Does better information lead to lower prices? Price and Advertising Signaling under External Information about Product Quality

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ABSTRACT

Firms have traditionally used price and advertising to signal product quality when consumers initially are not well-informed about qualities of competing sellers. In the last two decades, the Internet has made it more feasible for buyers to connect with new sellers and products which they cannot inspect before purchase. But the Internet also provides abundant external sources of information about sellers' product qualities, including online review and ratings systems, search engines, user forums, online social networks, expert opinions etc. This paper examines how the availability of external information to consumers impacts sellers' use of price and advertising as signaling instruments, and thereby how it impacts market prices. We demonstrate a rich and complex interaction between the informational roles of price, advertising, and the external information environment. First, contrary to expectation, better information sometimes may have no impact at all on firms' pricing strategy or consumer welfare. Second, when price alone is sufficient as a signaling instrument, we find that better external information about product quality acts as a substitute, hence reduces the level of price distortion (i.e., increase) needed for signaling. But, external information may alter firms' mix of signaling instruments, motivating firms to place more weight on price and less on (the more expensive instrument) advertising. This shift causes an *increase* in market prices when there is an increase in the quality of external information available to buyers. Surprisingly, therefore, better information is not always a boon to buyers because it can lead to higher prices when both price and advertising are needed to signal quality. Even when external information impacts price in the expected direction (reduction), our work adds a new explanation beyond the prior understanding that search costs affect prices by changing the level of competition.

1 Introduction

The Internet has transformed commercial activity in the last few decades. One fundamental, well-understood, change is the ease with which consumers can learn about sellers and their prices through, for example, generic search engines such as Google, specialized vertical search providers (e.g., Expedia for travel), price-comparison and tracking sites (e.g., PriceGrabber), and domain-specific forums (e.g., TripAdvisor), etc. These technologies have radically reduced search costs for consumers, which may lead to more efficient allocations, lower prices, higher consumer surplus, and lower profits for sellers (Bakos, 1997). But the Internet has also vastly expanded consumers' and firms' abilities to find each other and transact at levels vastly greater than in the past (Brynjolfsson et al., 2011). With these expanded opportunities, consumers face much more uncertainty about product or seller quality, compared with the traditional economy where they could physically inspect the product or dealt with local sellers. Typically, quality uncertainty disadvantages higher-quality sellers, motivating them to take some actions to signal their qualities.

Price and advertising can be used to signal product quality when consumers otherwise lack perfect information about quality, and this purpose has been studied in the academic literature since Nelson (1974) and Milgrom and Roberts (1986). But the use of price and advertising as signaling instruments today occurs in a transformed information environment, compared with past decades. Today's buyers have tremendous opportunities to learn about new products and firms, e.g., through online review and reputation systems, search engines, online social networks, and expert or user forums which offer opinions and experiences about products. As the buyers' external informational environment changes, firms use of advertising varies from traditional ways such as TV commercials, newspaper ads or online promotions, to pay information intermediaries a commission fee in return for a more favor-

able quality recommendation (Armstrong and Zhou, 2011; Inderst and Ottaviani, 2012), or pay search engines for prominent placement in the result pages (Athey and Ellison, 2011; Introna and Nissenbaum, 2000).

This paper examines how the availability of external information to consumers (who initially are uncertain about product quality) impacts sellers' use of quality-signaling instruments such as price and advertising. We also examine the combined effect of buyers' access to more information (including about sellers' qualities) and sellers' adjustments of these instruments. Our work is similar in spirit to Kuksov (2004), who noted that firms could respond to increased competition (due to reduced buyer search costs) by increasing differentiation through product design and innovation, even excessively so, leading to higher prices and lower consumer welfare relative to the case without search costs. In this paper, we ask similar questions about price and advertising expenditures: 1) how does a better information environment (for buyers) affect the signaling role of pricing? 2) how does it alter the mix of pricing and advertising as signaling instruments? 3) as the level of external information changes, how do alterations in the use of price signaling, and in the mix of price and advertising signaling, affect price, competition and social welfare?

We model a context where consumers who are heterogeneous in quality-sensitivity can easily locate new, vertically-differentiated, sellers, but cannot *a priori* distinguish between high and low quality sellers. Consumers can access abundant information about sellers and their products, but are heterogeneous in their ability to process or exploit such information. Moreover, the information-level itself may vary for different products. Our model includes a measure of the information-level in the market, which correlates with the fraction of consumers who become fully informed upon using these information sources. Separately, sellers may also actively try to inform consumers by using price and advertising expenditures to

signal quality. Our analysis examines the efficacy and impact of these mechanisms with respect to the level of external information in the environment. The novelty and research contributions of this paper stem from the model's simultaneous consideration of an exogenously given information level and sellers' endogenous actions in signaling quality through price and advertising in the presence of this external information.

We find a rich and complex interaction between the informational roles of price, advertising, and the external information environment. Prior literature shows that a price distortion (a higher price) can effectively signal high quality when consumers cannot initially distinguish between low and high quality products (Farrell, 1981; Wolinsky, 1983; Milgrom and Roberts, 1986; Janssen and Roy, 2010). We find that better external information about product quality can reduce the need for signaling quality through price (i.e., serves as a substitute for price-signaling), and hence the level of price distortion (i.e., a mark up), when price-signaling is needed. Surprisingly, though, we find that this effect does not always occur and depends on whether advertising, the more expensive signaling tool, is also needed to signal. When price signaling alone is insufficient and advertising is needed (that is when the quality/cost differential between competing products is too large), higher levels of external information reduce the seller's need to signal through advertising. Then, sellers will alter the mix of signaling instruments by shifting signaling effort from the more expensive instrument (advertising) to the less expensive one (price). So, in this case, better information *increases* the level of price signaling and hence causes a price increase. When advertising is not needed, then more external information reduces the need for price signaling, hence leads to less price distortion and lower prices. Here, our work adds a new dimension and explanation, beyond the prior understanding that search costs affect prices by changing the level of competition (Bakos, 1997; Lynch and Ariely, Jr., 2000; Lal and Sarvary, 1999).

2 Literature

Several existing streams of literature are relevant to the issues raised in this paper. One stream includes studies of the effect of online word-of-mouth, which consumers frequently turn to (e.g., web-based forums and product ratings sites) before making a purchase decision. A second is the literature on price and advertising as signaling instruments. These papers generally do not consider the role of external information. The third stream is related to the effect of search costs on prices; but this literature does not consider the use of price (or advertising) for signaling.

2.1 The Impact of Online Word-of-Mouth

The explosion of supply and usage of online word-of-mouth has led to a substantial literature on its role. Ba and Pavlou (2002) and Chen and Xie (2008) argue that consumer reviews provide product-matching information for consumers to find products that match their needs. Along this line, it is found that online WOM (review valence, volume and variances affect the sale of the products (Godes and Mayzlin, 2004; Chevalier and Mayzlin, 2006; Chintagunta et al., 2010; Sun, 2012). While generally a higher rating is associated with more sales, Dellarocas et al. (2007) and Berger et al. (2010) show that even negative reviews may have positive effects on sales, since they may increase product publicity, especially for lesser-known products. There is also evidence that this sales impact is influenced by product and consumer characteristics and even textual content of reviews (Zhu and Zhang, 2010; Archak et al., 2011; Lee and Bradlow, 2012).

A few papers examine whether and how WOM affect seller's pricing strategy. In general, consumers are willing to pay price premiums to sellers with better services and higher

reputations (Li et al., 2009; Liu, 2006). Some other studies find that sellers with higher reputation set lower prices (Baylis and Perloff (2002); Ba et al. (2008). Liu et al. (2012) suggest that a high-reputation seller could set higher or lower price depending on various conditions. Li and Hitt (2010); Jing (2011); Kuksov and Xie (2010) find that it is optimal to set a lower price initially in order to generate favorable reviews that will positively influence future consumers' perception about the product. This social learning gives room for the sellers to use pricing as a mechanism to manage and manipulate initial online WOM. Li et al. (2011) also find that consumer reviews may intensify price competition by changing consumers' propensity to switch among products.

We extend this line of literature by considering the impact of WOM with different quality levels (that is, with different ability to inform consumers about quality differences of the products) on the ability of firms to differentiate themselves through price and/or advertising signals.

2.2 Signaling

When there exists information asymmetry such that consumers cannot initially detect the quality levels among multiple products, firms may employ various mechanisms to signal their product quality. Milgrom and Roberts (1986) view the situation as a two-stage game where consumers may be uncertain at initial purchase but have identified quality before repeat purchase. They show that a high-quality manufacturer will set an initial price above the full information level and possibly spend in advertising; at which price the lower-quality firm is better off setting a lower price and being viewed as a lower-quality firm, than mimicking the high price of the higher-quality product and suffer from not being able to generate sufficient repeart purchase. Thus, the firms separate in equilibrium, consumers properly infer product

quality from prices.

Kirmani and Rao (2000) provide an excellent survey of literature on quality signaling mechanisms, the most common tools being price (Farrell, 1981) and advertising (Nelson, 1974; Kihlstrom and Riordan, 1984; Milgrom and Roberts, 1986; Fluet and Garella, 2002). These papers, however, do not consider the impact of external information, such as word-of-mouth, search engines, or recommendations, on the signaling ability of the firms. Several papers incorporate the discussion about "information". Gerstner (1985) empirically finds that the relationship between quality and price may be stronger for product classes about which word-of-mouth information is more likely to be generated or used, because a seller who cheats is likely to have a bad reputation. When product quality can be endogenously determined, Wolinsky (1983) finds that price may signal qualities when information can be generated based on the quality levels, which affect consumers perception about the product. In addition, the poorer the information received by consumers about the product quality, the higher the mark-up of the price signals. However it does not consider the "quality" of the external information, in the sense that the information generated in the market can always perfectly help consumers infer the quality levels. In our paper, we not only specifically model the "quality" of such information, but also incorporate advertising as a signaling mechanism, as well as explore how the change in the external information affect the mix of the two signaling instruments.

2.3 Buyer Search Costs

The conventional wisdom is that a reduction in buyers' search costs results in lower prices and reduced price dispersion (Bakos, 1997). However, researchers find that a high degree of price dispersion exists across homogeneous products even in electronic markets (Brynjolfsson

and Smith, 2000; Pan et al., 2002; Smith and Brynjolfsson, 2001). Lindsey-Mullikin and Grewal (2006) further find that as the variation in the store qualities increases, the price dispersion increases. For the selling of homogeneous goods, such findings can be explained by firms' mixed strategy in pricing (Baye and Morgan, 2001; Varian, 1980). For more complex scenarios, explanations are provided from the perspective of different types of search costs, or different types of product attributes. For example, Lynch and Ariely, Jr. (2000) study the impact of three different kinds of search costs on price sensitivity: search cost for price information, search cost for quality information within a store and search cost for comparing two competing stores. They find that a reduction in the search cost for information regarding product quality reduces consumers' price sensitivity. For instance, price sensitivity for wines that are offered in only one store is not affected when cross-store comparison becomes easier, whereas price sensitivity for wines that are offered by both stores increases.

In Lal and Sarvary (1999), consumers search information on two types of product attributes: digital (that can be satisfied by Internet search) and non-digital (the "fit" attributes that require physical inspection). This paper finds that the introduction of the Internet may reduce product prices, but also may discourage consumer search and result in monopoly prices if the non-digital attributes are relevant but not overwhelming, and consumers engage in "destination shopping" (that is, when the fixed cost of undertaking the shopping trip is higher than the cost of visiting an additional store). In addition, as lower search cost is associated with a higher share of niche products, Brynjolfsson et al. (2011) and Cachon et al. (2013) find that price can go up when consumer search becomes easier: when consumers can search more firms, each firm's market is expanded when consumers' search becomes easier, which enables firms to charge higher prices.

Our paper is related to this line of literature, as an increase in the "quality" of information

in our model makes consumers better informed about firms' quality levels, which has similar effects as the reduction in the cost of searching for quality information. However, the reason that the high-quality firm can either increase or reduce its price is neither market expansion as in Cachon et al. (2013), nor simply uncertainty reduction as in Lynch and Ariely, Jr. (2000), but rather the endogeneity of price and advertising as two signaling mechanisms, and the relative weight that firms place on them when the quality of information changes.

3 Model

We develop a model with vertically-differentiated sellers, so that we can focus on the effect of external information (such as online reviews, recommender sites, ratings) when consumers are initially uncertain about the quality of multiple sellers they might find on the Internet. Consider a market comprising low and high quality variants of a good, respectively, from two sellers L and H (whose prices are denoted by p_L, p_H), facing consumers who are heterogeneous in their quality-sensitivity. Let parameter θ represent consumers' taste for quality. Following Fluet and Garella (2002), our model assumes that a type θ consumer gets an *ex post* net surplus $1 + \delta\theta - p_H$ upon purchasing H, while the surplus of all consumers for good L is normalized to $1 - p_L$. Seller H has a production cost c in excess of L's (normalized to zero), while the quality difference is denoted by δ. Sellers do not know the type of each consumer but are aware that the overall distribution of types is uniform in $[0, 1]$.

While consumers do not directly observe quality hence cannot differentiate the two sellers *a priori*, they have access to a variety of information from search engines, review systems, social networks, seller-operated sites, etc. Consumers are heterogeneous in their ability to find and process this information. Specifically, some consumers are able to distinguish sellers

L and H upon consulting the external information. We call this segment I. The relative size of this segment, denoted by y, increases with the overall quality of information. Without loss of generality, the quality of external information in the market is considered to be interchangeable with the fraction y. The second set of consumers (U) remains uninformed from the external information, but might infer additional signals by observing sellers' price and advertising. The type parameter θ is distributed identically across the two segments.

Our formulation is novel in multiple ways. The treatment of signaling is distinctive relative to, say, Fluet and Garella (2002) or Milgrom and Roberts (1986), in its incorporation of the quality of external information. Conversely, our treatment of information (i.e., reduced search costs) differs from models in which individual consumers' trade off higher cost of information search against expected increase in utility (for instance, the cost-benefit of learning about seller or product attributes in Bakos (1997) and Moorthy et al. (1997); or the cost-benefit of obtaining an additional price quote in Kuksov (2004)). We adopt a high-level formulation of the effect of better external information, and focus on how this will impact actions of sellers under a price and advertising signaling framework. Second, while past papers consider spatially-differentiated sellers (so that search helps consumers learn seller attributes, but seller's use price only to trade off margin and market share), our vertically differentiated setting drives firms to use price (and advertising)—as a signal of quality—to manipulate consumers' uncertainty about quality. Finally, the distinction between informed and uninformed consumers is different from that in (Varian, 1980). In their model, uninformed consumers purchase once the expected payoff exceeds a threshold (rather than search or compare across multiple competing sellers), while in our paper the uninformed consumers are not sufficiently educated by the available information and purchase based on the signals.

Let $D_i = D_i(p_L, p_H)$ and $\Pi_i = \Pi_i(p_L, p_H)$ denote seller i's market shares and profits,

respectively, under the pair of prices (p_L, p_H). Then $\Pi_L = p_L D_L$, and $\Pi_H = (p_H - c)D_H$. The demand curve for each seller is an aggregate of the demand curves over the Informed (I) and Uninformed (U) consumer segments.[1] Let D_j^I and D_j^U represent the fraction of I and U customers, respectively, captured by firm $j = L, H$. Then, $D_j = yD_j^I + (1-y)D_j^U$.

$$D_L^I = \begin{cases} \frac{P_H - P_L}{\delta} & \text{if } P_L < 1 \\ 0 & \text{if } P_L \geq 1 \end{cases} \tag{1}$$

$$D_H^I = 1 - \frac{P_H - P_L}{\delta}. \tag{2}$$

When U segment consumers can identify low and high quality sellers, their purchase actions are identical to those of the I segment.[2] When U segment consumers cannot identify sellers qualities, then they purchase from the lowest-priced seller (and split if sellers have identical prices). For the equal price case, $P_H = P_L = P$,

$$D_L^U = D_H^U = \begin{cases} \frac{1}{2} & \text{if } P \leq 1 \\ \frac{1}{2}\left(1 - \frac{2(P-1)}{\delta}\right) & \text{if } P \in [1, 1 + \frac{1+\delta}{2}] \\ 0 & \text{if } P > 1 + \frac{1+\delta}{2}, \end{cases} \tag{3}$$

whereas if one firm has a higher price, then the lower-priced firm captures all buyers whose expected benefit exceeds the price, i.e., $(1 - \frac{2(P-1)^+}{\delta})^+$.

[1] May need to show that in any equilibrium, $p_H \geq p_L$.

[2] If U segment adopts incorrect beliefs, then Eq. 1 will still capture their actions, after swapping the L and H labels in the prices.

3.1 Full Information Benchmark ($y = 1$)

Before proceeding to the main model it is useful to state a benchmark solution corresponding to the extreme case of y=1, in which the information environment is so superior that all buyers become fully informed about quality *ex ante*. Under this setting the U segment behaves identically to the I segment. Firms set prices p_L and p_H and there is no need to advertise since consumers are fully informed. We add the superscript ^{f} to our notation to indicate equilibrium outcomes under full information. To simplify the exposition we assume that the market is fully covered under full information, which happens under the condition below.

Assumption 1. *($c < 2\delta$) AND ($\delta \leq 1$).*

Under assumption 1, the sale goes to firm H if $\theta \in [\frac{p_H - p_L}{\delta}, 1]$ and to L if $\theta \in [0, \frac{p_H - p_L}{\delta}]$ (and $p_L \leq 1$). Thus, the firms' expected demand and profits are

$$D_H = (1 - \theta) = 1 - \frac{p_H - p_L}{\delta}; \qquad \pi_H = D_H \cdot (p_H - c), \tag{4a}$$

$$D_L = \theta \qquad = \frac{p_H - p_L}{\delta}; \qquad \pi_L = D_L \cdot p_L. \tag{4b}$$

The pricing game has a unique Nash Equilibrium with full-information-prices and equilibrium profits as stated below.

$$p_H^f = P^f = \frac{2(\delta + c)}{3}; \qquad \pi_H^f = \frac{(2\delta + c)^2}{9\delta}, \tag{5a}$$

$$p_L^f = \frac{P^f}{2} = \frac{(\delta + c)}{3}; \qquad \pi_L^f = \frac{(\delta + c)^2}{9\delta}. \tag{5b}$$

where the notation P^f, π^f is used to summarize the equilibrium price under full information.

3.2 Equilibrium under Information Level y

For the general case of unobserved quality, high-quality firms will attempt to differentiate themselves in different ways, and we focus on price and advertising efforts at differentiation when fraction y of consumers (segment I) become informed upon accessing external information. We analyze the problem under the following sequence. First, sellers set prices p_L, p_H and advertising levels A_L, A_H. Second, Nature picks a type $\theta \in [0,1]$ for each shopper, who is further assigned to segment I with probability y and segment U otherwise. Third, an I-type shopper purchases from L or H based on $\theta, \{p_L, p_H\}$. U shoppers observe, and might infer signals from, sellers' prices and advertising. These shoppers either learn which firm is H (in a *separating equilibrium*) or remain uninformed and purchase from the lower-priced seller. At the start of the game, the firms set price and advertising to maximize expected profits subject to the consumer belief and purchase process.

A separating equilibrium, indicated with the superscript *, is possible in two ways, that U consumers infer firm identities through a) prices (p_L^*, p_H^*) alone (i.e., both sellers do zero advertising, $A_L = A_H = 0$), and b) through price+advertising, i.e., H must incur advertising cost to signal quality. In both cases, all consumers learn firms' identities, and the I and U segments behave identically. Hence the consumer decision process and firms' market shares are as given in Eq. 4, and a separating equilibrium solution (which differs from the full information benchmark because the sellers have to exert price to convey quality) has the following properties.

Lemma 1. *Any separating equilibrium satisfies* $P_L^* = \frac{P_H^*}{2}$*, hence can be summarized via a single price* P^* *(equals* P_H^* *and* $2P_L^*$*). The market is fully covered under Assumption 1.*

Sellers' market shares and equilibrium profits of L and H are, respectively,

$$D_L^* = \frac{P^*}{2\delta}; \qquad \pi_L^*\left(\frac{P^*}{2}, P^*\right) = \frac{(P^*)^2}{4\delta}; \tag{6a}$$

$$D_H^* = 1 - \frac{P^*}{2\delta} \qquad \pi_H^*\left(\frac{P^*}{2}, P^*\right) = (P^* - c)\left(1 - \frac{P^*}{2\delta}\right) - A. \tag{6b}$$

This price rule works in the entire parameter space because Assumption 1 ensures that H always prices below 2, hence (in a separating equilibrium) L prices below 1 and captures positive market share. However, when U buyers cannot identify sellers' quality, a type θ buyer anticipates a net surplus equal to $(1 + \frac{\delta\theta}{2} - p_j)$ on buying from seller j. Then, L may set price above 1 (and lose the entire I segment) or below 1 if forced by H's price and L's own need to mask itself.

4 Price Signaling

Lemma 1 sets up the basic architecture for the analysis of price and advertising signaling in the context of an external information environment with information quality y. It is evident from Eq. 6b that signaling can occur with price alone ($A = 0$), or with a mix of price and advertising ($A > 0$). We analyze the first case in this section, and the second more general case in §5.

Definition 1 (Price Signaling Separating Equilibrium)**.** *The pair of prices (p_L^*, p_H^*) defines a separating equilibrium if and only if*

1. *sellers play pure strategies p_L^*, p_H^*,*
2. *U-segment consumers have the following beliefs, which are confirmed at equilibrium: if only one seller plays p_H^*, it is perceived as H with probability 1, and the other as L; in any other strategy profile,* ex ante *beliefs are symmetric and each seller is seen as H with probability $\frac{1}{2}$, and*

3. each seller's profit weakly exceeds profit under any unilateral deviation.

The conditions underlying a separating equilibrium are summarized in Lemma 2. We sketch the derivation of these conditions below, a more detailed and formal proof of the Lemma is in the Appendix. Starting at y=1, both sellers can use full-information prices. But as the size of the U segment increases (as y falls) and reaches a critical point, L finds it advantageous to mimic H's full-information price instead. At this point, H must shift to a price that actively induces L to separate. From Lemma 1, L sets $\frac{P_H}{2}$ in a separating equilibrium, hence H can maximize its profit subject to this pricing rule, so long as its price maintains L's incentive to separate. That is, for L, separation must be more profitable than mimicking H (when mimicking, it loses all I buyers to H and, the U segment buyers split equally between the two sellers). The equilibrium also requires that H be better off from separation, vs. the case where the U-type consumers perceive them to be identical. The only and best plausible deviation then is to just undercut L by $\epsilon \to 0$ and capture the entire market, which works as long as $\frac{P^*}{2} > c$. These properties are summarized below.

Lemma 2. *The pair of prices* $(p_L{=}\frac{P^*}{2}, p_H{=}P^*)$ *is a price-signaling equilibrium if* P^* *maximizes H's profit under separation* $(P-c)(1-\frac{P}{2\delta})$*, subject to such separation being advantageous (over mimicry) for both sellers, i.e.,*

$$\textit{for } H: \quad \Pi_H^* = \quad (P-c)\left(1-\tfrac{P}{2\delta}\right) \quad \geq \quad \left\{\frac{P}{2}-c\right\} \tag{7}$$

$$\textit{for } L: \qquad \Pi_L^* = \quad \tfrac{P}{2}\left(\tfrac{P}{2\delta}\right) \quad \geq \quad \begin{cases} 0 & \textit{if} \quad P \geq 1+\frac{\delta}{2} \\ \frac{P}{2}(1-y)(1-\frac{P-1}{\delta/2}) & \textit{if} \quad P \in [1, 1+\frac{\delta}{2}] \\ P\frac{(1-y)}{2} & \textit{if} \quad P \leq 1 \end{cases} \tag{8}$$

4.1 Existence and Properties of A Separating Equilibrium

The separating equilibrium regions are obtained by solving Eq. 7–8. For high enough y, the constraints are irrelevant as both firms find separation optimal at full information prices.

When y hits a critical (lower) level, H shifts to a price that maximizes its profit subject to L being better off when separating (PS-1 region). This price remains optimal until y drops to a threshold where L has incentive to mimic the H seller again and give up all the I segment. In this case, H must further compromise its price to induce L to separate (yielding equilibrium region PS-2).

Lemma 3. *A separating equilibrium exists with prices* $(p_L^* = \frac{P^*}{2}, p_H^* = P^*)$*, if:*

conditions			*type of equilibrium*	*equilibrium price* P^*
	$\Gamma_2(y)$	$\leq \frac{2(\delta+c)}{3}$	*full-information (F)*	$\frac{2(\delta+c)}{3}$
$\frac{2(\delta+c)}{3} <$	$\Gamma_2(y)$	$\leq \delta + \frac{c}{2}$	*price signaling (PS-1)*	$\delta + \frac{c}{2}$
$\delta + \frac{c}{2} <$	$\Gamma_2(y)$	$\leq \delta + c$	*price signaling (PS-2)*	$\Gamma_2(y)$

where $\Gamma_2(y) = \min\left\{2\delta(1-y), 2\frac{(1-y)(\delta+2)}{5-4y}\right\}$*. When* $\Gamma_2(y) > \delta + c$*, there does not exist a price-signaling separating equilibrium, and advertising may be needed to signal quality.*

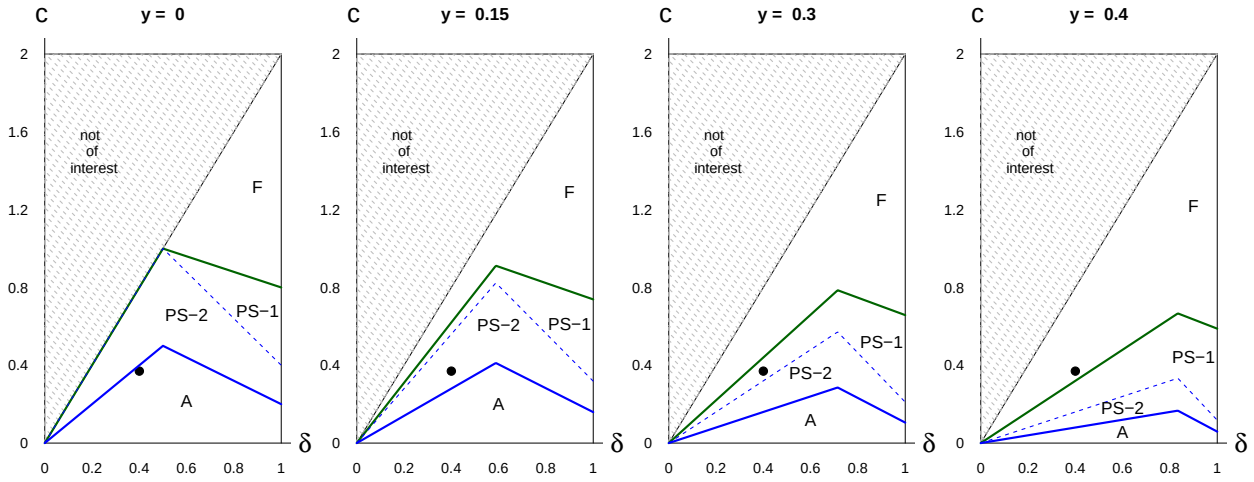

Figure 1: Comparison of equilibrium regions in the (δ, c) space for y=0 vs. a positive value of y. F is the full-information equilibrium. PS-1 and PS-2 are the price-signaling equilibrium regions. Price alone is insufficient for signaling quality in region A. The 4 panels visualize the regions for 4 values of y, and the bullet point illustrates how a (δ, c) pair moves from A to PS-2 to PS-1 and F as y increases.

Figure 1 illustrates the equilibrium regions for two specific values of y. In the F region, both firms prefer separation at full-information prices. The intuition is that when consumers' perceived benefit from high quality is quite low relative to the cost of producing it, H must set price quite high ($P > \Gamma_2(y)$), which implies a lower level of expected utility for any uncertain buyers. Then, L finds it more attractive to face buyers as an L with a lower price (but with relatively high margin because its competitor has a high price), than to mimic H and set a high price to buyers whose expected benefit is a not-so-high average of the two products. L earns higher profit even though consumers recognize its lower quality and only the low-end consumers purchase from it.

Next, for products where consumers' perceived benefit from high quality is moderate relative to the cost of producing it (i.e., cost of producing high quality is not too high), H's full-information price drops low enough to hurt substantially the margin that L gets in a separating equilibrium; this gives L an incentive to mimic, forcing H to raise (distort) price in order to convince L to not mimic H. This gives rise to the price signaling regions PS-1 and PS-2, and we will show shortly that prices are progressively higher going from F to PS-1 to PS-2. For even higher value of δ relative to c, H would set a lower full-information price because of low c, but the higher δ makes it more attractive for L to mimic H. For high enough δ, H is unable to convince L to separate and may have to employ advertising to achieve a separating equilibrium (explored in §5).

4.2 Impact of External Information

To understand the role of external information, and of its quality level, it is useful to rewrite the conditions for the separating equilibrium in terms of y. Start by writing Γ_2 (from Lemma 3) as:

$$\Gamma_2 = \begin{cases} 2\delta(1-y) & \text{if } y \geq 1 - \frac{1}{2\delta} \\ \frac{2(\delta+2)(1-y)}{5-4y} & \text{if } y < 1 - \frac{1}{2\delta}. \end{cases} \tag{9}$$

Proposition 1. *Better external information reduces the need for price signaling, and also reduces the need for advertising as an instrument to signal quality. The different equilibrium regions and the corresponding conditions are given below.*

	When $y < 1 - \frac{1}{2\delta}$	*When* $y \geq 1 - \frac{1}{2\delta}$	*Equilibrium*
	$y > \frac{6-2\delta-5c}{6-\delta-4c}$	$y > \frac{2-c/\delta}{3}$	*F*
and	$y \in [\frac{8-6\delta-5c}{8-4\delta-4c}, \frac{6-2\delta-5c}{6-\delta-4c}]$	$y \in [\frac{2-c/\delta}{4}, \frac{2-c/\delta}{3}]$	*PS-1*
	$y \in [\frac{2-3\delta-5c}{2-4\delta-4c}, \frac{8-6\delta-5c}{8-4\delta-4c}]$	$y \in [\frac{1-c/\delta}{2}, \frac{2-c/\delta}{4}]$	*PS-2*
	$y < \frac{2-3\delta-5c}{2-4\delta-4c}$	$y < \frac{1-c/\delta}{2}$	*A*

Proposition 1 illuminates the impact of external information on the necessity and sufficiency of price signaling. One straightforward observation is that there exist information environments such that a change in information quality has no impact on prices. This corresponds to the first case where when y is sufficiently high ($> \frac{2-c/\delta}{3}$, an expression that varies in $[\frac{1}{2}, \frac{2}{3}]$), where both sellers organically prefer the full-information prices, hence any change in y (within the bounds) doesn't affect their pricing strategy. This indicates that conventional wisdom may overestimate the effect of information or reduced search costs on sellers' strategies and prices. For the remaining cases where y is not so high, a change in the level of external information is indeed impactful and captured in Proposition 1.

Fluet and Garella (2002) have previously shown that the need for price-signaling, and the ability to signal through price alone, depends on the quality-differentiation δ and cost-difference c between low and high quality sellers. We show that it becomes easier for the H firm to signal through price as the buyers' external information improves (y increases): the

full information region expands and no-separation region reduces to a smaller (c, δ) parameter space. Specifically, higher y will more often produce a *full-information equilibrium*, relieving sellers from any effort to signal quality. Notably, $y = 1$ is not necessary for this outcome, but an increase in y does expand the product categories (defined in the (c, δ) space) for which full-information prices emerge. Additionally, higher y makes it more likely that price alone is sufficient to signal quality, reducing the (c, δ) parameter space for which $A > 0$ is necessary to achieve a separating equilibrium.

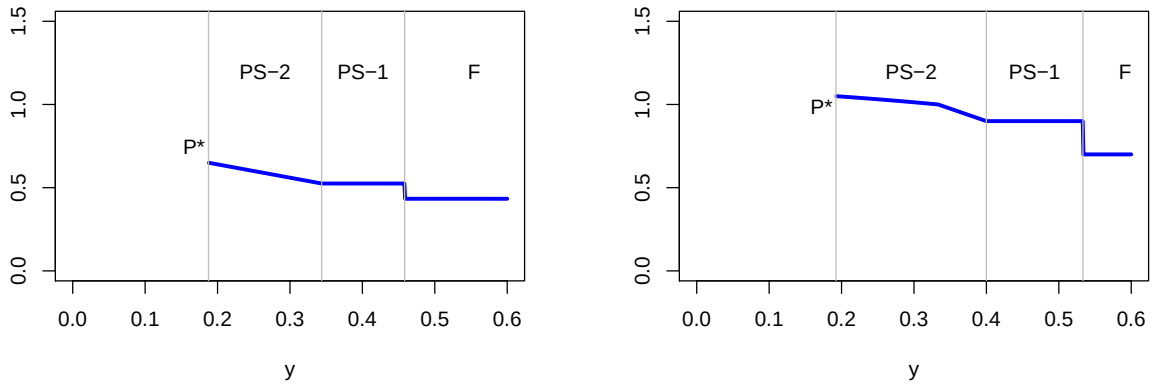

Figure 2: Impact of buyers' information environment: increase in y does not necessarily cause price reduction. For a product (c, δ), if (at current y) L already has selfish motive to prefer separation to mimicry, then a small increase in y has no effect on prices (regions F and PS-1). Prices drop only in the PS-2 price signaling region where L prefers mimicking, hence an increase in the fraction of informed buyers affects firms' induces H to exert greater effort to ensure separation. Large changes in y can also affect price by altering the nature of the separating equilibrium.

Will market prices always reduce as buyers gain better information about sellers? Intuitively, higher y should make it either unnecessary for the sellers to use (i.e., raise) price for signaling, or reduce the extent of price distortion needed to signal, both of which should lead to lower prices. Specifically, a higher y worsens L's possible benefit from mimicking H

because it stands to lose a bigger chunk of the market (the I segment) when it matches H's price, and so H expends lower, or no, effort to signal quality. However, we find that better information only *weakly* leads to lower prices, i.e., improvement in buyers' information level will often lead to no change in prices. As shown in Fig. 2, a strict reduction in price occurs only when an increase in the fraction of informed buyers alters the sellers' existing incentives and competitive tradeoffs, specifically the incentive of the lower-quality firm to mimic H. This corresponds to the PS-2 region with equilibrium price $\Gamma_2(y)$ which is a decreasing function of y. In the remaining regions (F and $PS-1$), a small increase in y does not change L's incentive to set a lower price and compete as a low-quality seller, so there is no effect on equilibrium prices.

Proposition 2. *Better information weakly reduces the level of price-distortion necessary to signal quality, leading (weakly) to lower prices and higher consumer surplus.*

The price-reduction effect of better y confirms prior understanding that a reduction in buyers' search costs can lead to lower prices. However, we uncover a new explanation for such reduction: it occurs because external information reduces the high-quality seller's need to use price as a signaling instrument, rather than because of more competition (Bakos, 1997), changes in level of search (Lal and Sarvary, 1999), changes in price sensitivity (Lynch and Ariely, Jr., 2000), or market expansion (Cachon et al., 2013). This price reduction exerts a positive impact on welfare. As y increases, consumers get higher surplus as prices of both products fall, and more consumers purchase the higher-quality product leading to an increase in total welfare.

5 Advertising Signals with Information Level y

When price alone is insufficient for signaling quality, the high quality seller will turn towards non-price instruments, such as advertising, to signal quality. In this case, seller H can signal its identity if it can afford an advertising expenditure $A_H = A$ that L cannot afford to match (and therefore, L simply sets its advertising expenditure A_L to 0). In this region, H will set a price that makes L indifferent between separating and mimicking H.

Definition 2 (Advertising Signaling Separating Equilibrium)**.** *The pair of prices (p_L^*, p_H^*) and advertising level A, written as $(\frac{P^*}{2}, P^*, A)$, is an advertising-signaling equilibrium, if*

1. *H cannot separate via price alone, and must set $A_H > 0$,*
2. *H has higher profit (after deducting A_H) in this separating solution than not advertising and just undercutting L on price, and*
3. *L earns higher profit playing p_L^* and being considered low quality than by mimicking H on advertising (and price).*

Formally, a separating equilibrium exists if and only if $\exists\ A > 0$ such that

$$\pi_H^*(p_L^*, p_H^*) - A \geq \pi_H(p_L^*, p_L^* - \epsilon) \tag{10}$$

$$\pi_L^*(p_L^*, p_H^*) \geq \pi_L(p_H^*, p_H^*) - A. \tag{11}$$

Lemma 4. *When $\delta + c < \Gamma_2(y)$, price-signaling fails and H employs advertising to signal its identity, setting $A = \frac{(1-y)P^*}{2} - \frac{(P^*)^2}{4\delta} > 0$, with $P^* = 2(c + \delta y)$ and seller's prices being $(\frac{P^*}{2}, P^*)$.*

Proposition 3. *When sellers must use advertising as an instrument to signal high quality, an increase in external information*

1. *reduces the seller's reliance on the advertising instrument, and the level of advertising expenditure,*

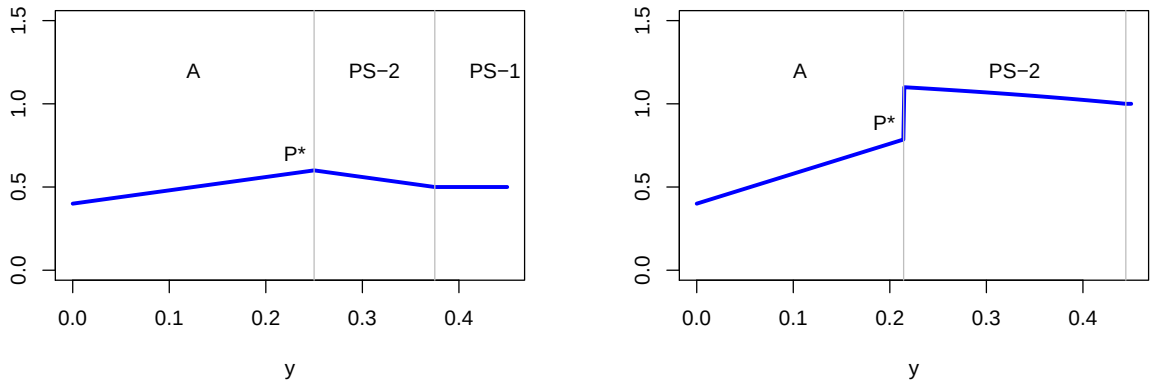

Figure 3: Impact of better information on prices when advertising expenditure is necessary for signaling. A better information environment shifts the firm's signaling effort towards price, leading to higher prices as y increases.

2. *alters the optimal mix towards less advertising signaling and more price signaling, and*
3. *causes an increase in product prices and seller's profit, while reducing consumer surplus.*

Proposition 3 presents the surprising finding that an action which should normally benefit consumers (better information about competing sellers) actually harms them through higher prices. This result applies when advertising is being used as an instrument to signal product quality, a scenario that is prevalent in many industries and becomes more relevant because of consumers' quality uncertainty as they increasingly shop via the Internet. Moreover, then, sellers are the real beneficiary when consumers' external information improves. The intuition is that a better information environment facilitates the use of price to signal quality, so that price takes over some of the signaling effort previously performed by the more expensive instrument, advertising. Therefore, H can either a) increase the share of price-signaling in an advertising-signaling equilibrium, or b) switch from advertising-signaling to signaling with price alone. But this increase in the use of price as a signal of quality naturally results

in a higher price to consumers.

6 Conclusion

The Internet has vastly expanded the possibilities for consumers to interact with sellers for whom they lack definitive information about seller quality, and simultaneously creates a rich information environment that provides consumers with abundant cues regarding sellers and their product qualities. It is generally understood that "more information is better," that is consumers are better off when they have easy access to more information about sellers. Specifically, past research has shown that a better informational environment (i.e., lower search costs) increases competition and leads to lower prices. This paper expands the analysis to settings in which information reduces consumer uncertainty about product quality. It contributes towards developing a sharper understanding of the ways in which the Internet is impacting commerce.

We modeled a setting where vertically differentiated sellers compete in a market where consumers have heterogeneous preferences for quality, but lack *a priori* the ability to distinguish between low and high quality sellers. Typically, when consumers are uncertain about sellers' quality levels, high quality sellers will attempt to signal quality through price and advertising instruments. It is generally understood that price is a cheaper instrument for quality signaling, hence sellers will use price to the extent possible and then add advertising as needed, finding an optimal mix based on the cost/efficiency of each instrument. One important insight from this paper is that exogenous external information can act as a substitute for instruments which firms actively use to signal quality. Our research sheds light on the effect of the interaction between external information and signaling instruments on

sellers' choices (mix of signaling instruments, and price levels) and consumer surplus as a result of these choices.

When price alone is sufficient to signal product quality, the substitution effect of external information leads to lower prices by reducing the degree to which price must be distorted (increased) to signal quality. This applies to product categories where higher quality imposes relatively high incremental cost, causing the high quality seller to seek relatively high price; this makes it relatively attractive for the low quality seller to serve consumers with low sensitivity to quality. More information makes price signaling more efficient, so that less price distortion is needed in order to signal quality. This effect causes prices to drop as external information improves. While this finding is consistent with past literature and general intuition, our analysis provides a new explanation for why more information should lead to lower prices.

One striking feature of our analysis is that arming buyers with better information need not necessarily lead to price reduction. This occurs when either other market parameters (such as incremental cost of high-quality product and incremental valuations) already persuade low-quality sellers to separate and present themselves truthfully rather than masquerade as high-quality sellers. It also occurs when the level of external information is already "good enough" to lead to full-information prices, so that an improvement in information has no effect. These insights underline a caution against overestimating the beneficial impacts of arming buyers with more information.

Moreover, we show that better information may not be just irrelevant (with respect to market prices) but can actually hurt buyers in terms of higher prices. When both price and advertising are needed to signal, the presence of external information causes the firm to reduce its reliance on the more expensive instrument, advertising, as the level of external

information increases. This happens when the high-quality seller faces a low incremental cost (relative to lower quality product); then, the tighter price competition shrinks the low quality seller's margin and raises its incentive for price mimicry, due to which the high quality seller must signal through higher advertising expenditures. Then, as external information increases the efficiency of price signaling, it also shifts the optimal mix of price and advertising instruments towards an increased use of price-signaling. Due to this, an increase in external information causes an increase in product prices.

Our work contributes to the literature on signaling by demonstrating how firms' use of price and advertising to signal product quality must be refined as the external information environment changes. Conversely, our combination of external information with seller-managed instruments for signaling leads to a richer understanding of how information influences market outcomes and consumer surplus. Just like Kuksov (2004) we show that the impact of better information (or reduced search costs) must be viewed not just in terms of a short-run direct effect (better-informed consumers leads to better prices) but should also consider the controllable variables that firms can vary in the longer term, such as product design (Kuksov) or signaling (us). Once we consider this factor—that the external information environment alters the firms' mix of signaling instruments—we find that better information may not always be a good thing for consumers. Better information can improve market outcomes by reducing uncertainty and the need for signaling, but it can also have no impact at all, or even have a detrimental effect of higher prices and lower consumer surplus. To sum, the impact of better information must be viewed with a combined lens of product characteristics, market competition structure, and the prevailing information level.

A Appendix

Lemma 1. In a separating equilibrium, the I and U segments behave identically (and demands are given Eq. 1). Hence with prices p_L, p_H the two firms' profits are

$$\Pi_L = p_L D_L^I \tag{12}$$

$$\Pi_H = (p_H - c) D_H^I. \tag{13}$$

Obtaining best-response behavior for the two firms, the first equation yields that L's optimal response to H in a separating equilibrium is always to set p_L to $\frac{p_H}{2}$. ■

Proof of Lemma 2. To consider possible deviations for L (from p_L^*), note that p_L^* is already the optimal price under separation, i.e., when L is recognized as low quality. Now, if L deviates to any price other than p_H^*, it will still be perceived as low quality (and would get zero market share if it exceeds H's price), therefore these deviations are trivially suboptimal. Hence the only possible deviation is that L mimics H by playing p_H^*. Then, a type θ buyer (in the U segment) anticipates a net surplus equal to $(1 + \frac{\delta\theta}{2} - P^*)$ on buying from seller j. Therefore, L gets none of the I segment, and either i) half the U segment if $P^* < 1$, or ii) no market share if $P^* \geq (1+\frac{\delta}{2})$ (because this price exceeds expected utility of every U shopper), or iii) $\frac{P^*}{2}(1-y)(1-\frac{2(P^*-1)}{\delta})$ if $P^* \in [1, 1+\frac{\delta}{2}]$ (because, again, U shoppers with $\theta < \frac{2(P^*-1)}{\delta}$ do not purchase).

For H's strategy, when L plays $p_L^* = \frac{P^*}{2}$ any deviation from p_H^* implies that both sellers' qualities are identical in the perception of U-type consumers. Then, if H just undercuts L by $\epsilon \to 0$ then it can capture the entire market and earn $(p_L^* - c)$. This works as long as $\frac{P^*}{2} > c$. The other possible deviation is $p_H > p_L^*$, which yields H a fraction of the I-segment, and profit $(p_H - c)y(1 - \frac{p_H - p_L^*}{\delta})$. However, this deviation can be rejected because it produces

a lower profit for H than when H plays p_H^* (this follows trivially from Lemma 1). ■

Proof of Lemma 3. We first consider the boundary conditions for H and L to be willing to separate from each other. From Eq. 7, H prefers separating to undercutting L if and only if $(P-c)\left(1-\frac{P}{2\delta}\right) \geq \frac{P}{2}-c$, which gives us $P < \delta + c$ (Condition 1). From Eq. 8, L prefers separating to mimicry H if and only if: $\frac{P^2}{4\delta} \geq \frac{1-y}{2}P$ when $P \leq 1$ or when $\frac{P^2}{4\delta} \geq \frac{P}{2}(1-y)\left(1-\frac{2(P-1)}{\delta}\right)$ when $P \in [1, 1+\frac{\delta}{2}]$. This gives us: (2a) $P \geq 2\delta(1-y)$ and $P \leq 1$; or (2b) $P \geq \frac{2(1-y)(\delta+2)}{5-4y}$ and $P > 1$. Define $\Gamma_2 = \min\{2\delta(1-y), \frac{2(1-y)(\delta+2)}{5-4y}\}$. Note that

Property 1 $\left(\frac{2(1-y)(\delta+2)}{5-4y} > 1\right) \leftrightarrow (2\delta(1-y) > 1)$;

Property 2 $(2\delta(1-y) > 1) \leftrightarrow \left(2\delta(1-y) > \frac{2(1-y)(\delta+2)}{5-4y}\right)$.

So, when $P \leq 1$, condition (2a) yields $2\delta(1-y) < 1$, upon which Property 2 implies $\Gamma_2 = 2\delta(1-y)$; When $P > 1$, combine condition (2b) with Property 1 to get $2\delta(1-y) > 1$, and then property 2 yields $\Gamma_2 = \frac{2(1-y)(\delta+2)}{5-4y}$. Hence conditions (2a-2b) specify that L prefers separating to mimicry if only if $P \geq \Gamma_2$ (Condition 2).

We now consider possible combinations of the conditions.

1. At the full information price $P^f = \frac{2(\delta+c)}{3}$, Condition 1 is automatically satisfied. So a Full-information equilibrium exists if and only if Condition 2 is met, i.e., $P^f \geq \Gamma_2$.

2. When $P^f < \Gamma_2$, a full-information equilibrium does not exist. The optimal price that H can make is obtained through solving $\max(P-c)\left(1-\frac{P}{2\delta}\right)$. That is, $P_1^p = \delta + \frac{c}{2}$. Obviously Condition 1 is automatically satisfied. So $P_1^p = \delta + \frac{c}{2}$ will be the Price-signaling Equilibrium (PS1) if and only if Condition 2 is met, that is, $\delta + \frac{c}{2} \geq \Gamma_2$. So $P_1^p = \delta + \frac{c}{2}$ is a Price Signaling Equilibrium (PS1) if and only if: $P^f < \Gamma_2 \leq \delta + \frac{c}{2}$.

When $\delta + \frac{c}{2} < \Gamma_2$, however, L is better-off by mimicking H's price. So $P_1^p = \delta + \frac{c}{2}$ is not an equilibrium. In this case, H can set a price at Γ_2, the level just to prevent L from mimicry. Since Condition (2) is automatically satisfied, in order for $P_2^p = \Gamma_2$ to be in equilibrium, it has to satisfy Condition 1. That is, $\Gamma_2 \leq \delta + c$. So, $P_2^p = \Gamma_2$ is a Price Signaling Equilibrium if and only if: $\delta + \frac{c}{2} < \Gamma_2 \leq \delta + c$.

3. When these conditions fail to be satisfied, there does not exist any separating equilibrium.

This completes the proof. ■

Proposition 1. Lemma 2 states the equilibrium regions and conditions in terms of $\Gamma_2(y)$, which is redefined in Eq. 9 as

$$\Gamma_2 = \begin{cases} 2\delta(1-y) & \text{if } y \geq 1 - \frac{1}{2\delta} \\ \frac{2(\delta+2)(1-y)}{5-4y} & \text{if } y < 1 - \frac{1}{2\delta}. \end{cases}$$

Applying this definition, and with some algebraic manipulations, the terms in Lemma 2 can be refined and split into two cases, one where $y \geq 1 - \frac{1}{2\delta}$ and the other where $y < 1 - \frac{1}{2\delta}$. This leads to the arrangement of the conditions and regions as stated in the Proposition. Price signaling is unnecessary under conditions that lead to a full-information equilibrium. These conditions are of the form $y > f(\delta, c)$ therefore an increase in y makes it more likely that price signaling is not needed. ■

Proof of Proposition 2. From Lemma 3 it can be shown that prices in the region of full-information equilibrium (F) and PS-1 are constant that does not change with y. Meanwhile, since $\delta + \frac{c}{2} \geq \frac{2(\delta+c)}{3}$, equilibrium prices drop from PS-1 region to F region.

For PS-2 region, since $\Gamma_2(y)$ is decreasing in y (both $2\delta(1-y)$ and $2\frac{(1-y)(\delta+2))}{5-4y}$) are

decreasing in y), the equilibrium price in PS-2 drops with an increase in y. Now since the condition for PS-2 ensures that $\Gamma_2(y) > \delta + c$, where $\delta + c$ is the equilibrium price in the PS-1 region, we have that the equilibrium price in PS-2 region is higher than that in the PS-1 region.

In summary, as y improves, the equilibrium prices weakly reduces, and this naturally result in a higher consumer surplus. ■

Proof of Lemma 4. From Lemma 3 it can be shown that when $\delta + c < \Gamma_2(y)$, price alone is not sufficient and advertising is needed. According to Equation 11, the H seller only needs to spend an amount of advertising at a level that makes L feel indifferent between mimicry and separation, which is $A^* = \pi_L^*(p_L^*, p_H^*) - \pi_L(p_H^*, p_H^*) = \frac{(1-y)P^*}{2} - \frac{(P^*)^2}{4\delta}$. Plug the equilibrium A^* into Eq. 11 and solve for the optimal p^* that maximizes H's profit $(\pi_H^*(p_L^*, p_H^*) - A)$, we get that $P^* = 2(c + \delta y)$. ■

Proof of Proposition 3. When y increases, as $\Gamma_2(y)$ is decreasing, the region that satisfies $\delta + c < \Gamma_2(y)$ is reducing, too. This shows that the region for advertising-signaling equilibrium reduces with an increase in y, indicating less reliance on advertising as a signaling instrument. Trivially, $\frac{\partial A}{\partial y} < 0$, hence the advertising expenditure decreases as y increases.

The equilibrium price in this region, $P^* = 2(c + \delta y)$ is increasing in y. This indicates that the H seller has to set a higher price mark-up in order to signal. This reduces consumer surplus. In summary, as y increases, H uses less advertising and more pricing signal in the region of Advertising Signaling equilibrium (A). ■

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