will provide low quality and no quality-revealing information. Given this, we are in the situation as in Proposition 2, and the results about who may provide preference-for-quality revealing information follows. The proof is complete. □

Proof of Corollary 3. The first result directly follows from Proposition 4. The second claim (neither firm providing information) follows because otherwise profits of the firm providing quality-revealing information are negative. Finally, if only the cost of preference-revealing information provision is too high, then this type of information will not be provided, but if one of the firms chooses high quality and provides information about it, while the other firm does not provide information about quality, the profits of the low-quality firm will be zero and the profits of the high-quality

firm will be $\Delta/2 - \delta - c_{Iq}$. Therefore, one firm providing high quality and the other firm providing low quality with the high-quality firm providing information about quality is the equilibrium as far as $\Delta/2 - \delta - c_{Iq} > 0$. The proof is complete. □

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