

Quality Disclosure Formats in a Distribution Channel

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Firms normally disclose quality information to consumers using two alternative formats: either directly to consumers or indirectly through downstream retailers. This study investigates optimal disclosure strategies/formats in a channel setting with bilateral monopolies. It shows that retail disclosure leads to more equilibrium information revelation. This is because the manufacturer can, through wholesale price cuts, partially absorb the retailer's effective disclosure cost and thus increase the retailer's incentive for disclosure. The conditions under which a particular disclosure format arises as the manufacturer's optimal choice are also examined. Even though direct disclosure is the *ex post* dominated option, the manufacturer may benefit from committing *ex ante* to the direct disclosure format when the cost of disclosure is sufficiently high.

Key words: communication; disclosure; disclosure format; distribution channel; quality

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1. Introduction

Firms typically know more about their product quality than prospective consumers. The proliferation of new products, in many markets ranging from automobiles, computers, electronics, to fashion, has increasingly led to shorter product lifespan and consumer uncertainty about quality. In these markets, quality disclosure has been recognized as an important information revelation means to address the information asymmetry problem (e.g., Jovanovic 1982, Guo and Zhao 2009). Nevertheless, the manner in which quality information is disclosed to consumers varies significantly. Some manufacturers employ product labels, traditional media (e.g., newspapers, television), or expert certifications (e.g., *Consumer Reports*, ISO 9000) to disclose product information directly to consumers. For example, computer processor producers such as Intel and AMD normally invest in national advertisements to inform consumers of the quality of their newly introduced products. In other markets such as cosmetics, fashion, medicine, and real estate, the dissemination of quality information to consumers is typically through downstream partners using, for example, free samples and returns, sales assistance, in-store media, etc.¹ Moreover, the ubiquity of the Internet has resulted in significant enhancement in the scope and credibility

of seller information disclosure. Many retailers (e.g., Amazon) have set up online forums where consumers can post and browse through each other's product usage experiences, representing a credible mechanism for sellers to provide truthful product information (Chen and Xie 2008). These quality disclosure arrangements can be classified into two formats. In the first—the direct disclosure format—only the upstream firm is involved in the disclosure process. In the second—the retail disclosure format—the downstream firm retains control over information revelation although the upstream firm can influence the retailer's disclosure behaviors (e.g., through wholesale price cuts, trade promotions, or advertising allowances).

In this paper, I seek to provide insights into two issues regarding quality disclosure in a distribution channel. First, I am interested in the impacts of the direct versus the retail disclosure format on the revelation of quality information. Would more or less information be voluntarily revealed to consumers when it is the upstream (versus the downstream) firm that controls the disclosure decision? Answering this question can shed light on firms' optimal quality disclosure strategies under different disclosure formats. Second, I investigate the payoff implications of the alternative disclosure formats. Which disclosure format would lead to higher equilibrium *ex ante* payoff and arise as the upstream firm's choice? Should the upstream firm seize complete control over the disclosure decision or cede this control to the downstream

¹ It has been recognized that a significant function of downstream firms (e.g., retailers) in a distribution channel is to provide information to consumers (e.g., Churchill et al. 2000, Kotler 2003).

partner? Should a manufacturer establish quality disclosure capabilities internally at the upstream level, or at the downstream level through the adoption of channel partners with this capability? The disclosure format choice is a critical decision because the development of quality disclosure capabilities typically involves substantial upfront investments, whereas the need for disclosure may arise frequently with the proliferation of new products. For example, to implement the direct disclosure format, a manufacturer may have to invest in the setup and maintenance of an advertising/communications department and in employee management (e.g., recruiting, training, and retention). The establishment of online forums to provide truthful product information through consumer-posted reviews also represents a significant strategic move (Chen and Xie 2008). Similarly, the use of sales assistance or in-store media to communicate product information entails substantial investment and commitment.

To address these questions, I consider a three-stage setup of discretionary and truthful quality disclosure in a channel setting with bilateral monopolies. Consumers are heterogeneous in their valuation of quality and the quality is initially unknown. The direct versus the retail disclosure format is chosen and committed to in the first stage of the game. The firms can become privately informed of the quality and voluntarily disclose it at a cost to the consumers. They make disclosure and pricing decisions sequentially in the second and the third stage, respectively. The upstream firm can make a take-it-or-leave-it wholesale price offer to the downstream firm who then decides on the retail price.

In the basic model, the upstream firm can select either but not both of the disclosure formats. This represents a stark comparison to highlight the basic difference between the disclosure formats, which is the locus of the disclosure decision right. It also captures situations when it is too costly to develop the disclosure capability for both firms. It is shown that, even though the manufacturer's and the retailer's incentives for disclosure may not agree with each other under the retail disclosure format, more information is revealed than under the direct disclosure format. This can be attributed to the endogenous impact of the wholesale price on the retailer's disclosure, which essentially leads to an equilibrium partial shift of the cost of disclosure from the upstream to the downstream firm. Therefore, both firms have a lower effective disclosure cost than that faced by the upstream firm under the direct disclosure format, resulting in more equilibrium information revelation.

The upstream firm obtains a lower (higher) equilibrium ex ante profit under the direct disclosure format when the cost of disclosure is relatively low (high).

This result identifies the conditions under which the upstream firm should favor a particular disclosure format. However, it may appear at odds with the intuition that the benefit of transferring the disclosure cost to the downstream firm under the retail disclosure format is more significant as information revelation becomes more costly. This result arises because of the information withholding effect whereby the firms can credibly commit not to reveal relatively lower quality levels (and thus not to incur the disclosure cost) as disclosure becomes more costly. This information withholding effect is stronger for the direct disclosure format under which less information is revealed in equilibrium. This explains why the upstream firm can be better off under the direct disclosure format, when the per-disclosure cost becomes sufficiently high.

I extend the basic model to an alternative timing in which the disclosure format choice can be ex post made after the quality is learned.² This could represent scenarios when quality is more difficult to modify in the short run than the disclosure format choice. It is shown that direct disclosure is the ex post dominated option for the manufacturer at any quality level. Intuitively, all else being equal, it is beneficial for the manufacturer to shift the cost of disclosure to the retailer. This result further reinforces the above discussion on the mechanism underlying the manufacturer's ex ante preference for direct disclosure: By committing not to transfer the disclosure cost to the retailer, the manufacturer can credibly withhold relatively lower quality levels and thus reduce the need to incur the disclosure cost. Moreover, this endogenously justifies the implicit assumption in the basic model that the disclosure formats are ex ante perfect substitutes. That is, even without setup cost considerations, there is zero incremental gain from developing disclosure capabilities by both firms.

I further investigate the robustness of the results in an extended setup in which a firm's disclosure efforts cannot communicate the quality to all consumers. I characterize a separating perfect Bayesian equilibrium in which the retail price serves as a signal of quality to the uninformed consumers. Conditional on the chosen disclosure format(s), the firms' equilibrium disclosure strategies remain unchanged even when disclosure is imperfect. This is because, at the disclosure threshold, the quality can be (naturally) signaled without retail price distortion, leading to the same *marginal* incentive for information revelation as in the basic model. Nevertheless, the informativeness of quality disclosure may influence the choice of disclosure format. The manufacturer's equilibrium payoff

² Throughout the paper, where no confusion arises, the term ex ante (ex post) is used to represent the scenario before (after) the quality is learned by the firms.

under the direct disclosure format increases with more informed consumers, although it remains unchanged under the retail disclosure format. Moreover, in contrast to the case of perfect disclosure, these two disclosure formats may complement each other in increasing the total number of informed consumers. That is, it may be beneficial for the manufacturer to adopt both disclosure formats from an ex post perspective (and thus from an ex ante perspective as well).

There is a large literature on voluntary provision of verifiable information, including Grossman and Hart (1980), Grossman (1981), Milgrom (1981), and Okuno-Fujiwara et al. (1990). It is established that any private information will be voluntarily unraveled as long as disclosure and verification are costless. Other studies examine factors that may lead to partial disclosure, e.g., disclosure costs (Viscusi 1978, Jovanovic 1982), information acquisition costs (Matthews and Postlewaite 1985, Farrell 1986, Shavell 1994), limited consumer understanding (Fishman and Hagerty 2003), and competition (Board 2009). Lizzeri (1999) investigates certification intermediaries' optimal strategies. Relatedly, Guo and Zhao (2009) examine the effects of disclosure cost and disclosure timing on duopoly firms' equilibrium information revelation strategies and payoffs.

Chen and Xie (2005) examine when and how competing firms should adapt their marketing mix decisions (i.e., pricing and advertising) when preference fit information is provided to consumers by third-party reviews. Chen and Xie (2008) investigate the interaction between seller-supplied and consumer review information, which generates asymmetric uncertainty on product valuation between consumers and a monopoly firm. In a monopoly setting, Bhardwaj et al. (2008) address optimal—seller- versus buyer-initiated—sales presentation formats as a signaling device. In contrast to these studies, this paper investigates optimal quality disclosure strategies in a channel setting. Moreover, the equilibrium format of information transmission—either directly to consumers or indirectly through the downstream firm—is examined in the current paper.

The rest of this paper is organized as follows. Section 2 lays out the model setup. The analysis and results for the basic model are presented in §3. Model extensions on ex post disclosure format choice and imperfect disclosure are examined in §4. Section 5 discusses managerial implications, identifies

potential directions for future research, and concludes the paper.

2. Model

Consider a distribution channel with an upstream firm that produces a good (or service) and a downstream firm that distributes the product to end consumers. The product cannot be sold directly to the end consumers but has to be distributed through the downstream firm. The upstream firm will be referred to as the manufacturer (M) and the downstream firm as the retailer (R). The firms' marginal costs of production/operation are constant and normalized to zero. When no transaction occurs, both the firms' and the consumers' utilities are, without loss of generality, set to zero.

The mass of consumers in the market is normalized to one. Each consumer demands at most one unit of the product from the retailer. The consumers' surplus of purchase is given by

$$V = \theta q - p, \quad (1)$$

where q denotes the quality of the manufacturer's product, θ represents consumer type, and p is the price charged by the retailer. The quality could represent, for example, gas mileage or horsepower for automobiles, nutritional content for food, technical specifications for electronics, etc. Both the firms and the consumers are risk neutral, maximize expected payoffs, and maintain the prior belief that the quality of the product follows a uniform distribution between zero and one: $q \sim U[0, 1]$. Consumer heterogeneity in willingness to pay or valuation for quality is captured by the index θ , which is assumed to be uniformly distributed between zero and one: $\theta \sim U[0, 1]$.

I consider the following three-stage sequence of moves as shown in Figure 1. In the first stage of the game, the manufacturer decides on and commits to a disclosure format through which privately known quality information can be disclosed to the consumers. There are two disclosure formats to select, as illustrated in Figure 2. These alternative disclosure formats differ in terms of whether it is the manufacturer or the retailer that can communicate the quality information. In particular, the manufacturer can communicate directly to the consumers using, for example, product labels, third-party certifications, or advertisements (direct disclosure; M-C). Alternatively, the man-

Figure 1 Timing of the Basic Model

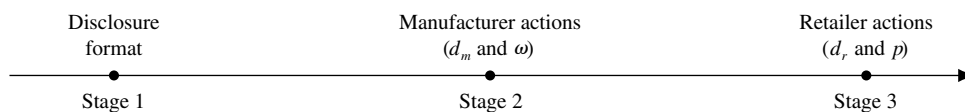
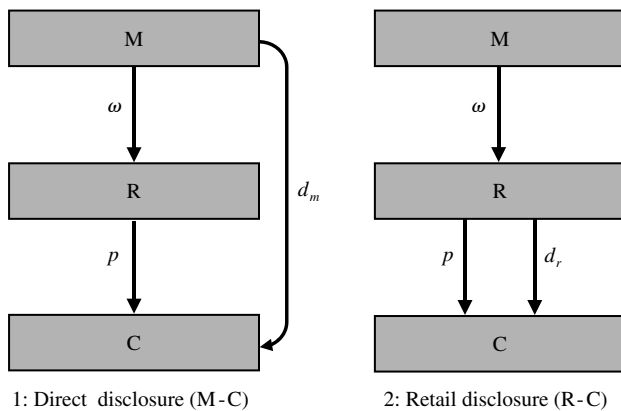


Figure 2 Quality Disclosure Formats



ufacturer can offer incentives (e.g., wholesale price cuts, trade promotions, advertising allowances) to the retailer and allow the retailer to decide whether to disclose the quality information through, for instance, free samples/returns, sales assistance, or in-store media (retail disclosure; R-C). The selected disclosure format will then become common knowledge to all parties.

In the second stage, the firms become informed of the quality q of the product. The quality will remain the firms' private knowledge and unknown to the consumers unless it is voluntarily disclosed. The manufacturer can then make two decisions. It can decide whether to disclose the quality, if the direct disclosure format is adopted in the first stage. The manufacturer also sets, on a take-it-or-leave-it basis, a per-unit wholesale price ω for transferring the product to the retailer. Constant wholesale prices in vertical relationships are frequently implemented in practice and commonly utilized in the literature. Previous studies have investigated the rationalization for the equilibrium occurrence of constant wholesale prices (e.g., Iyer and Villas-Boas 2003).

The retailer takes actions in the third stage. If the retail disclosure format has been implemented, the retailer can decide whether to disclose the quality. Moreover, the retailer sets the retail price p . It is assumed that no price discrimination across different consumer types can be exercised. The retailer then orders the product from the manufacturer and resells it to the consumers. Finally, the consumers make their purchase decisions based on their updated belief about the quality of the product, which can be influenced by the firms' disclosure strategies.

A firm incurs an aggregate cost c in disclosing the quality. This could represent the costs to acquire verifiable quality information (e.g., through product testing, marketing research, or reputed third-party certifications) and/or the costs to transmit the acquired information to the consumers (e.g., advertising costs, free samples/returns, product demonstration, sales

assistance efforts, etc). To rule out the trivial case that the quality information is never disclosed, it is assumed throughout the paper that the disclosure cost is positive but not too high, i.e., $0 < c < 1/16$. As will be shown, when $c \geq 1/16$, no information will be disclosed at all under either disclosure format in the basic model. Moreover, I assume that information revelation is credible and truthful. As a result, a firm's disclosure decision amounts to either revealing the true quality or remaining silent.

It is deliberately assumed that the firms have symmetric information about quality under either disclosure format. As a result, the essential difference captured in this paper between the disclosure formats is the locus of the ultimate decision right for quality disclosure. Thus, the manufacturer's disclosure format choice amounts to either centralizing the disclosure decision or delegating it to the retailer. This allows us to highlight the manufacturer's strategic consideration in disclosure format selection. It is also important to emphasize that the possession of quality information is not equivalent to the possession of disclosure capability. The development of disclosure capabilities may involve long-term strategic moves and substantial upfront investments. Therefore, I intentionally rule out the scenario that, under the direct disclosure format, the retailer's disclosure capability can be enabled simply through learning about the quality from the manufacturer's disclosure. Nevertheless, I will investigate the scenario when both firms can disclose the quality in §4.

Some additional discussions on the model setup and timing are warranted. Note that the manufacturer's disclosure format choice precedes the firms' disclosure and pricing decisions. This allows us to assess the firms' equilibrium disclosure strategies and ex ante payoffs under different disclosure formats. In addition, the manufacturer commits to a disclosure format prior to being informed of the quality. This would hold when the setup of communication/disclosure vehicles constitutes a long-term strategic move and entails significant human and technological resources, whereas the market is characterized by proliferation of new products, shorter product lifetime, and increasing consumer uncertainty about quality. Nevertheless, in §4.1, I will also investigate the case when the disclosure format is ex post determined after the quality becomes known. Moreover, the retailer's disclosure decision takes place after the wholesale price is set. This follows the standard Stackelberg setup in the literature and allows us to examine the interesting case when the manufacturer can strategically set its wholesale price to influence the retailer's disclosure strategy. This completes the discussion of the model setup. A summary of the model notation is presented in Table 1.

Table 1 Model Notation

Notation	Explanation
θ	Consumer willingness to pay for quality
q	Product quality
p	Retail price
ω	Wholesale price
c	Disclosure cost
d_f	Disclosure strategy for firm $f \in \{m, r\}$, $d_f \in \{1, 0\}$
\bar{q}	Expected quality conditional on no disclosure
\hat{q}	Quality disclosure threshold
\tilde{q}	Updated belief on quality ($\tilde{q} \in \{q, \bar{q}\}$)
D	Retail demand
Π	Coordinated channel's profit
Π_f	Profit for firm $f \in \{m, r\}$ in a decentralized channel
$\hat{\omega}$	Cutoff wholesale price to induce retail disclosure
$o \in \{b, *, \#\}$	Equilibrium outcome under benchmark, direct, and retail disclosure format
Extensions	
\hat{q}_d	Quality threshold between direct disclosure and no disclosure
\hat{q}_r	Quality threshold between retail disclosure and no disclosure
α	Informativeness of disclosure
$\hat{\alpha}$	Size of informed consumers ($\hat{\alpha} \in \{\alpha, \alpha(2 - \alpha)\}$)
\hat{q}	Expected quality for uninformed consumers
$B^s(p)$	Uninformed consumers' equilibrium belief function
$p^s(q)$	Retail price function under the separating perfect Bayesian equilibrium

3. Analysis and Results

I start the analysis by characterizing the firms' equilibrium disclosure strategies. Next, the equilibrium ex ante profits under each disclosure format are derived, and the conditions under which a particular disclosure format arises in equilibrium in the first stage of the game are determined. In solving the game, backward induction is used to ensure subgame perfection.

3.1. Disclosure Strategies

Let us now investigate the equilibrium disclosure strategies when the quality is a priori unknown to the consumers. To this end, the disclosure format is taken as given and the analysis proceeds with the subgame starting from the second stage. To highlight the role of double marginalization in the equilibrium disclosure strategies, I will analyze the benchmark case in a coordinated channel where channel conflict in pricing is absent (e.g., with channel integration or two-part tariffs). I will then investigate the cases when the manufacturer has to sell the product through the retailer by charging a constant wholesale price. The disclosure format whereby the manufacturer communicates directly to the consumers is examined first, which is followed by the scenario when the disclosure decision is made by the retailer.

Denote the disclosure decision of a firm $f \in \{m, r\}$ as $d_f(q): [0, 1] \rightarrow \{1, 0\}$, where $d_f = 1$ means *disclosing* and $d_f = 0$ represents *not disclosing*. For tie-breaking,

it is assumed that a firm will remain silent if it is indifferent between disclosing and not disclosing. To derive the equilibrium solution, it is necessary to specify both the consumers' updated belief about quality given the firms' disclosure decisions, and the firms' optimal disclosure strategies in anticipation of the influence exerted on the updating of the consumers' belief. Let us denote the consumers' expectation of quality when no information is revealed by any firm as \bar{q} , and the threshold below which the quality is not disclosed as \hat{q} . To facilitate exposition, the superscript $o \in \{b, *, \#\}$ is used throughout the paper to represent the equilibrium outcomes under the benchmark, the direct disclosure format, or the retail disclosure format, respectively.

3.1.1. Benchmark. Given the coordinated channel's disclosure decision, the consumers update their belief about the (expected) quality, \tilde{q} , which is equal to the true quality q when it is disclosed, or \bar{q} when no information is revealed. The value of $\tilde{q} \in \{q, \bar{q}\}$ becomes common knowledge to all parties at the time when the retail price is set and the consumers make purchase decisions. Given \tilde{q} and p , a consumer will buy the product if and only if $\theta > p/\tilde{q}$. This leads to the demand function $D = 1 - p/\tilde{q}$. The channel's profit is hence $\Pi = p(1 - p/\tilde{q}) - c$ if the quality is revealed to the consumers, and $\Pi = p(1 - p/\bar{q})$ if otherwise. It follows that the equilibrium retail price is $p^b = \tilde{q}/2$, yielding an expected payoff of $q/4 - c$ or $\bar{q}/4$, when the quality is disclosed or withheld, respectively. As a result, the quality would be revealed if and only if $q > \hat{q}$, where $\hat{q} = \min\{\bar{q} + 4c, 1\}$ represents the disclosure threshold.

By definition, the consumers' conditional expectation \bar{q} , in anticipation of the channel's optimal disclosure strategy, is given by $\bar{q} = E[q | q \leq \hat{q}] = \min\{\bar{q} + 4c, 1\}/2$. Solving this allows us to derive the consumers' equilibrium conditional expectation, $\bar{q}^b = 4c$. It follows that the equilibrium disclosure threshold is given by $\hat{q}^b = \bar{q}^b + 4c = 8c$.

This benchmark model extends Jovanovic (1982) to the case with heterogeneous consumers. The equilibrium disclosure strategy is characterized by partial information revelation: The quality is disclosed if and only if it is above a particular threshold. The partial disclosure equilibrium is sustainable because information revelation is too costly for low levels of quality.

3.1.2. Direct Disclosure (M-C). Consider then the scenario in an uncoordinated channel when the manufacturer can disclose the quality information directly to the consumers. Given the consumers' updated belief $\tilde{q} \in \{q, \bar{q}\}$ and the wholesale price $\omega \leq \tilde{q}$, the retailer's profit function is $\Pi_r = (p - \omega)(1 - p/\tilde{q})$. The optimal retail price is then $p(\omega | \tilde{q}) = (\tilde{q} + \omega)/2$

and the equilibrium demand is $D(\omega | \bar{q}) = (\bar{q} - \omega) / (2\bar{q})$, conditional on the wholesale price ω and the updated quality \bar{q} .

In anticipation of the retailer’s optimal response, the manufacturer’s payoff is given by $\Pi_m = \omega D(\omega | \bar{q}) - d_m c = \omega(\bar{q} - \omega) / (2\bar{q}) - d_m c$. Optimizing with respect to the wholesale price leads to $\omega^* = \bar{q} / 2$. Therefore, if the manufacturer chooses to disclose the quality, it will obtain an expected profit that is equal to $q / 8 - c$. If instead the manufacturer selects to withhold the quality information, its expected profit would be $\bar{q} / 8$. We can then determine the manufacturer’s optimal disclosure strategy, conditional on \bar{q} . It is evident that the manufacturer will reveal the quality if and only if $q > \hat{q}$, where $\hat{q} = \min\{\bar{q} + 8c, 1\}$ denotes the manufacturer’s disclosure threshold.

It follows that the consumers’ conditional expectation \bar{q} , given the manufacturer’s optimal disclosure strategy, is $\bar{q} = E[q | q \leq \hat{q}] = \min\{\bar{q} + 8c, 1\} / 2$. Solving this leads to the consumers’ equilibrium conditional expectation, $\bar{q}^* = 8c$. The equilibrium threshold, above which the manufacturer discloses the quality, is given by $\hat{q}^* = \bar{q}^* + 8c = 16c$.

PROPOSITION 1. *Under the M-C format, there exists a unique equilibrium where $d_m(q) = 1$ if and only if $q > \hat{q}^* = 16c$.*

The equilibrium disclosure threshold under the M-C format, \hat{q}^* , is higher than that in the coordinated channel, $\hat{q}^b = 8c$. This implies that the manufacturer reveals less information when it distributes the product through the decentralized channel. Intuitively, channel decentralization leads to a lower marginal benefit of information revelation. Note that the change in the manufacturer’s expected profits under the M-C format when it discloses versus when it does not is $(q - \bar{q}) / 8$. In contrast, information revelation leads to an increase in the coordinated channel’s expected payoff by $(q - \bar{q}) / 4$, which is higher than that in the decentralized channel. Given that the cost of disclosure remains the same, the manufacturer distributing through the decentralized channel thus has a lower incentive to disclose the quality.

3.1.3. Retail Disclosure (R-C). Let us now consider the case when it is the retailer who decides whether to disclose the quality. Under the R-C format, the manufacturer cannot directly reveal the quality to the consumers, but can influence the retailer’s disclosure decision through the setting of the wholesale price. Let us start by investigating the retailer’s optimal decisions in the third stage of the game, given the wholesale price ω . If the retailer decides to disclose the quality, its profit function will be $\Pi_r = \max\{(p - \omega)(1 - p/q) - c, 0\}$. This yields the optimal retail price $p(\omega | q) = (q + \omega) / 2$ if $\omega < q$, and the retailer will not

sell to the consumers if $\omega \geq q$. It follows that the equilibrium conditional demand is $D(\omega | q) = \max\{(q - \omega) / (2q), 0\}$, and the equilibrium conditional payoff for the retailer is given by

$$\Pi_r(\omega | q) = \begin{cases} (q - \omega)^2 / (4q) - c & \text{if } \omega < q, \\ 0 & \text{if otherwise.} \end{cases} \quad (2)$$

Conversely, if the retailer does not reveal the quality, its payoff will be $\Pi_r = \max\{(p - \omega)(1 - p/\bar{q}), 0\}$. The optimal retail price would then be $p(\omega | \bar{q}) = (\bar{q} + \omega) / 2$ if $\omega < \bar{q}$, and the retailer does not sell to the consumers if otherwise. As a result, the equilibrium conditional demand is $D(\omega | \bar{q}) = \max\{(\bar{q} - \omega) / (2\bar{q}), 0\}$, and the equilibrium conditional payoff for the retailer is

$$\Pi_r(\omega | \bar{q}) = \begin{cases} (\bar{q} - \omega)^2 / (4\bar{q}) & \text{if } \omega < \bar{q}, \\ 0 & \text{if otherwise.} \end{cases} \quad (3)$$

Comparing $\Pi_r(\omega | q)$ with $\Pi_r(\omega | \bar{q})$, we can then determine the retailer’s optimal disclosure strategy, conditional on the manufacturer charging ω :

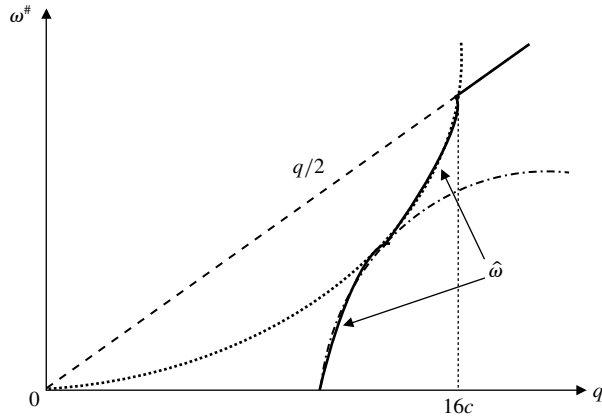
LEMMA 1. *Under the R-C format, in equilibrium the retailer discloses the quality (i.e., $d_r = 1$) if and only if $q > \bar{q} + 4c$ and $\omega < \hat{\omega}$, where*

$$\hat{\omega} = \begin{cases} \sqrt{\frac{q\bar{q}(q - \bar{q} - 4c)}{q - \bar{q}}} & \text{if } q < \bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c}, \\ q - 2\sqrt{q\bar{q}c} & \text{if otherwise.} \end{cases}$$

The retailer discloses the quality to the consumers if and only if the quality is sufficiently high and the wholesale price is sufficiently low. As the wholesale price increases, the retailer suffers from a lower profit margin for each unit of demand. This in turn implies a lower incentive to boost consumer demand through quality disclosure. As a result, there exists a unique cutoff point on the wholesale price, $\hat{\omega}$, that determines the conditions under which the retailer discloses or conceals the quality information. If the wholesale price is too high, the marginal benefit of information revelation cannot compensate for the disclosure cost, and the retailer is hence better off remaining silent. In addition, a necessary condition for retailer disclosure is that the quality is high enough. Should the quality be too low, revealing the quality is a dominated strategy even when the wholesale price is negligible such that the retailer can accrue all the benefit of increasing demand through quality revelation. Moreover, as illustrated in Figure 3, the cut-off wholesale price $\hat{\omega}$ increases with the quality q .

Let us then examine the manufacturer’s optimal decision in the second stage of the game. Should the retailer withhold the quality information, the manufacturer’s payoff would be $\Pi_m(\omega | \bar{q}) = \omega D(\omega | \bar{q}) = \omega \max\{(\bar{q} - \omega) / (2\bar{q}), 0\}$. This leads to the optimal wholesale price that is equal to $\bar{q} / 2$, and the expected

Figure 3 Optimal Wholesale Price Under the Retail Disclosure Format (When $\bar{q} < 8c$)



manufacturer payoff is $\bar{q}/8$. In contrast, should the retailer reveal the quality, the manufacturer would have a payoff that is equal to $\Pi_m(\omega | q) = \omega D(\omega | q) = \omega \max\{(q - \omega)/(2q), 0\}$. Therefore, the manufacturer's profit maximization problem, subject to the constraint that the charged wholesale price can induce the retailer to disclose the quality, is given by

$$\begin{aligned} \max_{\omega} \quad & \Pi_m(\omega | q) = \omega(q - \omega)/(2q) \\ \text{s.t.} \quad & \omega \leq \hat{\omega}. \end{aligned} \quad (4)$$

This gives rise to the optimal wholesale price, $\omega^\# = \min\{q/2, \hat{\omega}\}$, when the manufacturer offers enough incentive for the retailer to reveal the quality information to the consumers.

We are then ready to examine the equilibrium disclosure strategy under the R-C format. This is essentially determined by resolving the manufacturer's trade-off between distorting the wholesale price downward to $\omega^\# = \sqrt{q\bar{q}(q - \bar{q} - 4c)/(q - \bar{q})}$ while inducing retail disclosure, and charging a wholesale price of $\bar{q}/2$ while inducing information withholding by the retailer.³ Note that the manufacturer's expected payoff when information revelation is induced, $\Pi_m(\omega | q)$ in (4), when evaluated at the optimal wholesale price $\omega^\# = \min\{q/2, \hat{\omega}\}$, is increasing with q . This is because both the objective function and the constraint on the manufacturer's optimization problem, $\Pi_m(\omega | q)$ and $\hat{\omega}$, increase with a higher quality. As a result, similar to the M-C format, the equilibrium disclosure strategy here is characterized by partial information revelation.

PROPOSITION 2. *Under the R-C format, there exists a unique equilibrium where $d_r(q) = 1$ if and only if $q > \hat{q}^\# = 32(2\sqrt{2} - 1)c/7$.*

³Note that this trade-off and the downward distortion in wholesale pricing to induce retail disclosure occurs at the equilibrium disclosure threshold \hat{q} . When the quality is sufficiently high, the manufacturer can charge the unbounded optimal wholesale price (i.e., $\omega^\# = q/2$) while inducing information revelation by the retailer.

The disclosure threshold under the R-C format (i.e., $\hat{q}^\#$) is lower than that under the M-C format (i.e., $\hat{q}^* = 16c$). This suggests that the R-C format results in more information being revealed in equilibrium. Note that, for the quality information to be revealed to the consumers, both channel members' interests need to be coordinated. Nevertheless, there may be a conflict in the firms' incentives for quality disclosure. To align the retailer's interest in information revelation, as shown in Lemma 1, the wholesale price may have to be distorted downward from the unconstrained optimal level (i.e., $q/2$). As a result, in the presence of this incentive-compatibility concern, conventional wisdom may suggest that less information will be disclosed in equilibrium under the R-C format.

However, this is only part of the story, because the R-C format may also effectively shift the burden of the disclosure cost partially from the manufacturer to the retailer. Under the M-C format, the cost of disclosure is completely shouldered by the manufacturer. The retailer can then "free ride" on the manufacturer's communication efforts: With a constant wholesale price, the manufacturer cannot extract all the benefit of quality disclosure from the retailer. In contrast, under the R-C format, not only does information revelation need to be desired by both firms, but the cost of disclosure may in equilibrium be "shared" by both firms as well. On one hand, it is the retailer who has to directly incur the cost of disclosure, i.e., there is no free riding in quality disclosure from the retailer's perspective. On the other hand, in equilibrium, the cost of disclosure may not be completely carried by the retailer. In this case, the wholesale price serves not only to extract surplus from the retailer but also to manipulate the retailer's incentive for disclosure. To induce the retailer to disclose the quality, the manufacturer may have to cut the wholesale price. The discretion in the retailer's disclosure decision may hence, in equilibrium, lead to a partial absorption of the disclosure cost by the manufacturer. As a result, in equilibrium, the effective disclosure cost for either firm may be lower than that under the M-C format, which is indeed the case at the equilibrium quality disclosure threshold. Therefore, despite the potential conflict in the firms' incentives for disclosure, the firms are actually more compelled not to withhold information under the R-C format. This explains why the equilibrium quality disclosure threshold is driven down and more information is revealed when the ultimate disclosure right resides with the retailer.⁴

⁴Nevertheless, because the cost of disclosure is only partially transferred to the retailer, the equilibrium disclosure threshold under the R-C format is still higher than that in the coordinated channel, i.e., $\hat{q}^\# > \hat{q}^b = 8c$.

3.2. Payoff Implications

In this section, I investigate the firms' equilibrium ex ante payoffs under the alternative disclosure formats and determine which of the disclosure formats will arise, in equilibrium, in the first stage of the game. Let us start with the M-C format. Recall that when $q \leq \hat{q}^* = 8c$, the quality will be concealed, in equilibrium, leading to ex post payoffs of $\Pi_m = \bar{q}^*/8$ and $\Pi_r = \bar{q}^*/16$ for the manufacturer and the retailer, respectively. In comparison, any $q > \hat{q}^*$ will be disclosed such that the firms' equilibrium ex post payoffs are $\Pi_m = q/8 - c$ and $\Pi_r = q/16$, respectively. It follows that the firms' respective equilibrium ex ante payoffs are given by

$$\begin{aligned} \Pi_m^* &= \int_0^{\hat{q}^*} \bar{q}^*/8 dq + \int_{\hat{q}^*}^1 (q/8 - c) dq \\ &= 1/16 - c(1 - 16c), \end{aligned} \tag{5}$$

$$\Pi_r^* = \int_0^{\hat{q}^*} \bar{q}^*/16 dq + \int_{\hat{q}^*}^1 q/16 dq = 1/32. \tag{6}$$

Similar to the unilateral monopoly case in Guo and Zhao (2009), the manufacturer's equilibrium ex ante payoff first decreases and then increases with the disclosure cost c . This nonmonotonicity arises because a higher c increases not only the per-disclosure cost, but also the probability that relatively low quality levels are concealed (i.e., the equilibrium disclosure threshold \hat{q}^* increases with c). In contrast, the retailer's equilibrium ex ante profit does not change with the disclosure cost c .

Next, let us investigate the R-C format. There are four scenarios to consider in the second stage of the game. First, when $q \leq \hat{q}^\#$, no information will be revealed to the consumers, and the firms' equilibrium ex post payoffs will be $\Pi_m = \bar{q}^\#/8$ and $\Pi_r = \bar{q}^\#/16$ for the manufacturer and the retailer, respectively. These ex post payoffs are lower than those under the M-C format, because under the R-C format, the consumers have a lower expected quality conditional on no information being received. Equilibrium information revelation will arise when $q > \hat{q}^\#$, for which there are three scenarios depending on the level of distortion in the equilibrium wholesale price used to induce disclosure by the retailer. In particular, the second scenario occurs when $\hat{q}^\# < q \leq \bar{q}^\# + 2c + 2\sqrt{c^2 + \bar{q}^\#c}$. In this case, the quality is not sufficiently high, such that the retailer will not disclose the quality unless the wholesale price is sufficiently cut, i.e., $\omega^\# = \sqrt{q\bar{q}^\#(q - \bar{q}^\# - 4c)/(q - \bar{q}^\#)}$. Moreover, at this equilibrium wholesale price, the retailer will be able to earn a positive surplus. In contrast, as the quality becomes higher in the third scenario when $\bar{q}^\# + 2c + 2\sqrt{c^2 + \bar{q}^\#c} < q \leq 16c$, the retailer has a higher incentive for disclosure, such that the

manufacturer can charge an equilibrium wholesale price $\omega^\# = q - 2\sqrt{q\bar{q}^\#}$ to induce retailer disclosure while extracting all surplus from the retailer. That is, at this equilibrium wholesale price, the retailer earns zero profit while indifferent between disclosure and no disclosure. Finally, when the quality becomes sufficiently high (i.e., $q > 16c$), the manufacturer can "cheaply" induce retailer disclosure without distorting the optimal wholesale price—the incentive-compatibility constraint is not binding and $\omega^\# = q/2$ in (4). Summarizing the above four ex post scenarios leads to the firms' equilibrium ex ante payoffs under the R-C format. In comparison to the direct disclosure format, we have the following:

PROPOSITION 3. *Under the R-C format:*

- (i) *There exists a cutoff point $c^* > 0$ such that, if $c < c^*$ ($c > c^*$), the manufacturer's equilibrium ex ante payoff, $\Pi_m^\#$, is higher (lower) than that under the M-C format, Π_m^* .*
- (ii) *The retailer's equilibrium ex ante payoff, $\Pi_r^\#$, is lower than that under the M-C format, Π_r^* .*

This proposition indicates that the retailer is worse off under the R-C format. As discussed previously, this disclosure format permits the manufacturer to use the wholesale price more effectively to extract retailer surplus, leading to a partial shift of the disclosure cost from the manufacturer to the retailer. As a result, the retailer's equilibrium ex ante profit is undoubtedly lower than that under the M-C format when the disclosure cost is completely incurred by the manufacturer. This implies that the ability to disclose the quality may not necessarily be translated to increasing profitability for a retailer in a distribution channel.

One might follow the same reasoning to infer that the manufacturer would benefit from adopting the R-C format, especially when the disclosure cost c becomes higher. As information revelation becomes more costly, intuition suggests that the gain from transferring the disclosure cost to the retailer will be more significant. However, this proposition suggests the opposite: It is when the disclosure cost is relatively low that the manufacturer's equilibrium ex ante profit is higher under the R-C format than under the direct disclosure format. Moreover, the manufacturer is hurt by shifting the burden of the disclosure cost to the retailer when the disclosure cost is sufficiently high. Therefore, if the fixed costs of implementing the different disclosure formats are not significantly different from each other, the manufacturer should, in equilibrium, choose the R-C format when the cost of disclosure is relatively low, but advocate the M-C format when the disclosure cost is relatively high.

This result is driven by the endogenous and positive effect that the disclosure cost exerts on the extent to which the firms can hide relatively unfavorable

quality information from the consumers and thus save the disclosure cost. Note that the equilibrium disclosure thresholds (i.e., both $\hat{q}^\#$ and \hat{q}^*) increase with the disclosure cost c . More information would be concealed in equilibrium as the disclosure cost increases, in which case the information withholding effect would loom larger and become more dominant. This information withholding effect is stronger under the M-C format (i.e., $\partial\hat{q}^*/\partial c > \partial\hat{q}^\#/\partial c$), because the effective disclosure cost is higher for the manufacturer than for the retailer. Therefore, as c becomes sufficiently high, the manufacturer is better off adopting the M-C format and refraining from delegating the disclosure decision (and cost) to the retailer.

4. Extensions

In the basic model, it is implicitly assumed that the two disclosure formats are perfect substitutes. That is, the manufacturer chooses either, but not both, of the disclosure formats in the first stage of the game. This would hold if it is too costly to establish the disclosure capability for both the upstream and the downstream firms. Nevertheless, it would be interesting to investigate the robustness of this premise in the absence of cost considerations. To this end, in this section I examine two model extensions in which both disclosure formats can be ex post invoked for quality disclosure.

4.1. Ex Post Disclosure Format Choice

Consider the following modification to the basic model regarding the timing on the choice of disclosure format. Suppose that the disclosure format can be ex post chosen by the manufacturer after the quality is learned. This may represent scenarios when quality is more difficult to modify than the development of disclosure capability. Conditional on the quality q , the manufacturer can choose to either remain silent, disclose the quality directly, or cut the wholesale price to induce retailer disclosure. Other aspects of the basic model are maintained. This modified setup can also be interpreted as a second-stage subgame where both disclosure formats are chosen in the first stage of the game.

Note that now the manufacturer has three options regarding quality disclosure. The comparison between the manufacturer's incentives for no disclosure and for direct disclosure has been presented in §3.1.2. That is, the manufacturer prefers revealing the quality directly to the consumers over no disclosure if and only if $q > \hat{q}_d \equiv \bar{q} + 8c$, conditional on the consumers' updated quality expectation \bar{q} . Similarly, the manufacturer's trade-off between no disclosure and retail disclosure is analyzed in §3.1.3. In particular, the manufacturer prefers cutting the wholesale price to $\omega^\# = \sqrt{q\bar{q}(q - \bar{q} - 4c)/(q - \bar{q})}$ to induce retail disclosure over no disclosure if and only if $q > \hat{q}_r$, where \hat{q}_r is

the solution to $\omega^\#(q - \omega^\#)/(2q) = \bar{q}/8$. It can be readily verified that $\hat{q}_d > \hat{q}_r$, in equilibrium. This implies that the equilibrium threshold of information revelation is determined by the manufacturer's marginal preference for retail disclosure over no disclosure, i.e., $\hat{q}^\# = 32(2\sqrt{2} - 1)c/7$. What remains to be determined is, when the quality level is above this equilibrium threshold, whether the M-C format or the R-C format should be chosen to reveal the quality.

PROPOSITION 4. *When the disclosure format can be chosen by the manufacturer after the quality is learned, there exists a unique equilibrium where no firm discloses if and only if $q \leq \hat{q}^\#$, and the manufacturer cuts the wholesale price to induce retail disclosure if and only if $q > \hat{q}^\#$.*

This suggests that in equilibrium the manufacturer chooses either no disclosure at all or to reveal the quality indirectly through the retailer. It is never profitable to disclose the quality directly to the consumers, even though it is feasible to do so. In other words, direct disclosure is a dominated option from an ex post perspective by either the R-C format or no disclosure. Nevertheless, recall from Proposition 3 that the M-C format can be ex ante preferable if the disclosure cost c is sufficiently high. Note that this reversal in the preference for the M-C format is driven by the timing under which the disclosure formats are chosen. There may exist an intertemporal inconsistency in the manufacturer's preference for direct disclosure: the manufacturer may choose to implement the M-C format, but only when the quality is not known yet.

The intuition is as follows. As discussed previously, the retail disclosure format effectively transfers part of the information revelation cost from the upstream to the downstream firm. As a result, conditional on any given quality level, the manufacturer prefers retail disclosure over direct disclosure. This is why the M-C format is always ex post dominated. However, if the M-C format is chosen before the quality is known, the manufacturer can credibly commit not to reveal some (intermediate) quality levels that are otherwise preferable to disclose under the alternative R-C format (i.e., $\hat{q}_d > \hat{q}_r$). Therefore, committing to the M-C format can help the manufacturer to save the cost of disclosure and thus result in higher ex ante profits. Note that this commitment is immaterial when the manufacturer can flexibly adjust the disclosure format choice conditional on the realized quality. This explains why the manufacturer's preference over the disclosure formats can be driven by the timing of format choice.

This result also allows us to endogenously justify the implicit assumption made in the basic model that the M-C format and the R-C format are ex ante perfect substitutes. Should each of the disclosure formats be ex post chosen for some (but not all) quality levels,

it would have been profitable to implement both formats from an *ex ante* perspective before the quality is known, although they are *ex post* substitutes. However, given that the manufacturer never finds it optimal to disclose directly at any realized quality level, there is no gain from maintaining flexibility in the *ex post* disclosure format choice even when the incremental setup cost is negligible.

4.2. Imperfect Quality Disclosure

The basic model assumes perfect disclosure in that a firm's disclosure decision amounts to revealing the quality to either none or all of the consumers. As a result, the firms' disclosures are *ex post* perfect substitutes and only one firm would be engaged in communicating product quality. This is the standard premise in the literature, and there are numerous scenarios in which it is a good approximation for reality. For example, some quality disclosure vehicles such as product labels, free returns, and sales assistance, can reach approximately all consumers who are considering purchasing the product. The prevalence of the Internet has also led to an unprecedented reach of communications about quality through online consumer-posted reviews. However, there may exist forces that prevent all consumers in the market from being informed of a product's disclosed quality. The reach of advertisements can be imperfect, technical details in product labels/manuals can be too complex to digest, consumers may not be completely aware of the availability of free product trials/returns, and/or communications between sales personnel and consumers may not be fully informative, etc. To accommodate these situations, I now consider an extended model in which a firm's disclosure efforts can communicate the product's quality to only a proportion $\alpha \in (0, 1)$ of the consumers. The remaining $1 - \alpha$ of uninformed consumers are aware of the firm's disclosure but cannot update their beliefs based on the content of the disclosure. The consumers informed by the manufacturer's disclosure are independent of those informed by the retailer's disclosure.

When the quality is disclosed, there are both informed and uninformed consumers in the market. Nevertheless, the uninformed consumers can infer the quality from the retail price. In the supplementary appendix (provided in the e-companion),⁵ I characterize a separating perfect Bayesian equilibrium in which the retail price serves as a signal of quality. The mechanism that separates high quality types from low ones

is the existence of informed consumers.⁶ In equilibrium the retail price is distorted upward to credibly communicate the quality to those consumers who are uninformed by the firm(s)' disclosure.

Two sets of results emerge from the analysis. First, the equilibrium disclosure threshold under this extended setup remains unchanged from that in the basic model under either the direct or the retail disclosure format (or when both disclosure formats are feasible). This is because the quality at the disclosure threshold constitutes the lower boundary of the separating equilibrium, which can be (naturally) signaled without the need to distort the retail price. That is, the equilibrium profit at the disclosure threshold is the same as that under full information. As a result, the economic forces that drive the equilibrium disclosure decisions and the manufacturer's relative preference for the disclosure formats remain influential even when quality disclosure is imperfect. That is, the M-C format involves a higher equilibrium threshold of quality disclosure and thus a larger *ex ante* probability to save the disclosure cost than the R-C format.

Second, some additional insights arise regarding the manufacturer's preference over the disclosure formats. The manufacturer's equilibrium payoff under the M-C format increases with more informed consumers. This is because, as more consumers become informed, the upward distortion in retail price signaling is weakened and the equilibrium retail demand is increased. In contrast, the manufacturer's equilibrium profit under the R-C format may not change with the number of informed consumers. This can be attributed to the immutability of the retailer's equilibrium payoff to the change in the number of informed consumers. Intuitively, in the end, all consumers are informed of the quality (through either firm disclosure or retail price signaling). As a result, the maximum wholesale price $\hat{\omega}$ that can induce retail disclosure remains irresponsive to the number of informed consumers. Therefore, when the optimal wholesale price is bounded by this constraint to induce retail disclosure, the manufacturer's equilibrium profit does not change with the number of informed consumers. Overall, this suggests that the manufacturer's relative preference for the direct disclosure format becomes higher when the informativeness of quality disclosure increases.

Moreover, although the total number of informed consumers is higher when both firms disclose the quality (i.e., $\alpha(2 - \alpha)$) than when only one firm does so

⁵ An electronic companion to this paper is available as part of the online version that can be found at <http://mansci.journal.informs.org/>.

⁶ This separating mechanism is endogenously absent when the quality is not disclosed by any firm (and thus all consumers remain uninformed). See Daughety and Reinganum (2008) on a complementary model in which disclosure is fully informative while differential marginal costs serve as the separating mechanism when quality is not disclosed.

(i.e., α), the manufacturer may not employ both formats for quality disclosure. This is because, if the R-C format is used, as discussed previously, the manufacturer's equilibrium profit may be immutable to the number of informed consumers. It is only when the quality level becomes sufficiently high that the manufacturer's equilibrium payoff increases with more informed consumers under the retail disclosure format. It is in this case that it may be beneficial for the manufacturer to increase the total number of informed consumers by engaging both firms' disclosure efforts. In other words, these two disclosure formats may emerge as *ex post* (and thus *ex ante*) complements. Intuitively, this complementarity can be strengthened by the incremental increase in the number of informed consumers, i.e., $\alpha(1 - \alpha)$, which is maximized when α is intermediate, or by the reduction in the disclosure cost c , or both.

5. Conclusion

In this study, I investigate quality disclosure strategies and format choice in a distribution channel. This paper extends the literature on voluntary quality disclosure by considering the strategic interaction between channel partners. Several findings emerge from the analysis that can provide managerial insights into communications of quality in markets characterized by information asymmetry and channel decentralization.

First, this paper sheds light on optimal quality disclosure strategies under alternative disclosure formats. It suggests that less information should be provided when an upstream firm communicates directly with consumers than when the upstream firm relies on downstream partners for information revelation. This result may contradict the common sense that channel conflict should lead to the provision of less information. Nevertheless, it highlights the importance for firms to adjust their quality disclosure strategies according to the format of disclosure. Firms should be more conservative in disclosing their product's quality and reveal less information to consumers under the direct disclosure format. For example, national advertisements run by manufacturers can focus less on quality-related product characteristics but more on other roles (e.g., increasing awareness, brand image development, facilitating product-consumer match, etc). On the other hand, firms can be more aggressive when they can engage downstream firms for quality communication, adjusting downward the threshold of disclosure, and revealing more information to consumers. They should also provide appropriate incentives to induce downstream firms' disclosure efforts. For instance, manufacturers can strategically offer wholesale price cuts or trade

promotions in support of retailers' quality communication activities such as product demonstration, sales assistance, and in-store advertisements. The bottom line of the insights offered in this paper is that, when deciding on quality disclosure strategies, firms should carefully scrutinize the format of disclosure.

This paper also provides insights into upstream firms' optimal choice of disclosure format. Should a manufacturer retain complete control over the disclosure decision or delegate it to the downstream retailer? Should the manufacturer develop its own capability for quality disclosure or outsource it to the downstream retailer? It is suggested that delegating quality disclosure to the retailer can be profitable because it can transfer the cost of disclosure while extracting more surplus from the downstream firm. This is consistent with the prevalent use of downstream retailers in the supply of product information to consumers in many markets (e.g., Churchill et al. 2000, Kotler 2003). Nevertheless, the M-C format can be a beneficial choice when the manufacturer can commit not to outsource the disclosure to the retailer once the quality level is learned. The manufacturer may *ex ante* prefer the M-C format because it can give rise to a credible commitment not to disclose quality levels that are relatively low. It is shown that this preference is stronger when the disclosure cost becomes higher. In practice, the commitment for direct disclosure can be made by investing in the development of internal advertising/communications departments and personnel, or through the selection of downstream retailers without disclosure capabilities. Therefore, this paper offers a rationale for why some manufacturers develop their own quality disclosure capabilities and establish a reputation for direct communication with consumers (e.g., through national advertising campaigns). Moreover, this paper extends the investigation to the case when neither direct nor retail disclosure can inform all consumers. It suggests that imperfect disclosure can yield complementarity between these two disclosure formats, and the overall reach of quality disclosure can be enhanced by engaging both the upstream and the downstream firms.

A critical assumption in the model is that quality disclosure is truthful. The truth-telling assumption would hold if false claims are not legally permitted (e.g., by advertising laws), if certifications can be sought from trustworthy third-party experts, or if verifiable evidence can be collected and presented (e.g., free trials, online consumer reviews, product demonstration). Therefore, the quality disclosure problem in this paper is particularly relevant for products whose quality level can be measured (e.g., gas mileage, nutritional content, technical specifications). Nevertheless,

it does not include general claims that are unverifiable or infallible. As a result, in situations when quality information cannot be credibly conveyed (e.g., independent certification absent for new product categories), the disclosure strategy considered in this paper would be immaterial. Alternative information transmission mechanisms may then have to be used (e.g., price signaling, warranties).

Another assumption in the paper is that consumers' uncertainty about quality can be completely resolved by the firms' disclosure efforts. Nevertheless, there may exist residual uncertainty about the product's quality even when it is disclosed. Consider the following extension. Suppose that the disclosure by a firm $f \in \{m, r\}$ provides only an imperfect signal about the true quality, i.e., $\check{q}_f = q + \epsilon_f$, where $\epsilon_f \in \{-\check{\epsilon}_f, \check{\epsilon}_f\}$ and $\Pr(-\check{\epsilon}_f) = \Pr(\check{\epsilon}_f) = 1/2$. One can interpret $\check{\epsilon}_f > 0$ as the noise level in firm f 's signal. If the manufacturer's and the retailer's signals are perfectly positively correlated (i.e., $\epsilon_m = \epsilon_r$), then one can interpret the signals as the "average quality" and the results of the paper hold straightforwardly. Alternatively, if the correlation is imperfect, then a firm's disclosure can provide additional information that is not contained in the other firm's disclosure. In this case, the manufacturer may find it beneficial to ex post invoke both firms' disclosure efforts if that increases consumers' updated expectation on quality. However, it may be ex ante unprofitable to implement both disclosure formats even though doing so can ex post reduce the consumers' uncertainty in quality expectation. This is because uncertainty reduction is a double-edged sword, leading to either upward or downward revision in the consumers' expected quality.

Furthermore, it is assumed that the disclosure formats are symmetric to each other (e.g., establishment costs, the reach and cost of disclosure). I also deliberately assume symmetric information across the firms. This rules out the possibility that, under the M-C format, the retailer can learn about the quality from the manufacturer's disclosure and thus engage in communicating with the consumers. The intention in making these assumptions is to capture and highlight the manufacturer's strategic consideration in disclosure format selection. Nevertheless, in real life the disclosure formats can be asymmetric. For example, retail disclosure can be less costly, whereas direct disclosure by upstream firms may reach more consumers beyond local markets. One can extend the current model to accommodate these asymmetries, e.g., the cost and the reach of disclosure for firm $f \in \{m, r\}$ is c_f and α_f , respectively. The equilibrium disclosure strategies and profits under either disclosure format are similar to the symmetric case. The comparison between the disclosure formats is

straightforward when they differ only in the disclosure cost. Note that an increase in c_m does not necessarily lead to a decreasing preference for the M-C format. With asymmetry in the reach of disclosure, comparing the equilibrium profits between the disclosure formats is more involved, whereas the insights obtained in this paper are expected to hold.

In the separating perfect Bayesian equilibrium characterized in the extension on imperfect disclosure in §4.2, price signaling and disclosure are complements (see also Caldieraro et al. 2008). It would be interesting to investigate the substitute case in which the price can communicate quality information if the quality is not disclosed. Daughety and Reinganum (2008) address this case in a monopoly setup in which the signaling mechanism is differential marginal costs across different quality levels. Future research can study multiple communication devices as complements or substitutes, with the potential extension to a channel setting.

The results in this paper can be empirically validated in future research. To this end, experimental methods have some advantages that are absent in alternative approaches (e.g., field studies). Other confounding factors can be directly controlled in lab experiments. Moreover, the model setup in this paper can be readily replicated in a lab setting. An exemplary outline of the experimental design to examine the empirical validity of the basic model is as follows. A two-factor design can be employed to manipulate the impacts of disclosure format and disclosure cost on the players' equilibrium disclosure strategies and payoffs. Each manipulation cell is represented by two sessions. In each session, participants are randomly paired as manufacturer-retailer dyads in each of a predetermined number of interaction rounds. In each round, instructions on the details of the basic model (i.e., information, decisions, and payoff determination) are elaborated to the participants. The participants then make the disclosure/pricing decisions, conditional on a quality level drawn from a uniform distribution. The theoretical insights can be examined by comparing the documented disclosure behaviors and the computed payoffs across the manipulation cells.

The current research can also be extended in a number of other directions. The model assumes that quality is exogenously determined and beyond the control of firms. The endogeneity of quality choice can be investigated in future investigation. In addition, firms' information acquisition decisions and the interaction with subsequent disclosure strategies can be considered. It may be interesting to examine the case when advertising plays the dual role of both increasing consumers' perceived quality and

communicating objective quality. Future research can also examine the effects of channel structure and competition on optimal disclosure strategies and formats. We may expect that, similar to Guo and Zhao (2009), competition can lead to the provision of less information. However, a thorough analysis of these issues is complicated and thus reserved for future exploration. I hope that this paper inspires interest in quality disclosure in distribution channels.

6. Electronic Companion

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

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Appendix

PROOF OF LEMMA 1. Consider first the case when $\omega < \bar{q}$. We then have $\Pi_r(\omega | \bar{q}) = (\bar{q} - \omega)^2 / (4\bar{q})$. As a result, $\Pi_r(\omega | q) > \Pi_r(\omega | \bar{q})$ if and only if $(q - \omega)^2 / (4q) - c > (\bar{q} - \omega)^2 / (4\bar{q})$. This in turn implies that $q > \bar{q} + 4c$ and $\omega < \sqrt{q\bar{q}(q - \bar{q} - 4c) / (q - \bar{q})}$. Moreover, $\sqrt{q\bar{q}(q - \bar{q} - 4c) / (q - \bar{q})} < \bar{q}$ if and only if $q < \bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c}$.

Next, consider the case when $\omega \geq \bar{q}$. We then have $\Pi_r(\omega | q) > \Pi_r(\omega | \bar{q})$ if and only if $(q - \omega)^2 / (4q) - c > 0$. This in turn implies that $\omega < q - 2\sqrt{q\bar{c}}$. In addition, $q - 2\sqrt{q\bar{c}} \geq \bar{q}$ if and only if $q \geq \bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c}$. The lemma follows immediately. Q.E.D.

PROOF OF PROPOSITION 2. Let us first characterize the optimal wholesale price $\omega^\# = \min\{q/2, \hat{\omega}\}$ that can induce the retailer to disclose the quality information. Note first that $q - 2\sqrt{q\bar{c}} < q/2$ if and only if $q < 16c$, and $16c > \bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c}$ if and only if $\bar{q} < 8c$. Moreover, when $\bar{q} \geq 8c$, $\sqrt{q\bar{q}(q - \bar{q} - 4c) / (q - \bar{q})} < q/2$ if and only if $q < (5\bar{q} - \sqrt{9\bar{q}^2 - 64\bar{q}c})/2$ or $q > (5\bar{q} + \sqrt{9\bar{q}^2 - 64\bar{q}c})/2$. Therefore, conditional on $q > \bar{q} + 4c$, when $\bar{q} < 8c$, we have

$$\omega^\# = \begin{cases} \sqrt{\frac{q\bar{q}(q - \bar{q} - 4c)}{q - \bar{q}}} & \text{if } q < \bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c}, \\ q - 2\sqrt{q\bar{c}} & \text{if } \bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c} \leq q < 16c, \\ q/2 & \text{if otherwise,} \end{cases} \quad (7)$$

and, when $\bar{q} \geq 8c$,

$$\omega^\# = \begin{cases} \sqrt{\frac{q\bar{q}(q - \bar{q} - 4c)}{q - \bar{q}}} & \text{if } q < (5\bar{q} - \sqrt{9\bar{q}^2 - 64\bar{q}c})/2 \text{ or } \\ & q > (5\bar{q} + \sqrt{9\bar{q}^2 - 64\bar{q}c})/2, \\ q/2 & \text{if otherwise.} \end{cases} \quad (8)$$

To solve for the equilibrium disclosure threshold \hat{q} , let us suppose first that in equilibrium $\bar{q} < 8c$. Using $\hat{q} = 2\bar{q}$, it follows that $\hat{q} < \bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c}$. The indifference

condition for the manufacturer between charging $\omega^\# = \sqrt{q\bar{q}(q - \bar{q} - 4c) / (q - \bar{q})}$ while inducing retail disclosure and charging $\bar{q}/2$ while inducing retail information withholding, is then given by $\omega^\#(\hat{q} - \omega^\#) / (2\hat{q}) = \bar{q}/8$. Substituting $\bar{q} = \hat{q}/2$, we can obtain $\hat{q} = 32(2\sqrt{2} - 1)c/7$ and $\bar{q} = 16(2\sqrt{2} - 1)c/7$. It can be readily verified that $16(2\sqrt{2} - 1)c/7 < 8c$. This proves that this is indeed an equilibrium.

Suppose next that in equilibrium $\bar{q} > 8c$. If furthermore $\hat{q} < (5\bar{q} - \sqrt{9\bar{q}^2 - 64\bar{q}c})/2$ or $\hat{q} > (5\bar{q} + \sqrt{9\bar{q}^2 - 64\bar{q}c})/2$, then the optimal wholesale price to induce retail disclosure at \hat{q} is $\omega^\# = \sqrt{q\bar{q}(q - \bar{q} - 4c) / (q - \bar{q})}$. This in turn leads to $\bar{q} = 16(2\sqrt{2} - 1)c/7$, which is a contradiction. If instead $(5\bar{q} - \sqrt{9\bar{q}^2 - 64\bar{q}c})/2 < \hat{q} < (5\bar{q} + \sqrt{9\bar{q}^2 - 64\bar{q}c})/2$, then we have $\omega^\#(\hat{q} - \omega^\#) / (2\hat{q}) = \bar{q}/8$, where $\omega^\# = \hat{q}/2$, which is impossible. Q.E.D.

PROOF OF PROPOSITION 3. To facilitate the exposition, let us define $\hat{q}' = \bar{q}^\# + 2c + 2\sqrt{c^2 + \bar{q}^\#c}$, $\omega_2^\# = \sqrt{q\bar{q}^\#(q - \bar{q}^\# - 4c) / (q - \bar{q}^\#)}$, and $\omega_3^\# = q - 2\sqrt{q\bar{c}}$. The manufacturer's and the retailer's equilibrium ex ante payoffs under the retail disclosure format are then given by, respectively,

$$\Pi_m^\# = \int_0^{\hat{q}^\#} \bar{q}^\# / 8 dq + \int_{\hat{q}^\#}^{\hat{q}' } \omega_2^\#(q - \omega_2^\#) / (2q) dq + \int_{\hat{q}' }^{16c} \omega_3^\#(q - \omega_3^\#) / (2q) dq + \int_{16c}^1 q/8 dq, \quad (9)$$

$$\Pi_r^\# = \int_0^{\hat{q}^\#} \bar{q}^\# / 16 dq + \int_{\hat{q}^\#}^{\hat{q}' } [(q - \omega_2^\#)^2 / (4q) - c] dq + 0 + \int_{16c}^1 (q/16 - c) dq, \quad (10)$$

where the terms in the right-hand side correspond to the four ex post scenarios regarding the quality q in the second stage of the game, as elaborated in the text. Simplifying and comparing with the firms' equilibrium ex ante profits under the direct disclosure format lead to the proposed results. Q.E.D.

PROOF OF PROPOSITION 4. Let us first verify that $\hat{q}_d > \hat{q}_r$ in equilibrium. Suppose otherwise. Then any $q \leq \hat{q}_d = \bar{q} + 8c$ will not be disclosed by either firm. But the manufacturer can charge a wholesale price $\omega^\# = \sqrt{q\bar{q}(q - \bar{q} - 4c) / (q - \bar{q})}$ and induce the retailer to disclose the quality. The manufacturer's expected profit following this deviation is given by $\omega^\#(q - \omega^\#) / (2q)$, which is strictly higher than the expected payoff with no disclosure (i.e., $\bar{q}/8$) when evaluated at $q = \bar{q} + 8c$. Therefore, in equilibrium we have $\bar{q} = \min\{\hat{q}_d, \hat{q}_r\} / 2 = \hat{q}_r / 2$. Similar to the R-C format case in §3.1.3, this leads to the equilibrium threshold of disclosure, $\hat{q}^\# = 32(2\sqrt{2} - 1)c/7$.

It follows that the manufacturer prefers the R-C format over no disclosure when $q > \hat{q}^\#$. The optimal wholesale price when retail disclosure is induced is given by Equation (7). Note that no disclosure is preferred over disclosing the quality directly when $q \leq \bar{q} + 8c$, and $\bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c} < \bar{q} + 8c$. Moreover, the manufacturer's expected payoff from inducing retail disclosure is $\omega^\#(q - \omega^\#) / (2q)$, where $\omega^\# = q - 2\sqrt{q\bar{c}}$ when $\bar{q} + 2c + 2\sqrt{c^2 + \bar{q}c} \leq q < 16c$ and $\omega^\# = q/2$ when $q \geq 16c$. It can be easily verified that this expected payoff is higher than that when the manufacturer discloses the quality directly (i.e., $q/8 - c$). This completes the proof. Q.E.D.

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