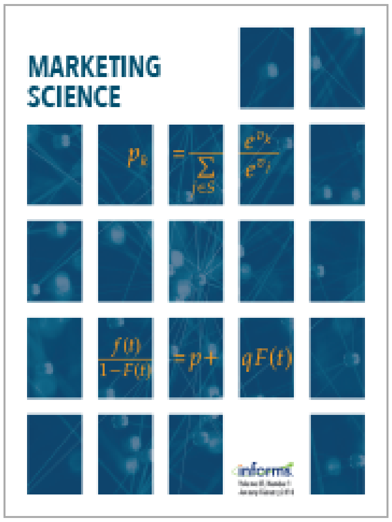

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Upstream Exploitation and Strategic Disclosure

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Abstract. Firms can improve market demand by disclosing privately known information on their advantages (e.g., quality) to potential buyers. The conventional prediction in the literature on voluntary disclosure is that, because of rational buyer expectation, any private information would be perfectly unravelled in equilibrium. However, concealments can be seen in practice for both low- and high-quality firms. This paper proposes a new explanation for this puzzle, based on downstream manufacturers' incentive to mitigate upstream exploitation by input suppliers. We highlight two natural consequences of increasing quality: higher product value and less elastic demand. The latter force would push up the wholesale price to yield a nonmonotonic impact of quality on equilibrium manufacturer payoff. Therefore, there may exist intermediate-disclosure equilibria where the manufacturer withholds both low- and high quality levels, even when disclosure is costless. In addition, partial disclosure can benefit not only channel members but also buyers. The intermediate-disclosure equilibria can survive even when supplier actions to influence the disclosure outcome are endogenized. Moreover, strategic concealment may undermine incentives for vertical integration.

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Keywords: channel conflict • communication • disclosure • distribution channel • unravelling

1. Introduction

Firms typically know more about their products than prospective buyers do. To remedy this information asymmetry problem that may lead to market failure (Akerlof 1970), firms can disclose privately known information using a variety of formats (e.g., product labels, advertising, free samples and returns, authority certifications). The classical result on voluntary disclosure is that any private information would be fully unraveled in equilibrium, as long as disclosure is truthful and costless (Grossman and Hart 1980, Grossman 1981, Milgrom 1981, Okuno-Fujiwara et al. 1990). This is because nondisclosure would be rationally inferred as unfavorable information.

However, both anecdotal evidence and academic research suggest that full disclosure is rarely observed in practice. The majority of higher-fat salad dressings do not have a nutrition label (Mathios 2000). Many commercials contain no hard information on quality-related attributes. As noted by Abernethy and Butler (1992), 37.5% of TV advertising in the United States is devoid of product attribute cues. Clearly, not all firms provide free samples/returns. Similarly, participation rate in quality reporting programs by health maintenance organizations or physicians is lower than expected (Jin 2005, Wang and Gao 2016). More puzzlingly, not all high-quality firms disclose their advantages. Some best-seller books (e.g., *Dog Man #6*, *Player's Handbook*) do not sign up for Amazon's "Look Inside" preview program. Firms such as Boeing and Toyota de-emphasize their qualities, and restaurants and airlines may underadvertise their performance on waiting/travel time and benefits (Kopalle and Lehmann 2006). Other examples exist that are inconsistent with the conventional wisdom that favorable information *should* always be disclosed:

- Manufacturers can publish their technical/digital specifications in specialized magazines. However, Mangani (2013) find that about 18% of 385 motorcycle models in Italy did not disclose their vertical attributes (e.g., horsepower, torque, vehicle weight). More surprisingly, there was no clear quality difference between disclosing and nondisclosing motorbikes, and a higher price was associated with a lower probability of quality disclosure. A remarkable example is Harley Davidson that traditionally does not disclose the performance of its powerful engines.
- Pharmaceutical companies may invest in informative advertising to promote their drugs' quality characteristics (e.g., strength, efficiency, safety). In a comprehensive content analysis of video commercials for the U.S. over-the-counter analgesics industry, Anderson et al. (2010) show that less information is disclosed by larger firms, which tend to have better-quality drugs.

The main objective of this paper is to provide a novel explanation for the absence of full disclosure in practice. We will explicate not only why firms may not be compelled to reveal their disadvantages, which is inconsistent with the prediction of extant literature (Grossman and Hart 1980, Grossman 1981, Milgrom 1981), but also why firms may voluntarily withhold superior information. Our explanation is simple and may prevail in many markets. In particular, our proposed rationale hinges on the interaction of two naturally counteracting effects of increasing a product's vertical attribute (e.g., quality). It is no surprise that a higher quality normally implies more value created for buyers and hence more surplus to be extracted and shared between firms in a channel. However, a higher quality may reduce buyers' price sensitivity, thus facilitating the ability of upstream firms to grab a larger share of surplus from the channel. As a result, downstream firms may end up having lower profits as their quality improves. That is, a higher quality may backfire and turn out to be "bad news" from the perspective of downstream firms. It is this upstream exploitation effect that may induce the concealment of private information, particularly for high-quality firms.

We consider a channel with an input supplier and a downstream manufacturer (e.g., food, motorcycles, drugs, digital products). Our setting can also characterize the interaction, for example, between input providers (e.g., personnel, contractors, equipment vendors, landlords) and service providers (e.g., hospitals, restaurants, airlines) or between platforms and online sellers. We assume that the product value increases with quality (in the sense of first-order stochastic dominance). The quality is privately known to the manufacturer and can be voluntarily and truthfully disclosed to potential buyers. To isolate the manufacturer's strategic incentive for quality disclosure, we intentionally assume that the cost of disclosure is zero. We consider a three-stage setup where the disclosure of quality precedes the firms' pricing decisions. The supplier can make a take-it-or-leave-it wholesale price to the manufacturer who then decides on the price charged to the buyers.

Our first contribution is to identify fairly general conditions under which upstream exploitation can decrease the manufacturer's profitability as quality increases. Intuitively, when the quality shifts the distribution of product value toward the upper bound, buyer demand may become less elastic. This implies not only that the manufacturer can extract more buyer surplus but also that the supplier can charge a higher predatory wholesale price to seize more channel surplus. As a result, both the manufacturer and the buyers can be hurt by an improvement in quality. We show that both manufacturer margin and buyer surplus can converge to zero as quality becomes infinitively high. We also demonstrate, for several specific cases, that the manufacturer's and the buyers' payoffs are unimodal (i.e., first increase and then decrease) in the perceived quality.

As a result of nonmonotonic manufacturer payoff, there may exist intermediate-disclosure equilibria where the manufacturer reveals the quality if and only if the quality is neither too low nor too high. Sufficiently low or sufficiently high quality would be withheld, in order to manipulate buyers' quality perception or to weaken the upstream exploitation effect, respectively. It is precisely because of the manufacturer's incentive to suppress the disclosure of overly high quality levels that low quality levels are not forced to be divulged, that is, the pooling of nonintermediate qualities would become credible. We identify general conditions that are sufficient to sustain the emergence of the intermediate-disclosure equilibria. We also show that there are cases where both the firms and the buyers are ex ante better off under these partial equilibria than under full disclosure.

We demonstrate that the intermediate-disclosure equilibria can exist even when the supplier can choose to subsidize downstream disclosure or to acquire the disclosure capability. The supplier may offer no subsidy at all, or ensure that the provided subsidy does not induce full disclosure. Similarly, the supplier may forbid itself from disclosure, even absent cost consideration. In addition, we show that strategic concealment can reduce, rather than enhance, incentives for vertical integration. Moreover, the results of the basic model can continue to hold even when we endogenize the timing of wholesale pricing or the product quality. These results suggest that intermediate disclosure can be sustainable even if we account for these market responses.

This paper is related to research on the rationalization of partial disclosure. If disclosure is costly, favorable information would be disclosed while unfavorable one partially concealed (e.g., Viscusi 1978, Jovanovic 1982, Verrecchia 1983, Dye 1986). Several studies (e.g., Matthews and Postlewaite 1985, Farrell 1986, Shavell 1994) investigate the role of information acquisition costs and show that mandatory-disclosure laws may paradoxically decrease equilibrium information revelation. Fishman and Hagerty (2003) propose that limited buyer understanding of disclosure may explain the failure of full disclosure. Board (2009) offers a competition-based explanation for the absence of full disclosure. Similarly, Hotz and Xiao (2013) show that full disclosure may not arise as it may decrease overall differentiation between competing firms: an increase in differentiation on the vertical dimension may cancel out that on the horizontal dimension if buyer preferences are negatively correlated across dimensions.[1] By contrast, we consider a bilateral-monopoly setting with one-dimensional costless disclosure of vertical information, where the driving mechanism is the downstream firm's incentive to strategically attenuate the upstream firm's exploitation.

There is an emerging literature in marketing on strategic quality disclosure. For example, Guo and Zhao (2009) examine how equilibrium disclosure strategies and payoffs in a duopoly may be influenced by the cost/timing of disclosure. One interesting result is that competition may lead to less information revelation. Guo (2009) investigates equilibrium disclosure strategies between, and an upstream firm's preference over, direct- and indirect-disclosure formats. He shows that indirect disclosure via the downstream firm leads to more information revelation and that the upstream firm may benefit from committing to the direct-disclosure format. Mayzlin and Shin (2011) present an interesting rationale for the equilibrium emergence of intermediate disclosure. They show that a high-quality firm may strategically pool with its low-quality counterpart to separate from the mediocre type, because disclosure cannot fully reveal all advantageous attributes (because of limited bandwidth in advertising) but buyer search can unveil all product information.

Our paper is also connected to the extensive literature on incentives/implications of firm information provision (e.g., Lewis and Sappington 1994).[2] Chen and Xie (2005) examine how the provision of preference fit information by independent third-party reviewers can influence pricing and advertising strategies. In a related paper, Chen and Xie (2008) investigate the interaction of seller-supplying and word-of-mouth information about the fit between product and consumers' characteristics. Bhardwaj et al. (2008) consider the role of seller- versus buyer-initiated sales presentation formats as a signaling device. Kuksov and Lin (2010) find that competition and free riding may yield a lower incentive for a high-quality firm to resolve consumer uncertainty about preference over quality. Similarly, Sun and Tyagi (2017) consider information provision on product fit uncertainty in distribution channels. In this research stream, the typical role of information provision is to increase the dispersion in value distribution (in the sense of mean-preserving spreads), *directly* yielding a margin/demand trade-off. Moreover, firms do not need to have private information over the buyers, making strategic buyer inference irrelevant. By contrast, we follow the literature on strategic disclosure of private information about vertical attributes. As a result, disclosure influences product value in the sense of first-order stochastic dominance, giving rise to the unravelling mechanism through strategic buyer inference. In addition, we endogenously derive, rather than assume, the manufacturer's differential margin/demand trade-offs across quality levels as the equilibrium outcome in the interaction between the channel members.

The rest of the paper is organized as follows. The next section presents the model and investigates the benchmark case with channel integration. Section 3 analyzes optimal pricing strategies and demonstrates the nonmonotonic impact of quality on the downstream firm's profitability. Section 4 characterizes equilibrium disclosure strategies and examines payoff implications of strategic concealment. We address the robustness of our results by considering several extensions in Section 5. The last section presents managerial implications and some extended discussions.

2. The Model

Consider a vertical relationship in which a downstream firm sources an essential input from an upstream firm. We refer to the upstream firm as the *supplier* and its input can represent, for example, accessories, components, designs, hardware/software, materials, patents, platforms, properties, protocols, recipes, services, systems, and trademarks. We call the downstream firm the *manufacturer*, whereas our model can also be applied to service/content providers (e.g., hospitals, restaurants, online sellers). The manufacturer has the capability to assemble the supplier's input into a product (or service) that would be sold to potential buyers. The input cannot be consumed in a stand-alone manner or sold directly to the buyers: it must be used by the manufacturer (along with other internal and external inputs/technologies).[3] The firms have constant marginal costs, which are set to zero.[4] Both the firms' and the buyers' payoff of no trade are normalized to zero.

There is a unit mass of buyers in the downstream market, and each buyer demands at most one unit of the manufacturer's product.[5] The buyers' utility of purchase is given by

$$u = v - p, \tag{1}$$

where v denotes the product value and p is the price charged by the manufacturer. The buyers are heterogenous in their value. Denote the cumulative distribution function (CDF) of v as $F(v, \tilde{q})$ and the density function as $f(v, \tilde{q})$, where $\tilde{q}$ is the buyers' perception of the product's quality. Denote the support of v as $[\underline{v}, \bar{v}]$ such that $F(\underline{v}, \tilde{q}) = 0$ and $F(\bar{v}, \tilde{q}) = 1$ for all $\tilde{q}$. We assume that both $F(v, \tilde{q})$ and $f(v, \tilde{q})$ are differentiable in v, and the support of product value is bounded from above (i.e., $\bar{v} \neq \infty$, whereas $\underline{v} = -\infty$ is allowed). In addition, the value distribution meets some regularity such that there exists a unique interior solution to the firms' pricing problems for any finite $\tilde{q}$.

Moreover, we make the following assumptions about how the perceived quality $\tilde{q}$ may influence the distribution of product value.

Assumption A1. $\frac{\partial F(v,\tilde{q})}{\partial \tilde{q}} < 0$ *for all* $v \in (\underline{v}, \bar{v})$.

Assumption A2. $\lim_{\tilde{q}\to\infty} F(v,\tilde{q}) = 0$ *for all* $v \in [\underline{v}, \bar{v})$, $\lim_{\tilde{q}\to\infty} F(\bar{v},\tilde{q}) = 1$, $\lim_{\tilde{q}\to\infty} f(v,\tilde{q}) = 0$ *for all* $v \in [\underline{v}, \bar{v})$, *and* $\lim_{\tilde{q}\to\infty} f(\bar{v},\tilde{q}) = \infty$.

Assumption A1 implies that a higher perceived quality increases the buyers' product value in the sense of first-order stochastic dominance. That is, $F(v,\tilde{q}) < F(v,\tilde{q}')$ for any $\tilde{q} > \tilde{q}'$. Intuitively, as the perceived product quality improves, the number of buyers with lower value decreases while that of higher-value buyers increases, shifting the density of v to the right. Assumption A2 further characterizes the limit condition when the perceived quality is infinitely high. It says that, as $\tilde{q}$ becomes overly large, the mass of buyers who value the product below (at) the upper bound $\bar{v}$ will converge to zero (one). As a result, both the CDF and the density converge to zero except at the upper bound $\bar{v}$. We will present examples of distributions that satisfy these assumptions.

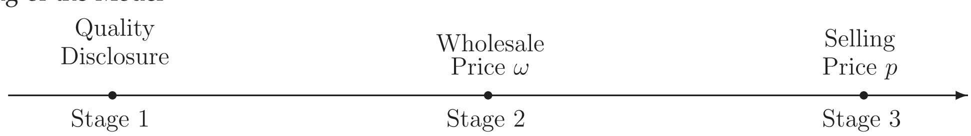
The *true* quality of the product, q, is initially unknown. We can interpret q as an index for the product's vertical attributes (e.g., technical specifications, performance, reliability, availability, safety, maintenance costs).[6] Note that typically q is not determined (solely) by the quality of the supplier's input, because the production process would involve many other inputs and/or technologies. Both the firms and the buyers maximize expected payoffs and maintain the prior belief that the quality of the product follows the CDF $G(q)$ and the density function $g(q)$ on $[\underline{q}, \bar{q}]$, where $G(\underline{q}) = 0$ and $G(\bar{q}) = 1$. Let us denote the prior expectation of the quality as $\hat{q} = \int_{\underline{q}}^{\bar{q}} q \, dG(q)$.

The sequence of moves is shown in Figure 1. In the first stage of the game, the manufacturer conducts independent product testing or market research and thus becomes informed of the quality q of the product, which will remain as private knowledge unless being voluntarily disclosed. The manufacturer then decides whether to disclose the quality through, for example, demonstration, free sample/return, product label, sales assistance, informative advertising, expert/consumer rating, and/or certification by a reputed agency. It is assumed that disclosure is credible and truthful. As a result, the disclosure decision amounts to either revealing the truth or remaining silent. The truth-telling assumption would hold if false claims are not legally allowed (e.g., by advertising law), verifiable evidence can be collected and presented (e.g., demonstration, free trial, consumer rating), and/or certification can be sought from trustworthy third-party experts. Let us denote the buyers' expected quality when no information is received as q_0, which will be derived endogenously by taking into account the manufacturer's strategic disclosure decision. Therefore, the buyers' perception of product quality is $\tilde{q} \in \{q, q_0\}$, depending on the manufacturer's disclosure choice. Moreover, we deliberately assume that the cost of disclosure is zero. This allows us to investigate whether the manufacturer may strategically withhold information even when the disclosure cost is negligible.

In the second stage, the supplier makes a take-it-or-leave-it offer on the per-unit wholesale price ω for the supply of the input to the manufacturer.[7] Constant wholesale prices in vertical relationships are frequently implemented in practice and commonly employed in the literature. It is a necessary assumption for our main results. Given the wholesale price, the manufacturer in the third stage sets the selling price p. It is assumed that the manufacturer cannot exercise price discrimination between different buyers. Finally, the buyers decide whether to make a purchase based on their updated belief about the quality of the product, $\tilde{q} \in \{q, q_0\}$, which is influenced by the manufacturer's disclosure strategy. This completes the description of the model setup. We will use backward induction and rational expectation to solve the game.

Note the assumption that the manufacturer makes the disclosure decision before the supplier sets the wholesale price. This timing captures scenarios when the disclosure decision constitutes long-term strategic move and involves significant financial and human resources (e.g., recruiting and training sales personnel, investing on advertising, setting up or participating in online rating systems, going through certification procedures), whereas the production process is typically ongoing and the wholesale price can be flexibly adjusted between the firms. The flexibility in adjusting wholesale prices can be justified if the terms about input supply cannot be completely specified in vertical contracts and the supplier cannot commit ex ante not to engage in renegotiations after the manufacturer makes the disclosure decision (Iyer and Villas-Boas 2003). Moreover, this timing allows us to examine the interesting issue about how the

Figure 1. Timing of the Model



revelation/concealment of product quality can be strategically used by the manufacturer to mitigate the problem of channel exploitation by the supplier in setting the wholesale price. Nevertheless, as we will show in Section 5.3, this timing can emerge endogenously in an extended setup in which the supplier decides whether to set and commit to an ex ante wholesale price or to keep it flexible.

Another crucial assumption is that only the manufacturer can make the disclosure decision. This can be justified if the product quality is private information that cannot be acquired or inferred by the supplier from its input's quality. Moreover, practical and/or legal concerns may prevent the supplier from making claims or taking actions on the downstream product which normally involve many other inputs/technologies: there may be safety or risk issues for products, such as food, drugs, or toys; certifications can be filed only by the legally liable manufacturers. For instance, engine suppliers may reveal the quality of their engines but may not have the expertise/credibility to convey to consumers the quality of the final product (e.g., motorcycles). Nevertheless, we will investigate in Section 5.1 whether the supplier may offer financial incentives to influence the manufacturer's disclosure and whether it may want to acquire its own disclosure capability.

Denote the disclosure decision as $d(q):[\underline{q},\bar{q}]\rightarrow\{0,1\}$, where $d=0$ represents "not disclosing" and $d=1$ means "disclosing," respectively. Without loss of generality, we assume that the manufacturer discloses the quality if indifferent between disclosing and not disclosing. To characterize the equilibrium, we need to specify how the manufacturer's optimal disclosure strategy $d(q)$ and the buyers' updated belief about the quality $\tilde{q}\in\{q,q_0\}$ are interactively influenced by each other.

As a benchmark, consider a single firm in an integrated channel (or the case when the channel can be perfectly coordinated with the use of, for example, two-part tariffs). The buyers will purchase the product if and only if $v-p>0$. This leads to the demand $1-F(p,\tilde{q})$, conditional on $\tilde{q}$. The firm's profit maximization problem is then to solve

$$\max_p \Pi = p\big[1-F\big(p,\tilde{q}\big)\big]. \tag{2}$$

Let the optimal price be p^b. The optimal profit is then $\Pi^b(\tilde{q})=p^b[1-F(p^b,\tilde{q})]$. It follows from the envelope theorem that $\Pi^b(\tilde{q})$ is increasing in $\tilde{q}$. This demonstrates that the direct effect of increasing the perceived quality is to enhance buyer demand and thus to improve firm profit.

Therefore, in the absence of channel conflict, in equilibrium, the firm will fully disclose the quality to the buyers, that is, $d^b(q)=1$ for any q and $q_0^b=\underline{q}$. The logic underlying this result is due to the unravelling mechanism as in Grossman (1981) and Milgrom (1981) and proceeds as follows. When the firm's optimal payoff $\Pi^b(\tilde{q})$ monotonically increases with $\tilde{q}$, it will disclose any quality level that is higher than what the buyers believe to be the expected quality q_0 of an undisclosed product. Anticipating this disclosure strategy, the buyers will rationally adjust down their expectation q_0 conditional on the firm disclosing nothing. But then the lower buyer expectation will induce the firm to decrease its threshold for quality disclosure. This iteration process continues until q_0 is adjusted down to the lowest quality level $\underline{q}$, and full disclosure arises.

3. Optimal Pricing Strategies

In this section, we analyze the subgame starting from the second stage, conditional on $\tilde{q}$. We will show that, in the presence of upstream exploitation, the perceived quality may not necessarily increase the manufacturer's equilibrium profit. This result will be established in the general setup, when the perceived quality is sufficiently high. We then present several specific cases and derive additional results on how the perceived quality may nonmonotonically influence the equilibrium payoffs. These results will serve as the basis to examine the equilibrium disclosure strategies.

3.1. Sufficiently High Quality in the General Setup

Consider the manufacturer's decision at the third stage of the game. Conditional on $\tilde{q}$ and ω, the manufacturer sets a price to solve the following problem:

$$\max_p \Pi_m = \big(p-\omega\big)\big[1-F\big(p,\tilde{q}\big)\big]. \tag{3}$$

The necessary first-order condition for the solution to the manufacturer's pricing problem is

$$\big[1-F\big(p,\tilde{q}\big)\big]-\big(p-\omega\big)f\big(p,\tilde{q}\big)=0. \tag{4}$$

The first-order condition can also be written as $p-\omega=\overline{H}(p,\tilde{q})$, where $\overline{H}(v,\tilde{q})=\frac{1-F(v,\tilde{q})}{f(v,\tilde{q})}$ is the inverse hazard rate function. Therefore, one sufficient condition for the existence of a unique interior solution is the familiar monotone hazard rate condition (i.e., $\overline{H}(v,\tilde{q})$ is weakly decreasing in v). Let us write the optimal price of solving (4) as $p(\omega)$. It follows that the impact of varying the wholesale price on the optimal selling price is given by

$$\frac{\partial p(\omega)}{\partial\omega}=\frac{1}{1-\frac{\partial\overline{H}(p,\tilde{q})}{\partial p}}. \tag{5}$$

In anticipation of the impact of ω on optimal p, the supplier's optimization problem is then

$$\max_{\omega}\ \Pi_s = \omega\big[1 - F\big(p(\omega), \tilde{q}\big)\big]. \tag{6}$$

The first-order condition for the wholesale pricing problem is

$$\big[1 - F\big(p(\omega), \tilde{q}\big] - \omega\, f\big(p(\omega), \tilde{q}\big)\ \frac{\partial p(\omega)}{\partial \omega} = 0. \tag{7}$$

The equilibrium outcome for the pricing subgame, $p^*(\tilde{q})$ and $\omega^*(\tilde{q})$, can then be obtained by solving (4) and (7) simultaneously. The resulting equilibrium profits of the subgame can be written as $\Pi_m^*(\tilde{q})$ and $\Pi_s^*(\tilde{q})$, respectively. Similarly, the equilibrium buyer surplus is $CS^*(\tilde{q})$.

Theorem 1. $\lim_{\tilde{q}\to\infty} p^*(\tilde{q}) = \bar{v}$, $\lim_{\tilde{q}\to\infty} \omega^*(\tilde{q}) = \bar{v}$, $\lim_{\tilde{q}\to\infty} \times \Pi_m^*(\tilde{q}) = 0$, $\lim_{\tilde{q}\to\infty} \Pi_s^*(\tilde{q}) = \bar{v}$, *and* $\lim_{\tilde{q}\to\infty} CS^*(\tilde{q}) = 0$.

This theorem characterizes the impact of increasing the perceived quality on the equilibrium outcomes in the limit. First, the equilibrium prices both converge to the upper bound $\bar{v}$ as the perceived quality becomes infinitely high. When the mass of buyers concentrate in the limit almost at the upper bound, the buyer demand becomes essentially inelastic for any selling price below $\bar{v}$. So the selling price will verge on its highest possible value with negligible loss in demand. This would be the case for any wholesale price. As a result of the irresponsiveness in the downstream pricing, the supplier will push its wholesale price sufficiently upward. Therefore, both firms' equilibrium prices are arbitrarily close to $\bar{v}$, whereas the equilibrium demand is still converging to one.

The large-$\tilde{q}$ results on equilibrium payoffs follow from the equilibrium prices in the limit. Even though the manufacturer can extract about all buyer surplus, as the perceived quality converges to infinite, its equilibrium profit actually goes to zero. This is because the virtual inelasticity of buyer demand can backfire and permit the supplier to charge a predatory wholesale price that is sufficiently close to the selling price. As a result, the manufacturer's profit margin is driven downward to zero.[8] In other words, all buyer surplus extracted by the manufacturer would be basically transferred to the supplier in the end. As a result, the supplier becomes the sole winner of infinitely increasing the perceived quality, appropriating nearly all surplus from both the manufacturer and the buyers. This implies that, paradoxically, the manufacturer and the buyers may be hurt by an unambiguous improvement in the buyers' perception about product quality.

In the appendix, we present several classes of distributions as examples for the large-$\tilde{q}$ results.

3.2. Any Quality for Specialized Cases

We then focus on several specific cases that are sufficiently tractable to yield reduced-form solutions. They also allow us to investigate how the equilibrium outcomes may be influenced by the perceived quality over the whole range. We will show that, because of upstream exploitation, the manufacturer and the buyer may be hurt by an increase in the perceived quality even for nonlimit scenario (i.e., small $\tilde{q}$). Fully characterizing the impact of any $\tilde{q}$ on the manufacturer's payoff would be necessary for our subsequent analysis about the equilibrium disclosure strategies.

Modified Pareto Distribution. The CDF for product value is $F(v, \tilde{q}) = 1 - (1 - v)^{1/\tilde{q}}$, where $v \in [0, 1]$ and $\tilde{q} > 0$. It can be verified that Assumptions A1 and A2 are satisfied. The inverse hazard function $\overline{H}(v, \tilde{q}) = \tilde{q}(1 - v)$ is decreasing in v. It follows from the first-order condition (4) that the optimal selling price is $p(\omega) = \frac{\tilde{q}+\omega}{1+\tilde{q}}$. Substituting this into the supplier's objective function (6) we can readily obtain the equilibrium wholesale price $\omega^*(\tilde{q}) = \frac{\tilde{q}}{1+\tilde{q}}$. The equilibrium selling price is then $p^*(\tilde{q}) = \frac{\tilde{q}(2+\tilde{q})}{(1+\tilde{q})^2}$. It is evident that both equilibrium prices increase with the perceived quality $\tilde{q}$.

Proposition 1. *When the product value follows the modified Pareto distribution, there exists a* $\dot{q} > 0$ *such that* $\Pi_m^*(\tilde{q})$ *increases with* $\tilde{q}$ *for* $\tilde{q} < \dot{q}$ *and decreases for* $\tilde{q} > \dot{q}$; $\Pi_s^*(\tilde{q})$ *always increases with* $\tilde{q}$; *there exists a* $\dot{q}_c > 0$ *such that* $CS^*(\tilde{q})$ *increases with* $\tilde{q}$ *for* $\tilde{q} < \dot{q}_c$ *and decreases for* $\tilde{q} > \dot{q}_c$.

This proposition illustrates how the change in the perceived quality may influence the equilibrium payoffs. It suggests that, although the impact of $\tilde{q}$ on the supplier's equilibrium profit is positive, the manufacturer's and the buyers' equilibrium payoffs may vary nonmonotonically with an increase in the perceived quality. In particular, there exists a point $\dot{q}$ such that a higher $\tilde{q}$ is beneficial for the manufacturer if and only if $\tilde{q}$ is below this point. In other words, the manufacturer's payoff may be a unimodal function of the perceived quality. In addition, the response of the equilibrium buyer surplus to $\tilde{q}$ also exhibits a similar unimodal pattern.

We use the envelope theorem to explicate the impact of $\tilde{q}$ on equilibrium manufacturer profit:

$$\frac{\partial \Pi_m^*(\tilde{q})}{\partial \tilde{q}} = -\big[p^*(\tilde{q}) - \omega^*(\tilde{q})\big]\frac{\partial F\big(p^*, \tilde{q}\big)}{\partial \tilde{q}} - \frac{\partial \omega^*(\tilde{q})}{\partial \tilde{q}} \times \big[1 - F\big(p^*, \tilde{q}\big)\big]. \tag{8}$$

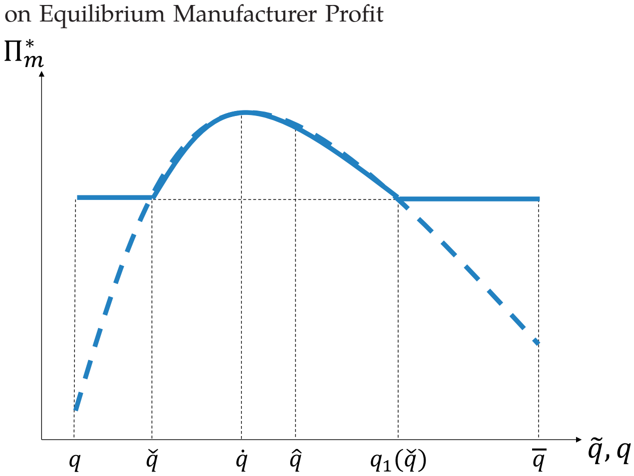
A higher perceived quality may exert two alternative effects on the equilibrium manufacturer profit.

As shown in (8), the first part of the right-hand side captures the positive direct effect of increasing $\tilde{q}$ on buyer demand. As in Assumption A1, a higher $\tilde{q}$ strictly reduces the CDF of the value distribution to raise buyer demand, keeping all else constant. On the other hand, the second part represents the indirect effect of $\tilde{q}$ through affecting the equilibrium wholesale price. As the perceived quality improves, buyer demand becomes less elastic and the supplier can charge a higher wholesale price. This upstream exploitation effect may then decrease the manufacturer's margin and constitute a negative pressure for the manufacturer's equilibrium payoff.[9]

The overall impact of $\tilde{q}$ on $\Pi_m^*(\tilde{q})$ hinges on the interplay of these two counteracting forces. When $\tilde{q}$ is not too high, the equilibrium demand is low such that margin reduction is not a significant concern. This implies that the direct effect of $\tilde{q}$ on buyer demand would be dominant, and thus a higher perceived quality would benefit the manufacturer. However, when $\tilde{q}$ becomes sufficiently high, lowering the manufacturer's margin would lead to larger profit loss, because the equilibrium demand would then be too high. That is, the upstream exploitation effect is more harmful as $\tilde{q}$ increases. This explains why the equilibrium manufacturer payoff may first increase and then decrease with the perceived quality, as illustrated by the "inverted-U" dashed curve in Figure 2.

Similarly, a higher $\tilde{q}$ can influence equilibrium buyer surplus in two offsetting manners. The first is the value-shifting effect whereby a higher perceived quality increase the number of higher-value buyers (Assumption A1). However, increasing the perceived quality would induce the manufacturer to charge a higher price, i.e., $p^*(\tilde{q})$ is increasing in $\tilde{q}$. Therefore, even though the product value becomes stochastically higher, the buyers may end up being hurt by a

Figure 2. (Color online) Impact of Perceived/True Quality on Equilibrium Manufacturer Profit



higher perceived quality. Proposition 1 shows that this would happen when and only when $\tilde{q}$ is above some point $\dot{q}_c$.

This demonstrates that the large-$\tilde{q}$ results established in Theorem 1 can arise for small $\tilde{q}$. Actually, $\tilde{q}$ need not be very large for a higher perceived quality to be harmful for the manufacturer and the buyers: The mode points for the payoff functions in Proposition 1 are $\dot{q} \approx 2.513$ and $\dot{q}_c \approx 0.834$.

Power Function Distribution. The CDF for product value is $F(v,\tilde{q}) = v^{\tilde{q}}$, where $v \in [0,1]$ and $\tilde{q} > 0$. It can be verified that Assumptions A1 and A2 are both satisfied. We can readily follow the steps laid out in Section 3.1 to derive the equilibrium results.[10] For example, we can show that the equilibrium selling price is $p^*(\tilde{q}) = (\frac{2+\tilde{q}+\tilde{q}\sqrt{5+4\tilde{q}}}{2(1+\tilde{q})^2})^{1/\tilde{q}}$. We can also confirm that the payoff implications of changing $\tilde{q}$ are qualitatively similar to those established in Proposition 1 (e.g., the unimodal patterns for the manufacturer's and the buyer's equilibrium payoff functions).

Uniform Distribution (Product Fit). Consider the following extension to the standard Hotelling model. The buyers' utility of purchasing the product is given by

$$u = z - x\, t(\tilde{q}) - p, \tag{9}$$

where $z > 0$ is the gross product value, $t(\tilde{q}) > 0$ captures the extent of product misfit to buyer tastes/needs, and x represents the per-unit disutility of product misfit. The buyers are heterogenous in how the product misfit may influence their utility: x is uniformly distributed between zero and one. A higher perceived quality $\tilde{q}$ decreases the degree of misfit, that is, $t'(\cdot) < 0$.

This model can be interpreted as a special case of the general setup. To see this, we can define $v = z - xt(\tilde{q})$ as the net product value. So v is uniformly distributed over $[z - t(\tilde{q}), z]$. Let $\underline{v} = z - t(\underline{q})$ and $\bar{v} = z$. We can then write the CDF and the density function of v as follows:

$$F(v,\tilde{q}) = \begin{cases} 1 + \frac{v-z}{t(\tilde{q})}, & \text{for } v \in [z - t(\tilde{q}), \bar{v}]; \\ 0, & \text{for } v \in [\underline{v}, z - t(\tilde{q})]. \end{cases}$$

and

$$f(v,\tilde{q}) = \begin{cases} \frac{1}{t(\tilde{q})}, & \text{for } v \in [z - t(\tilde{q}), \bar{v}]; \\ 0, & \text{for } v \in [\underline{v}, z - t(\tilde{q})]. \end{cases}$$

Assumption A1 follows from the monotonicity of $t(\cdot)$, and Assumption A2 would be satisfied if $\lim_{\tilde{q}\to\infty} t(\tilde{q}) = 0$. However, $F(v,\tilde{q})$ and $f(v,\tilde{q})$ are not differentiable everywhere, and the inverse hazard rate function $\overline{H}(v,\tilde{q})$ cannot be defined for the range $v \in [\underline{v}, z - t(\tilde{q})]$.

This means that we cannot directly apply Theorem 1 to the current setting. Nevertheless, we can readily solve the pricing subgame to obtain $p^*(\tilde{q}) = \max\{3z/4, z - t(\tilde{q})\}$ and $\omega^*(\tilde{q}) = \max\{z/2, z - 2t(\tilde{q})\}$, which are weakly increasing in $\tilde{q}$. Moreover, the equilibrium payoffs are $\Pi_m^*(\tilde{q}) = \min\{\frac{z^2}{16t(\tilde{q})}, t(\tilde{q})\}$, $\Pi_s^*(\tilde{q}) = \frac{z^2}{8t(\tilde{q})}$ for $\tilde{q} < t^{-1}(z/4)$ and $\Pi_s^*(\tilde{q}) = z - 2t(\tilde{q})$ for $\tilde{q} > t^{-1}(z/4)$, and $CS^*(\tilde{q}) = \min\{\frac{z^2}{32t(\tilde{q})}, \frac{t(\tilde{q})}{2}\}$.

Proposition 2. *With uniform distribution for product misfit, $\Pi_m^*(\tilde{q})$ and $CS^*(\tilde{q})$ increase with $\tilde{q}$ for $\tilde{q} < \dot{q}$ and decrease for $\tilde{q} > \dot{q}$, where $\dot{q} = t^{-1}(z/4)$; $\Pi_s^*(\tilde{q})$ always increases with $\tilde{q}$.*

The payoff implications of increasing the perceived quality here are similar to those in Proposition 1. The underlying mechanism is also akin to that for the other distributions. When the perceived quality is low such that the extent of product misfit is high, buyers are sufficiently heterogenous in their product value v and the firms' optimal pricing involves an interior solution. A lower level of product misfit would then increase buyer demand and hence the firms' and the buyers' equilibrium payoffs. It follows that increasing the perceived quality would benefit all parties by reducing product misfit.

However, when the perceived quality becomes high enough and hence the buyers are sufficiently homogenous, the supplier will charge a wholesale price such that the manufacturer will find it optimal to just cover the whole market. That is, a corner solution $p^*(\tilde{q}) = z - t(\tilde{q})$ would obtain. A lower $t(\tilde{q})$ would mean that the manufacturer can raise its price while ensuring that the buyer with the lowest value is indifferent between buying and not buying. Nevertheless, this in turn implies that the supplier can charge a higher equilibrium wholesale price (i.e., $\omega^*(\tilde{q}) = z - 2t(\tilde{q})$). It turns out that the equilibrium manufacturer margin is equal to $t(\tilde{q})$. Intuitively, a lower buyer heterogeneity reduces the manufacturer's leverage in dealing with the supplier. As a result, the manufacturer will be hurt as a higher perceived quality reduces the extent of product misfit, thanks to the supplier's exploitative pricing behavior. Moreover, increasing the perceived quality can be harmful to the buyers because they would then have to pay a higher selling price.

One simple example for the misfit function is $t(\tilde{q}) = 1/\tilde{q}$. We can then readily verify that the manufacturer's and the buyers' equilibrium payoffs will converge to zero as $\tilde{q}$ approaches either zero or infinity, that is, $\Pi_m^*(0) = \Pi_m^*(\infty) = 0$ and $CS^*(0) = CS^*(\infty) = 0$.

4. Equilibrium Outcome

In this section, we characterize the equilibrium disclosure strategies. We also investigate the firms' and the buyers' equilibrium ex ante payoffs and examine how a payoff criterion can be used to select the equilibrium outcome.

4.1. Disclosure Strategies

Let us now investigate the equilibrium disclosure strategies when q is privately known to the manufacturer. We will examine the case when the manufacturer's equilibrium subgame payoff is a unimodal function of the perceived quality, as shown in Propositions 1 and 2 and illustrated by the dashed curve in Figure 2. That is, $\Pi_m^*(\tilde{q})$ increases with $\tilde{q}$ for $\tilde{q} \in [\underline{q}, \dot{q}]$ and decreases for $\tilde{q} \in [\dot{q}, \bar{q}]$, where $\dot{q} \in (\underline{q}, \bar{q})$ is the payoff mode. To characterize the equilibrium, we need to specify the manufacturer's optimal disclosure strategy in anticipation of the impact on the buyers' belief as well as the buyers' updated belief about the quality conditional on the manufacturer's disclosure strategy.

Consider the manufacturer's optimal response, conditional on the buyers' expectation being q_0 when no information is received. To this end, we define the following two functions:

$$q_1(x) = \max\left\{y : \Pi_m^*(y) \geq \Pi_m^*(x), y \in \left[\underline{q}, \bar{q}\right]\right\}, \forall x \in \left[\underline{q}, \dot{q}\right];$$

$$q_2(x) = \min\left\{y : \Pi_m^*(y) \geq \Pi_m^*(x), y \in \left[\underline{q}, \bar{q}\right]\right\}, \forall x \in \left[\dot{q}, \bar{q}\right].$$

It follows that, when $q_0 \in [\underline{q}, \dot{q}]$, the manufacturer would optimally disclose the quality (i.e., $d(q) = 1$) if and only if $q \in [q_0, q_1(q_0)]$. Similarly, when $q_0 \in [\dot{q}, \bar{q}]$, the range of quality levels that would be disclosed is $q \in [q_2(q_0), q_0]$. In either case, quality levels that are either too low or too high would be withheld. Moreover, by definition, the buyers' expectation of quality when no information is received is defined as $q_0 \equiv E[q | q \in d^{-1}(0)]$, where $d^{-1}(\cdot)$ is the inverse of $d(\cdot)$ and captures the set of quality levels that are disclosed/withheld by the manufacturer.

Similar to the benchmark, there exists an equilibrium where the manufacturer chooses to disclose any quality $q \in [\underline{q}, \bar{q}]$. To see this, note that the buyers rationally infer that $q_0 = \underline{q}$ if $\Pi_m^*(\underline{q}) < \Pi_m^*(\bar{q})$ and $q_0 = \bar{q}$ if otherwise, in light of the manufacturer's disclosure strategy. Given this buyer inference, the manufacturer would be (weakly) better off disclosing all $q \in [\underline{q}, \bar{q}]$. As a result, we obtain an equilibrium of full disclosure. In other words, the traditional unravelling mechanism continues to work here even though the manufacturer's payoff $\Pi_m^*(\tilde{q})$ is nonmonotonic in $\tilde{q}$.

However, there may be equilibria with *partial disclosure*.

Proposition 3. *When $\Pi_m^*(\underline{q}) < \Pi_m^*(\bar{q})$ and $\hat{q} > \dot{q}$, or when $\Pi_m^*(\underline{q}) > \Pi_m^*(\bar{q})$ and $\hat{q} < \dot{q}$, there exist two types of equilibria:*

(1) $d(q) = 1$ *if and only if* $q \in [\check{q}, q_1(\check{q})]$, *and* $q_0 = \check{q}$, *where* $\check{q} \in (\underline{q}, \dot{q})$ *solves* $\check{q} = E[q|q < \check{q}$ *or* $q > q_1(\check{q})]$; (2) $d(q) = 1$ *if and only if* $q \in [q_2(\check{q}), \check{q}]$, *and* $q_0 = \check{q}$, *where* $\check{q} \in (\dot{q}, \bar{q})$ *solves* $\check{q} = E[q|q < q_2(\check{q})$ *or* $q > \check{q}]$.

This proposition demonstrates the existence of partial-disclosure equilibria, which may take two alternative forms, depending on whether the equilibrium buyer expectation q_0 falls into the ascending range (i.e., $(\underline{q}, \dot{q})$) or the descending range (i.e., $(\dot{q}, \bar{q})$) of the manufacturer's payoff function $\Pi_m^*(\cdot)$. In either case, the manufacturer would disclose if and only if the quality is in an intermediate range. As a result, the buyers rationally infer that the expected quality under concealment must be either sufficiently low or sufficiently high (i.e., outside the disclosure range). This implies that the equilibrium is obtained by solving $\check{q} = E[q|q < \check{q}$ or $q > q_1(\check{q})]$ or $\check{q} = E[q|q < q_2(\check{q})$ or $q > \check{q}]$ (subject to the corresponding range constraint), respectively. The solution determines not only the manufacturer's equilibrium disclosure range (i.e., $[\check{q}, q_1(\check{q})]$ or $[q_2(\check{q}), \check{q}]$) but also the buyers' equilibrium expectation $q_0 = \check{q}$.

This constitutes the central result of the paper that full disclosure may not always emerge in equilibrium even though the product value is stochastically increasing in quality. Interestingly, despite that disclosure is costless, in equilibrium the quality information may not be fully revealed by the manufacturer. This outcome contrasts sharply with the classical result in Grossman (1981) and Milgrom (1981) where full disclosure is the unique equilibrium. This is because of the nonmonotonicity in the manufacturer's payoff, which endogenously results from the interaction between the direct effect of quality improvement and the indirect effect of exploitation by the supplier. That is, as demonstrated in Section 3, when the perceived quality becomes sufficiently high, the supplier would charge a predatory wholesale price and thus squeeze the surplus left to the manufacturer.

In equilibrium, the manufacturer obeys a disclosure strategy that reveals the quality if and only if the quality is neither too low nor too high, that is, *intermediate disclosure*. When the quality is sufficiently low, the manufacturer chooses not to disclose because otherwise the buyers' product value would be too low. When the quality is sufficiently high, the manufacturer does not disclose either but for a different reason: the supplier would abuse the reduction in the buyers' price sensitivity to reduce the profit margin for the manufacturer. Note that the manufacturer is able to partially conceal some low quality levels because some high quality levels are credibly undisclosed. The concealment of the high quality levels raises the buyer conditional expectation q_0, permitting some low quality levels to be pooled with the high quality levels. Therefore, only when the quality takes intermediate values would the manufacturer choose to disclose: the quality is neither so low to drive down buyer utility too much nor so high to intensify the upstream exploitation effect.

Proposition 3 identifies sufficient conditions for the existence of the intermediate-disclosure equilibria. The conditions are quite general and hinge on the comparison of the mode $\dot{q}$ of the manufacturer payoff function with the prior distribution of the true quality. When the lower quality bound yields a lower manufacturer payoff than the upper bound does (i.e., $\Pi_m^*(\underline{q}) < \Pi_m^*(\bar{q})$), the unravelling logic underlying the standard full-disclosure result might drive down the equilibrium outcome (both the manufacturer's disclosure threshold and the buyers' expectation) toward the lower quality bound. Nevertheless, this force can be counterbalanced if the prior mean quality $\hat{q}$ is high relative to $\dot{q}$: the buyers' expected quality would be sufficiently high should the manufacturer choose not to disclose. Conversely, when the manufacturer payoff is higher at the lower quality bound than at the upper bound (i.e., $\Pi_m^*(\underline{q}) > \Pi_m^*(\bar{q})$), the unravelling mechanism would work in the opposite direction and might push the equilibrium toward the higher bound. In this case, a relatively low prior mean quality (i.e., $\hat{q} < \dot{q}$) would be sufficient to ensure that the unravelling force would not be dominant. Therefore, if either of these two sufficient conditions is satisfied, the intermediate-disclosure equilibria would arise. The former set of conditions is demonstrated in Figure 2, where the manufacturer's payoff under the first type of partial-disclosure equilibrium (i.e., $d(q) = 1$ if and only if $q \in [\check{q}, q_1(\check{q})]$) is depicted by the solid curve, whereas that under full disclosure is captured by the dashed curve.

As a specific example, consider the extended Hotelling model in Section 3.2. It can be verified that the manufacturer's payoff function $\Pi_m^*(\tilde{q})$ has a steeper slope for any $\tilde{q} < \dot{q} = t^{-1}(z/4)$ than for any $\tilde{q} > \dot{q}$. For example, if $t(\tilde{q}) = 1/\tilde{q}$, then $|\frac{\partial \Pi_m^*(\tilde{q})}{\partial \tilde{q}}| = z^2/16$ for $\tilde{q} < \dot{q} = 4/z$, which is higher than $|\frac{\partial \Pi_m^*(\tilde{q})}{\partial \tilde{q}}| = 1/\tilde{q}^2$ for $\tilde{q} > \dot{q} = 4/z$. This means that $\Pi_m^*(\tilde{q})$ is asymmetric around the mode $\dot{q}$ and "skewed" to the right. Therefore, the sufficient condition ($\Pi_m^*(\underline{q}) < \Pi_m^*(\bar{q})$ and $\hat{q} > \dot{q}$) in Proposition 3 is satisfied for any prior quality distribution that is symmetric around $\dot{q}$.[11] Conversely, $G(\cdot)$ needs to be sufficiently skewed to the right to meet the alternative sufficient condition for the emergence of the intermediate-disclosure equilibria: $\Pi_m^*(\underline{q}) > \Pi_m^*(\bar{q})$ and $\hat{q} < \dot{q}$.

4.2. Ex Ante Payoffs and Equilibrium Selection

We now compare the equilibrium ex ante payoffs (prior to the first stage of the game) between the intermediate-disclosure and the full-disclosure equilibria. Note first that the manufacturer is strictly better off under the intermediate-disclosure equilibria. This is because strategic concealment is "a stone to kill two birds" when the manufacturer's payoff function is unimodal in the buyers' perceived quality: it can boost product value if the true quality turns out to be relatively low and mitigate the problem of upstream exploitation if the quality happens to be too high (Figure 2).

The supplier's equilibrium ex ante profit is higher (lower) under partial disclosure if $\Pi_s^*(\tilde{q})$ is concave (convex) in $\tilde{q}$. We consider two specific cases that yield sharp payoff implications across the equilibrium scenarios for the supplier.

Proposition 4. *When the product value follows the modified Pareto distribution, the supplier's equilibrium ex ante profit is higher under partial disclosure than under full disclosure. With uniform distribution for product misfit, the supplier's equilibrium ex ante profit is higher under partial disclosure than under full disclosure if* $t''(\cdot) \geq 2[t'(\cdot)]^2/t(\cdot)$ *but lower if* $t''(\cdot) \leq 0$.

This proposition presents sufficient conditions under which strategic concealment may benefit or hurt the supplier. The first part of the proposition results from $\Pi_s^*(\tilde{q})$ being always concave when v follows the modified Pareto distribution. Similarly, with the uniform distribution for product misfit, $\Pi_s^*(\tilde{q})$ is concave if the misfit function $t(\cdot)$ is sufficiently convex. One such example is $t(\tilde{q}) = 1/\tilde{q}$. In contrast, the intermediate-disclosure equilibria would be harmful for the supplier's ex ante profit, if $t(\tilde{q})$ is concave in $\tilde{q}$.

As for the buyers' ex ante surplus, the comparison between the intermediate-disclosure and the full-disclosure equilibria is generally ambiguous, even though $CS^*(\tilde{q})$ is also unimodal in $\tilde{q}$. When the product value follows the modified Pareto distribution, it can be verified that we have $CS^*(\tilde{q}) = \frac{1}{1+\tilde{q}}\Pi_m^*(\tilde{q})$. It follows that $CS^*(\tilde{q}) < \Pi_m^*(\tilde{q})$ for all $\tilde{q} > 0$, and $\dot{q}_c < \dot{q}$. As a result, if the intermediate-disclosure equilibrium is such that $\check{q} = q_0 < \dot{q}_c$, the buyers would be strictly better off than under the full-disclosure equilibrium.[12] This is because $\check{q} < \dot{q}_c$ implies that $CS^*(\check{q}) > CS^*(q)$ for all $q < \check{q}$, and the condition $\Pi_m^*(\check{q}) = \Pi_m^*(q_1(\check{q}))$ under the intermediate-disclosure equilibrium implies that $CS^*(\check{q}) > CS^*(q_1(\check{q})) > CS^*(q)$ for all $q > q_1(\check{q})$. That is, any quality level that is concealed by the manufacturer under the intermediate-disclosure equilibrium (i.e., $q < \check{q}$ or $q > q_1(\check{q})$), should it be disclosed, would yield a lower buyer surplus. Alternatively, we have $CS^*(\tilde{q}) = \Pi_m^*(\tilde{q})/2$ for the extended Hotelling setup. This means that, similar to the manufacturer, the buyers are strictly better off under the intermediate-disclosure equilibria.

Therefore, there exist conditions under which the manufacturer's efforts to alleviate upstream exploitation under the intermediate-disclosure equilibria can benefit all parties in the market. This result allows us to employ a "Pareto-dominance" criterion for equilibrium selection. That is, we can eliminate the equilibrium where the equilibrium ex ante payoffs of the information sender (i.e., the manufacturer) and the receivers (i.e., the buyers) are not higher, and at least one party's is strictly lower, than those under the other equilibrium. Using this selection criterion, we can remove the full-disclosure equilibrium to retain the intermediate-disclosure equilibria under the extended Hotelling setting as well as under some conditions of the modified Pareto distribution.

5. Extensions

We consider several extensions to our model: supplier incentives for disclosure, vertical integration, endogenous timing for wholesale pricing, and endogenous quality. These extensions allow us to investigate the robustness of the intermediate-disclosure equilibria.

5.1. Supplier Incentives to Influence Disclosure

Because of practical and legal considerations, the supplier may not be able to directly disclose the quality of the manufacturer's product to the buyers, especially if its input is only a partial component in the production process (e.g., engines for motorcycles). We now investigate two issues regarding the supplier's incentives to influence the equilibrium disclosure outcome. First, the supplier may want to offer financial incentives to induce the manufacturer to disclose the quality, if doing so is necessary and desirable. We formally investigate this issue by allowing the supplier to provide a subsidy $S > 0$ for the manufacturer's quality disclosure. Consider the following model extension by adding a Stage 0 to the game in Figure 1. At the beginning of this added stage, the supplier decides how much to offer to subsidize the manufacturer's disclosure. If the offer is rejected by the manufacturer, the firms will play exactly the same three-stage game as in Figure 1. If the offer is accepted, we consider two alternative situations, depending on whether the manufacturer needs to commit to the disclosure before becoming privately informed about the quality.

In the former case, upon taking the subsidy, the manufacturer promises to disclose any quality q that will be stochastically realized later on. After the promised disclosure, the firms sequentially make their pricing decisions. To solve this extended game, note first that the manufacturer is always strictly better off under partial disclosure than under full disclosure (see Section 4.2). If the supplier is also strictly better off under the intermediate-disclosure equilibria, it will not offer any positive subsidy to the manufacturer. It follows from Proposition 4 that, when the product value follows the modified Pareto distribution, or when the product misfit distribution is uniform and $t''(\cdot) \geq 2[t'(\cdot)]^2/t(\cdot)$, the equilibrium outcome under this extended model would be exactly the same as that when subsidy is infeasible: the supplier will never offer any positive subsidy.

On the other hand, if $\Pi_s^*(\tilde{q})$ is convex in $\tilde{q}$, the supplier would be better off under full disclosure and thus can attempt to offer a subsidy to the manufacturer to disclose the quality. The subsidy will be accepted only if it is sufficient to compensate the loss of the manufacturer in giving up the opportunity of strategic concealment. Therefore, a positive subsidy will be provided in equilibrium if and only if the total channel ex ante payoff is higher under full disclosure than under the intermediate-disclosure equilibria. This would arise if the channel's payoff function, $\Pi_t^*(\tilde{q}) = \Pi_s^*(\tilde{q}) + \Pi_m^*(\tilde{q})$, is convex in $\tilde{q}$. However, the convexity of $\Pi_s^*(\tilde{q})$ does not imply that of $\Pi_t^*(\tilde{q})$. To see this, consider the example of uniform distribution for product misfit, where $\Pi_t^*(\tilde{q}) = \frac{3z^2}{16t(\tilde{q})}$ for $\tilde{q} < t^{-1}(z/4)$ and $\Pi_t^*(\tilde{q}) = z - t(\tilde{q})$ for $\tilde{q} > t^{-1}(z/4)$. It can be readily verified in this example that $\Pi_t^*(\tilde{q})$ is necessarily concave at $\tilde{q} = t^{-1}(z/4)$, that is, the left derivative is larger than the right derivative. As a result, there may exist scenarios under which the supplier desires to induce full quality disclosure from the manufacturer but fails to do so by offering a sufficiently attractive subsidy. One sufficient condition for this to happen is when $t''(\cdot) \leq 0$ such that the supplier is better off under full disclosure (Proposition 4), but the lower and the upper bounds of the support of quality ($\underline{q}$ and $\bar{q}$) are both close enough to the point $t^{-1}(z/4)$ such that the channel as a whole is better off under partial disclosure.

Consider then the other case when the manufacturer does not need to commit ex ante on the disclosure. Instead, the manufacturer can decide strategically, upon knowing q, whether to accept the offered subsidy S to disclose the quality. It is not very tractable to fully characterize the equilibrium disclosure strategies for all S. Nevertheless, as in the case of no subsidy, any non-full-disclosure equilibrium would involve intermediate disclosure, thanks to the unimodality of the manufacturer's payoff function $\Pi_m^*(\tilde{q})$. Moreover, in the same vein as before, if $\Pi_s^*(\tilde{q})$ is concave in $\tilde{q}$, the supplier will not offer a subsidy that would induce full disclosure. Therefore, intermediate-disclosure equilibria would continue to arise even under this extended model if, for instance, the conditions that imply concave $\Pi_s^*(\tilde{q})$ in Proposition 4 are satisfied.

Another related issue is whether the supplier may desire to directly influence the disclosure outcome by acquiring its own disclosure capability. Let us extend the model by adding a Stage 0 at which the supplier can decide whether to incur a cost to develop the disclosure capability. If the supplier becomes capable, it will fully disclose the downstream product's quality in equilibrium. This is because its payoff function $\Pi_s^*(\tilde{q})$ is monotonic in the perceived quality $\tilde{q}$. As a result, the supplier's decision about the development of disclosure capability boils down to comparing its ex ante payoffs under the full- and the intermediate-disclosure equilibria (against any potential development cost). Interestingly, full disclosure may generate lower ex ante profit for the supplier (e.g., Proposition 4). Therefore, in the same vein as the supplier may choose not to subsidize the manufacturer's promised disclosure, there exist conditions under which the supplier strategically chooses not to acquire the disclosure capability even in the absence of any cost consideration.

5.2. Incentives for Vertical Integration

The driving force we consider for the intermediate-disclosure equilibria is upstream exploitation leading to nonmonotonic payoff for the manufacturer. One natural question is then about the implications of the manufacturer's strategic quality concealment for vertical integration. For example, the supplier may consider to integrate forward by acquiring the downstream business. Alternatively, the manufacturer can merge backward with the input supplier. Recall that, as shown in the benchmark model in Section 2, the integrated channel would always disclose the quality. Therefore, the theoretically sensible question is how strategic concealment by the manufacturer may influence incentives for vertical integration, given that integration normally involves extra costs and uncertainty.[13] This amounts to comparing the ex ante nonintegrated payoffs under the intermediate-disclosure equilibria with those under full disclosure. Strategic concealment would give rise to private incentive for integration for an individual firm if and only if its ex ante profit is lower under the intermediate-disclosure equilibria. Similarly, public incentive for integration would be generated if and only if the firms' combined ex ante payoffs are lower under intermediate disclosure.[14]

The comparisons of equilibrium ex ante payoffs across the disclosure scenarios are essentially the same as those in Section 5.1. As we have shown there, nonpeculiar conditions exist under which the supplier actually benefits ex ante from the manufacturer's efforts to withhold the quality. This means that strategic concealment by the manufacturer may undermine, rather than generate, private incentive for vertical integration. Moreover, even when the intermediate-disclosure equilibria hurt the supplier's ex ante payoff, the firms as a whole can still be better off under partial disclosure. As a result, strategic concealment may give rise to (the supplier's) private incentive for vertical integration but at the same time erode the public incentive and thus reduce the chance that the firms actually get integrated in equilibrium.

A similar issue is addressed in Gupta et al. (1995). They consider a variant of the standard Hotelling model in a bilateral-monopoly channel setting and show that, as in this paper, the downstream firm's equilibrium payoff can be nonmonotonic in t (which is typically interpreted as transportation cost). However, they permit perfect price discrimination in the downstream market and the buyers' demand is always inelastic. They also assume that t is deterministic and can be strategically decided by the downstream firm. They show that the downstream firm would increase t at the expense of the upstream firm's and the channel's payoffs, giving rise to both private and public incentives for forward integration. This stands in sharp contrast to the research issue considered in the current paper, where $t(q)$ is stochastic and privately known and more importantly the downstream firm's response to upstream exploitation is strategic disclosure/concealment of private information to the buyers. It is this difference that leads us to obtain the opposite results that the manufacturer's strategic concealment can yield weakened (for both firms) or conflicting (between the supplier and the channel) incentives for vertical integration. This contrast across the papers reveals that upstream exploitation can generate qualitatively different implications for vertical restraints, depending on what instrument (deciding versus disclosing quality/transportation cost) the downstream firm can use to deal with upstream predatory pricing.

5.3. Timing for Wholesale Pricing

We have assumed that the wholesale price is set after the manufacturer's disclosure decision (Figure 1). This timing reflects the practice in many markets, as conventionally observed in the literature, that pricing decisions can be modified flexibly. Nevertheless, an interesting question is whether this assumption can be endogenized in our setting. To this end, we can enrich the setup by allowing the supplier to decide in Stage 0 whether to set and commit to an ex ante wholesale price or to keep it flexible: the basic model will be played as the subgame following the latter choice.

There would be two consequences if a wholesale price is committed. First, the wholesale price would not vary with the change in the buyer's perceived quality and thus would become ex post suboptimal. This is clearly a downside of the commitment option. Holding the manufacturer's disclosure unchanged, the supplier would prefer to set the wholesale price flexibly. Second, should the wholesale price be set in advance, the manufacturer would have no incentive to strategically conceal the product quality to mitigate the concern of upstream exploitation. Full disclosure would then arise in equilibrium. Recall from Section 4.2 that the supplier's equilibrium ex ante profit is higher under full disclosure if and only if $\Pi_s^*(\tilde{q})$ is convex in $\tilde{q}$.

Therefore, the supplier may want to commit to a wholesale price, only if the incremental gain from full revelation is positive and can sufficiently offset the negative effect of abandoned adjustment. The convexity of $\Pi_s^*(\tilde{q})$ is a necessary (but not sufficient) condition for this to happen. Conversely, as demonstrated in Proposition 4, there are conditions under which the supplier is strictly better off under partial disclosure. Flexibility would then be unambiguously beneficial for the supplier: not only market variations can be accommodated in the wholesale pricing but also quality concealment can be preferably induced. This means that the timing in Figure 1 can emerge endogenously even if the supplier can decide whether to fix the wholesale price in advance.

5.4. Endogenous Quality

We have also assumed that q is stochastic and cannot be changed by the firms. The former assumption is customary, as well as inevitable, to study strategic disclosure of private information. In addition, the issue of disclosure would be immaterial should we permit q to be a firm's deterministic decision, because the concept of equilibrium requires any optimally chosen q to be rationally expected. Moreover, it would be easier to justify these two assumptions if we do not interpret q as product quality: It can equivalently represent any random shock/news that is out of the firms' control but can positively influence the buyers' product value (e.g., technology breakthrough).

Nevertheless, in practice, a firm may have partial influence over q. For instance, product quality is likely to be higher as the supplier improves its input. Let us consider an extension to our setup: $q = Q + \rho$, where $Q \in [\underline{Q}, \bar{Q}]$ can be determined by the supplier or the manufacturer (at Stage 0) before the random term $\rho \in [\underline{\rho}, \bar{\rho}]$ is privately revealed to the manufacturer according to the distribution $B(\rho)$. Conditional on the chosen Q, the distribution of the true quality would be $G(q) = B(q - Q)$, for $q \in [Q + \underline{\rho}, Q + \bar{\rho}]$. Our results will continue to hold as long as the support of q is not too narrow. That is, we can still apply Proposition 3 to characterize the existence conditions for the intermediate-disclosure equilibria. In particular, the nonmonotonicity of the manufacturer's payoff function $\Pi_m^*(\tilde{q})$ would not collapse if $Q + \underline{\rho} < \dot{q}$ and $Q + \bar{\rho} > \dot{q}$. One sufficient condition to ensure this requirement for any Q is $\bar{Q} + \underline{\rho} < \dot{q}$ and $\underline{Q} + \bar{\rho} > \dot{q}$. This implies that the results on the intermediate-disclosure equilibria would be robust to endogenous (while stochastic) q.

6. Concluding Remarks

6.1. Implications

The gist of the paper is that supply side conflict may lead to concealment in voluntary quality disclosure to the market. We consider a particular form of channel friction: upstream firms may exploit the reduction of demand elasticity, which is associated with improved quality, to clutch more surplus from the channel. That is, a higher quality may not only enhance product value for buyers but also give rise to increasing imbalance in the split of payoffs between channel members. These two forces interact with each other and hence may, under very general conditions, lead the profit of a downstream manufacturer to be nonmonotonically influenced by product quality. As a result, a high-quality manufacturer may choose no disclosure and amalgamate with the low-quality type. This may then yield intermediate-disclosure equilibria and explain not only the lack of prefect unravelling but also resolve the puzzle of high-end concealment. Therefore, our results can be used to understand anecdotal and empirical findings regarding the absence of full disclosure. We present a novel explanation for why we sometimes observe high-quality brands choosing not to promote their advantages. We do not wish to claim that our explanation is the only possible theory for intermediate disclosure. Nevertheless, it can be a useful complement to alternative accounts.

Our study provides managerial insights to firms in decentralized markets. At the basic level, we point out the importance to fully take into account all possible consequences of value-enhancing improvements. In particular, a firm should invest extra care to estimate, as the product quality increases, whether the market is becoming more homogenous and demand less elastic. This can be an unexpected concern if the firm has to procure its essential input(s) from powerful suppliers. Reduced demand elasticity may not always be blessing news, because it can be exploited by upstream suppliers to squeeze a larger proportion of the channel surplus. This concern can be especially relevant for firms without suitable input replacements. Actually, in recent years, the upstream exploitation issue has been exceedingly recognized and escalated to an unprecedented level, as the supply chain in many industries becomes more decentralized/specialized and globalized. This issue can only become more complicated, if strategic or political factors are increasingly considered in the interaction of channel members across the global market.

Our research suggests that downstream firms can be proactive in dealing with the issue of upstream exploitation. In particular, firms can cautiously design their disclosure strategies to overcome potential predatory behavior from input suppliers. If it is determined that market demand may become less elastic, a downstream firm may strategically withhold superior information about its product to restore buyer price sensitivity. For example, manufacturers can delay the announcement of, or even understate, their breakthrough in new technologies (e.g., automobile batteries, next generation of mobile communications). Similarly, pharmaceutical companies may engage in noninformative advertising. These passive communication strategies can aggressively protect the downstream firms' position from being overly dominated by upstream partners.

This paper can also shed light on suppliers' optimal response to downstream firms' strategic concealment. We suggest that input suppliers do not need to always worry about defensive communication by the downstream firm. Conversely, the supplier's ex ante payoff can actually be lower if product quality is always fully disclosed. Therefore, there are situations in which quality disclosure need not be encouraged. This means that suppliers should be cautious in subsidizing the downstream firm's quality disclosure efforts or developing their own disclosure capabilities. Similarly, vertical-coordination instruments, such as forward integration, may not necessarily be desirable just for the purpose of facilitating communication in the downstream market.

6.2. Discussion and Future Research

We have posited that product quality shifts the concentration of product value distribution without modifying the upper bound $\bar{v}$. This assumption is quite general, because we allow $\bar{v}$ to be *any* finite number and infinitely high product value would be inconceivable. It can also match the practice for many products. Nevertheless, even if we relax this presumption and allow for quality-varying $\bar{v}$, we can continue to generate similar results. For example, suppose the upper bound of product value in the extended Hotelling setup is an increasing function of perceived quality: $\bar{v} = z(\tilde{q})$. The manufacturer's equilibrium payoff function $\Pi_m^*(\tilde{q})$ would still be unimodal, and those of the supplier and the channel remain monotonic in $\tilde{q}$. More generally, the economic mechanism we consider in this paper would continue to work as long as demand elasticity is sufficiently decreased at the margin as quality improves. That is, the manufacturer's equilibrium payoff can still be nonmonotonic for other classes of distributions with quality-varying bounds.

We have focused on upstream exploitation and downstream disclosure. Alternatively, we can consider the disclosure of upstream firms (e.g., manufacturers) that may be held up by downstream firms (e.g., dominant retailers). For example, if we allow the downstream firm to be the leader in channel pricing, we can obtain an analogous result that the upstream firm's payoff is nonmonotonic in quality because of downstream exploitation. This would then mean that equilibrium disclosure by the upstream firm may be incomplete. More generally, we can consider other forms of price determination (e.g., negotiation) where both channel members' payoffs might become nonmonotonic in product quality. This type of extension would add to the insights in this paper, especially when the channel members' disclosure decisions are complements rather than substitutes.

There are other avenues for future research. One direction is to investigate quality disclosure in the presence of other channel frictions (e.g., service provision). It would also be interesting to consider the impact of channel structure (e.g., upstream/downstream competition, exclusive dealing, exclusive territory, multilevel distribution). In addition, future research can study the interaction between firm information acquisition (e.g., product testing) and quality disclosure. Similarly, it is an interesting question whether firm disclosure and buyer information acquisition are complements or substitutes. Another direction for future research is to examine the impact of channel friction on other types of information transmission (e.g., signaling, cheap-talk communication). We hope these investigations can generate additional insights.

Appendix.

Proof of Theorem 1. When $\tilde{q} \to \infty$, by Assumption A1, we have $F(v,\tilde{q}) \to 0$ and $f(v,\tilde{q}) \to 0$ for all $v \in [\underline{v}, \bar{v})$. This implies that the first-order condition for the manufacturer's pricing problem (i.e., the left-hand side in (4)) is always positive for any $p < \bar{v}$ and $\omega \in [0, \bar{v})$. As a result, the optimal selling price converges to $\bar{v}$ for any $\omega \in [0, \bar{v})$ and $\frac{\partial p(\omega)}{\partial \omega} \to 0$. In anticipation of this, the first-order condition for the wholesale pricing problem (i.e., the left-hand side in (7)) is also always positive for any $\omega < \bar{v}$. This means that the equilibrium prices $p^*(\tilde{q})$ and $\omega^*(\tilde{q})$ both converge to $\bar{v}$.

Note that $\Pi_m^*(\tilde{q}) = [p^*(\tilde{q}) - \omega^*(\tilde{q})][1 - F(p^*(\tilde{q}), \tilde{q})]$. So $\lim_{\tilde{q}\to\infty} \times \Pi_m^*(\tilde{q}) = (\bar{v} - \bar{v}) * 1 = 0$. In addition, $\Pi_s^*(\tilde{q}) = \omega^*(\tilde{q})[1 - F(p^*(\tilde{q}), \tilde{q})]$. Therefore, $\lim_{\tilde{q}\to\infty} \Pi_s^*(\tilde{q}) = \bar{v}$. Moreover, the equilibrium buyer surplus is given by $CS^*(\tilde{q}) = \int_{p^*(\tilde{q})}^{\bar{v}} [v - p^*(\tilde{q})]\, dF(v,\tilde{q}) = \int_{p^*(\tilde{q})}^{\bar{v}} [1 - F(v,\tilde{q})]\, dv$, where the second step is obtained through integrating by parts. It follows that $\lim_{\tilde{q}\to\infty} CS^*(\tilde{q}) = 0$. Q.E.D

Proof of Proposition 1. Note that $p^*(\tilde{q}) = \frac{\tilde{q}(2+\tilde{q})}{(1+\tilde{q})^2}$ and $\omega^*(\tilde{q}) = \frac{\tilde{q}}{(1+\tilde{q})}$. It follows that the manufacturer profit margin is $p^*(\tilde{q}) - \omega^*(\tilde{q}) = \frac{\tilde{q}}{(1+\tilde{q})^2}$. It can be readily verified that the manufacturer profit margin is increasing in $\tilde{q}$ if $\tilde{q} < 1$ and decreasing if $\tilde{q} > 1$. Consider then the equilibrium demand $D^*(\tilde{q}) = [1 - p^*(\tilde{q})]^{1/\tilde{q}} = (1 + \tilde{q})^{-2/\tilde{q}}$. The derivative of $D^*(\tilde{q})$ with respect to $\tilde{q}$ has the same sign as that of $(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}$. The term $(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}$ is always positive for all $\tilde{q} > 0$, because it is equal to zero at $\tilde{q} = 0$ and its derivative is positive.

Substituting $p^*(\tilde{q}) = \frac{\tilde{q}(2+\tilde{q})}{(1+\tilde{q})^2}$ and $\omega^*(\tilde{q}) = \frac{\tilde{q}}{(1+\tilde{q})}$ into the equilibrium manufacturer profit function $\Pi_m^*(\tilde{q}) = [p^*(\tilde{q}) - \omega^*(\tilde{q})]D^*(\tilde{q})$ and taking the derivative, we ind that the sign is the same as that of $2ln(1 + \tilde{q}) - \tilde{q}$. It can be easily confirmed that $2ln(1 + \tilde{q}) - \tilde{q}$ is concave in $\tilde{q}$, converges to zero at $\tilde{q} = 0$ and to negative infinity for $\tilde{q} = \infty$, and has a derivative that is equal to one at $\tilde{q} = 0$ and to -1 as $\tilde{q}$ converges to positive infinity. Therefore, there must exist a unique point $\dot{q} > 0$ such that $2ln(1 + \tilde{q}) - \tilde{q}$ is positive (negative) for $\tilde{q} < \dot{q}$ ($\tilde{q} > \dot{q}$).

Next, consider the equilibrium supplier profit $\Pi_s^*(\tilde{q}) = \omega^*(\tilde{q})D^*(\tilde{q})$. Its derivative has the same sign as that of $2(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}$. This is always positive for all $\tilde{q} > 0$, because it is equal to zero at $\tilde{q} = 0$ and has a positive derivative.

The equilibrium buyer surplus is $CS^*(\tilde{q}) = \int_{p^*(\tilde{q})}^{1} [1 - F(v,\tilde{q})]\, dv = \frac{\tilde{q}[1-p^*(\tilde{q})]^{1+1/\tilde{q}}}{1+\tilde{q}}$. Its derivative has the same sign as that of $2(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}(1 + 2\tilde{q})$. The first-order derivative of $2(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}(1 + 2\tilde{q})$ is $1 + 2ln(1 + \tilde{q}) - 4\tilde{q}$, which is equal to one at $\tilde{q} = 0$ and converges to negative infinity for $\tilde{q} = \infty$. The second-order derivative of $2(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}(1 + 2\tilde{q})$ is $2/(1 + \tilde{q}) - 4$, which is negative for any $\tilde{q} > 0$. In addition, $2(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}(1 + 2\tilde{q})$ is equal to zero for $\tilde{q} = 0$ and converges to negative infinity for $\tilde{q} = \infty$. This means that there must exist a unique point $\dot{q}_c > 0$ such that $2(1 + \tilde{q}) \times ln(1 + \tilde{q}) - \tilde{q}(1 + 2\tilde{q})$ is positive (negative) for $\tilde{q} < \dot{q}_c$ ($\tilde{q} > \dot{q}_c$).

Moreover, we have $2(1 + \tilde{q})ln(1 + \tilde{q}) - \tilde{q}(1 + 2\tilde{q}) - [2ln(1 + \tilde{q}) - \tilde{q}] = 2\tilde{q}[ln(1 + \tilde{q}) - \tilde{q}]$. It can be verified that $ln(1 + \tilde{q}) - \tilde{q}$ is equal to zero at $\tilde{q} = 0$ and has a negative derivative for all $\tilde{q} > 0$. Therefore, $ln(1 + \tilde{q}) - \tilde{q} < 0$ for all $\tilde{q} > 0$. This implies that we must have $\dot{q}_c < \dot{q}$. Q.E.D

Proof of Proposition 3. Suppose that in equilibrium $q_0 \in (\underline{q}, \dot{q})$. Then the manufacturer discloses if and only if $q \in [q_0, q_1(q_0)]$. Given this, the buyers infer that $q_0 = E[q|q < q_0 \text{ or } q > q_1(q_0)]$. Then such an equilibrium exists if there is a $\check{q} \in (\underline{q}, \dot{q})$ that solves $\check{q} - E[q|q < \check{q} \text{ or } q > q_1(\check{q})] = 0$.

Note that $\Pi_m^*(\underline{q}) < \Pi_m^*(\bar{q})$ implies $q_1(\underline{q}) = \bar{q}$. This further implies that $\check{q} - E[q|q < \check{q} \text{ or } q > q_1(\check{q})] \to \check{q} - E[q|q < \check{q}] > 0$ as $\check{q} \to \underline{q}$. In addition, as $\check{q} \to \dot{q}$, we would have $q_1(\check{q}) \to \dot{q}$ and thus $\check{q} - E[q|q < \check{q} \text{ or } q > q_1(\check{q})] \to \dot{q} - E[q] = \dot{q} - \hat{q}$. This then proves the existence of a $\check{q} \in (\underline{q}, \dot{q})$ that solves $\check{q} - E[q|q < \check{q}$ or $q > q_1(\check{q})] = 0$, if $\Pi_m^*(\underline{q}) < \Pi_m^*(\bar{q})$ and $\hat{q} > \dot{q}$.

Conversely, $\Pi_m^*(\underline{q}) > \Pi_m^*(\bar{q})$ implies $q_1(\underline{q}) < \bar{q}$, resulting in $\check{q} - E[q|q < \check{q} \text{ or } q > q_1(\check{q})] \to \underline{q} - E[q|q \geq q_1(\underline{q})] < 0$ as $\check{q} \to \underline{q}$. Moreover, if $\hat{q} < \dot{q}$, we would have $\check{q} - E[q|q < \check{q} \text{ or } q > q_1(\check{q})] \to \hat{q} - E[q|q < \hat{q} \text{ or } q > q_1(\hat{q})] > 0$ as $\check{q} \to \hat{q}$. This means that there exists a $\check{q} \in (\underline{q}, \hat{q})$ that solves $\check{q} - E[q|q < \check{q} \text{ or } q > q_1(\check{q})] = 0$, if $\Pi_m^*(\underline{q}) > \Pi_m^*(\bar{q})$ and $\hat{q} < \dot{q}$.

Next, suppose that in equilibrium $q_0 \in (\dot{q}, \bar{q})$. The manufacturer discloses if and only if $q \in [q_2(q_0), q_0]$. Given this, the buyers infer that $q_0 = E[q|q < q_2(q_0) \text{ or } q > q_0]$. This equilibrium would exist if there is a $\check{q} \in (\dot{q}, \bar{q})$ that solves $\check{q} - E[q|q < q_2(\check{q}) \text{ or } q > \check{q}] = 0$.

If $\Pi^*_m(\underline{q}) < \Pi^*_m(\bar{q})$, we would have $q_2(\bar{q}) > \underline{q}$. This yields $\check{q} - E[q|q < q_2(\check{q}) \text{ or } q > \check{q}] \to \bar{q} - E[q|q < q_2(\bar{q})] > 0$ as $\check{q} \to \bar{q}$. Moreover, if $\hat{q} > \dot{q}$, we would have $\check{q} - E[q|q < q_2(\check{q}) \text{ or } q > \check{q}] \to \hat{q} - E[q|q < q_2(\hat{q}) \text{ or } q > \hat{q}] < 0$ as $\check{q} \to \hat{q}$. This means that there exists a $\check{q} \in (\hat{q}, \bar{q})$ that solves $\check{q} - E[q|q < q_2(\check{q}) \text{ or } q > \check{q}] = 0$, if $\Pi^*_m(\underline{q}) < \Pi^*_m(\bar{q})$ and $\hat{q} > \dot{q}$.

Consider then the condition $\Pi^*_m(\underline{q}) > \Pi^*_m(\bar{q})$ and $\hat{q} < \dot{q}$. Note that $q_2(\bar{q}) = \underline{q}$. It follows that $\check{q} - E[q|q < q_2(\check{q}) \text{ or } q > \check{q}] \to \check{q} - E[q|q > \check{q}] < 0$ as $\check{q} \to \bar{q}$. In addition, $\check{q} - E[q|q < q_2(\check{q}) \text{ or } q > \check{q}] \to \dot{q} - E[q] = \dot{q} - \hat{q} > 0$ as $\check{q} \to \dot{q}$. This again shows the existence of an interior solution, $\check{q} \in (\dot{q}, \bar{q})$, for $\check{q} - E[q|q < q_2(\check{q}) \text{ or } q > \check{q}] = 0$. Q.E.D

We present here several classes of distributions that satisfy the assumptions that are sufficient to establish the large-$\tilde{q}$ results in Theorem 1.

- Truncated Normal Distribution. Let $x \in (-\infty, \infty)$ be a normally distributed variable: $x \sim N(\tilde{q}, \sigma^2)$. v is constructed from x by truncating from above at $\bar{v}$, while keeping unchanged the relative probability density of any two points over the support $(-\infty, \bar{v}]$. The CDF and the density function for v are $F(v, \tilde{q}) = \frac{\Phi(\frac{v-\tilde{q}}{\sigma})}{\Phi(\frac{\bar{v}-\tilde{q}}{\sigma})}$ and $f(v, \tilde{q}) = \frac{\phi(\frac{v-\tilde{q}}{\sigma})}{\sigma\Phi(\frac{\bar{v}-\tilde{q}}{\sigma})}$, respectively, where $\Phi(\cdot)$ and $\phi(\cdot)$ are the CDF and the density function for a standard normal distribution.
- Truncated Gumbel Distribution (Type-I Extreme-Value Distribution). Let $x \in (-\infty, \infty)$ be a Gumbel-distributed variable with the location parameter $\tilde{q}$ and the scale parameter β. v is constructed from x by truncating from above at $\bar{v}$. The CDF and the density function for v are $F(v, \tilde{q}) = exp(e^{-\frac{\bar{v}-\tilde{q}}{\beta}} - e^{-\frac{v-\tilde{q}}{\beta}})$ and $f(v, \tilde{q}) = \frac{1}{\beta} exp(e^{-\frac{\bar{v}-\tilde{q}}{\beta}} - e^{-\frac{v-\tilde{q}}{\beta}} - \frac{v-\tilde{q}}{\beta})$, respectively.
- Truncated Generalized Logistic Distribution (Type I). Let $x \in (-\infty, \infty)$ be a random variable with type-I generalized logistic distribution with the parameter $\tilde{q} > 0$. v is formed from x by truncating from above at $\bar{v}$. The CDF and the density function for v are $F(v, \tilde{q}) = \frac{(1+e^{-\bar{v}})^{\tilde{q}}}{(1+e^{-v})^{\tilde{q}}}$ and $f(v, \tilde{q}) = \frac{\tilde{q}(1+e^{-\bar{v}})^{\tilde{q}} e^{-v}}{(1+e^{-v})^{\tilde{q}+1}}$, respectively.

We prove that these truncated distributions meet Assumptions A1 and A2. Moreover, their density functions $f(v, \tilde{q})$ are log-concave, implying that their inverse hazard rate functions $\overline{H}(v, \tilde{q})$ are decreasing in v (Bagnoli and Bergstrom 2005).[15] This corroborates the assumption about the existence of a unique interior solution to the pricing problems.

Proof for Truncated Distributions. Consider first the truncated normal distribution. For all $v < \bar{v}$, we have $\frac{\partial F(v,\tilde{q})}{\partial \tilde{q}} = \frac{-\frac{1}{\sigma}\phi(\frac{v-\tilde{q}}{\sigma})\Phi(\frac{\bar{v}-\tilde{q}}{\sigma}) + \frac{1}{\sigma}\Phi(\frac{v-\tilde{q}}{\sigma})\phi(\frac{\bar{v}-\tilde{q}}{\sigma})}{\Phi(\frac{\bar{v}-\tilde{q}}{\sigma})^2} = [\frac{f(\bar{v},\tilde{q})}{F(\bar{v},\tilde{q})} - \frac{f(v,\tilde{q})}{F(v,\tilde{q})}] F(v, \tilde{q}) F(\bar{v}, \tilde{q}) < 0$, where the inequity is due to the log-concavity of $F(v, \tilde{q})$. This confirms Assumption A1. In addition, $\lim_{\tilde{q}\to\infty} \times F(v,\tilde{q}) = \lim_{\tilde{q}\to\infty} \frac{-\frac{1}{\sigma}\phi(\frac{v-\tilde{q}}{\sigma})}{-\frac{1}{\sigma}\phi(\frac{\bar{v}-\tilde{q}}{\sigma})} = \lim_{\tilde{q}\to\infty} exp(\frac{1}{2\sigma^2}(\bar{v}+v-2\tilde{q})(\bar{v}-v))$, which is equal to zero for $v < \bar{v}$ and one for $v = \bar{v}$. Similarly, $\lim_{\tilde{q}\to\infty} f(v,\tilde{q}) = \lim_{\tilde{q}\to\infty} \frac{-\frac{1}{\sigma}\phi'(\frac{v-\tilde{q}}{\sigma})}{-\phi(\frac{\bar{v}-\tilde{q}}{\sigma})} = \lim_{\tilde{q}\to\infty} \frac{(\tilde{q}-v)\phi(\frac{v-\tilde{q}}{\sigma})}{\sigma^3\phi(\frac{\bar{v}-\tilde{q}}{\sigma})} = \lim_{\tilde{q}\to\infty} \frac{\tilde{q}-v}{\sigma^3} \times exp(\frac{1}{2\sigma^2}(\bar{v}+v-2\tilde{q})(\bar{v}-v)) = \lim_{\tilde{q}\to\infty} \frac{1}{\sigma exp(\frac{1}{2\sigma^2}(2\tilde{q}-\bar{v}-v)(\bar{v}-v))}$, which is equal to zero for $v < \bar{v}$ and positive infinity for $v = \bar{v}$.

Next, consider the truncated Gumbel distribution. We can rewrite the CDF as $F(v, \tilde{q}) = exp(e^{\tilde{q}/\beta}(e^{-\bar{v}/\beta} - e^{-v/\beta}))$. It follows that $\frac{\partial F(v,\tilde{q})}{\partial \tilde{q}} < 0$ and $\lim_{\tilde{q}\to\infty} F(v, \tilde{q}) = exp(-\infty) = 0$ for all $v < \bar{v}$. The density function can be rewritten as $f(v,\tilde{q}) = \frac{1}{\beta} exp(e^{\tilde{q}/\beta}(e^{-\bar{v}/\beta} - e^{-v/\beta}) + (\tilde{q}-v)/\beta)$. Therefore, $\lim_{\tilde{q}\to\infty} \times f(v,\tilde{q}) = \lim_{\tilde{q}\to\infty} \frac{1}{\beta} exp(e^{\tilde{q}/\beta}(e^{-\bar{v}/\beta} - e^{-v/\beta})/\beta + 1/\beta) = \frac{1}{\beta} exp(-\infty) = 0$ for all $v < \bar{v}$ and $\lim_{\tilde{q}\to\infty} f(v, \tilde{q}) = \infty$ for $v = \bar{v}$.

Consider then the truncated type-I generalized logistic distribution. It is straightforward that $\frac{\partial F(v,\tilde{q})}{\partial \tilde{q}} < 0$ and $\lim_{\tilde{q}\to\infty} F(v, \tilde{q}) = 0$ for all $v < \bar{v}$ and $F(\bar{v}, \tilde{q}) = 0$. Moreover, $\lim_{\tilde{q}\to\infty} f(v, \tilde{q}) = \lim_{\tilde{q}\to\infty} \frac{e^{-v}}{1+e^{-v}} \frac{\tilde{q}}{[(1+e^{-v})/(1+e^{-\bar{v}})]^{\tilde{q}}} = \lim_{\tilde{q}\to\infty} \frac{e^{-v}}{1+e^{-v}} \frac{1}{[(1+e^{-v})/(1+e^{-\bar{v}})]^{\tilde{q}} \cdot ln[(1+e^{-v})/(1+e^{-\bar{v}})]} = 0$ for any $v < \bar{v}$, and $\lim_{\tilde{q}\to\infty} f(\bar{v}, \tilde{q}) = \lim_{\tilde{q}\to\infty} \frac{e^{-\bar{v}}\tilde{q}}{1+e^{-\bar{v}}} = \infty$.

The density function for type-I generalized logistic distribution is $f(x, \tilde{q}) = \frac{\tilde{q}e^{-x}}{(1+e^{-x})^{\tilde{q}+1}}$. Therefore, the derivative of $\ln f(x, \tilde{q})$ with respect to x is equal to $-1 + (\tilde{q} + 1)\frac{e^{-x}}{1+e^{-x}}$, which is decreasing in x. This proves that this distribution has log-concave density. This also implies that the truncated type-I generalized logistic distribution has log-concave density (Bagnoli and Bergstrom 2005).

Endnotes

[1] Sun (2011) considers a setup with multidimensional buyer preferences and shows that a monopoly firm may not disclose high quality levels when the disclosure entails the revelation of a horizonal location as well.

[2] See also Lizzeri (1999) on the role of independent certification in strategic disclosure and Iyer and Soberman (2000) on optimal selling strategies for product modification information.

[3] Consider, for instance, the role of chips to smart phones, engines to automobiles, chemicals to drugs, or soybeans to poultry formulas, the importance of which has been increasingly recognized in the era of global supply chain.

[4] We deliberately make this assumption to rule out the signaling role of the manufacturer's selling price. See Daughety and Reinganum (2008) on a unified model where quality disclosure and price signaling are substitutes.

[5] The buyers can be end consumers who purchase directly from the manufacturer, independent distributors/retailers who resell the manufacturer's product in mutually exclusive markets, or firms that procure the manufacturer's product (e.g., equipment) as input in their businesses. In scenarios when there are more vertical levels beyond the supplier-manufacturer-buyer relationship, the buyers' value of purchasing from the manufacturer, v, can be derived as the equilibrium outcome of other strategic interaction that is beyond our current focus.

[6] We term q as quality for exposition purpose, whereas it can equivalently represent any shock/news that positively influences the product value and that can be truthfully disclosed by the manufacturer (e.g., technology breakthrough).

[7] Considering negotiation about the wholesale price does not qualitatively change our main results.

[8] This is due to the assumption that the value support is bounded from above. Should the upper bound of the value distribution be unbounded (i.e., $\bar{v} = \infty$), the manufacturer's equilibrium profit margin may not converge to zero. Nevertheless, it is plausible that product value has an upper bound in most markets.

[9] The equilibrium manufacturer margin, $p^*(\tilde{q}) - \omega^*(\tilde{q})$, need not always decrease with $\tilde{q}$, because $p^*(\tilde{q})$ is increasing in $\tilde{q}$. As shown in the appendix, a higher $\tilde{q}$ decreases the equilibrium manufacturer margin if and only if $\tilde{q} > 1$.

[10] The inverse hazard rate function is decreasing for all $v \in [0, 1]$ when $\tilde{q} \geq 1$ but is nonmonotonic when $\tilde{q} < 1$. Nevertheless, the second-order conditions for the pricing problems are negative. So the

monotone hazard rate condition is sufficient but not necessary for the existence of a unique interior solution.

[11] By continuity, this condition is also satisfied for small variations in the location and/or skewness of the (symmetric) distribution.

[12] Buyer surplus implications remain ambiguous under all other situations of the intermediate-disclosure equilibria.

[13] Incentives to implement other vertical-coordination devices (e.g., two-part tariff) are qualitatively similar.

[14] Vertical integration can occur in equilibrium if and only if the expected profit for the integrated channel, $\Pi^b = \int_{\underline{q}}^{\bar{q}} \Pi^b(q)dG(q)$, is higher than the firms' combined ex ante nonintegrated payoffs (under either intermediate or full disclosure) plus any costs of integration.

[15] As shown by Bagnoli and Bergstrom (2005), if the density function of a random variable x is log-concave, then the density of its linear transformations (i.e., $y = ax + b$) is log-concave and the hazard rate function is increasing. It is well known that normal and extreme-value distributions have log-concave density. We prove here the log-concavity of the density for type-I generalized logistic distribution.

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