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List Prices Signal Product Quality to a Behavioral Consumer

Abstract: In this model, a consumer is incompletely informed about the quality of two differentiated products, which causes an adverse selection problem. The manufacturers set list prices that are intended to serve as signals about quality. The retailers then decide about the actual transaction prices. Can the list prices be informative about product quality even if they are costless to transmit? They are uninformative for a rational consumer. A consumer who is subject to anchoring and loss aversion can, however, attain information about product quality and raise her surplus.

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1 Introduction

The model presented in this article explores the pricing of an industrially produced, branded consumer good such as apparel, sportswear, electronic articles, watches etc. It analyzes why manufacturers suggest a recommended, regular, or list price for their products even if the retailers may freely decide about the actual retail price, and if no consumer purchases the product at the list price. For example, in retail markets, sellers frequently advertise a uniform discounted price alongside a higher regular price, and all buyers get to purchase the product at the discounted price (Mayhew and Winer, 1992).

By focusing on situations where none of the purchases occurs at the list price, the model goes beyond prior literature explaining the practice of using list prices as a price discrimination strategy. Setting a list price while giving discounts to some customers allows distinguishing between sophisticated and naive customers (Armstrong and Chen, 2019), or between customers with and without opportunities to bargain/receive a discount (Raskovich, 2007; Gill and Thanassoulis, 2016). While these articles assume that at least some purchases are made at the list price, the present article studies a situation where none of the purchases is made at the list price.

In the absence of this price discrimination motive, other literature has explored the role of list prices as signals about product characteristics that are unobserved by the buyer. While Harrington and Ye (2019) and Lubensky (2017) concentrate on asymmetric information about production costs the present article studies asymmetric information about product quality, which is observed by the firms but not by the customer. This gives rise to an adverse selection (lemons) problem where the uninformed customer demands too much of a low quality product and too little of a high quality product.[2]

Adverse selection harms not only the customer but also the manufacturer of the high quality product; and the firm would want to signal product quality to the buyer. But what if signaling has no commitment value because it is costless, as is the case for setting list prices? Yet, evidence indicates that customers use list prices for inferring quality. Can list prices be informative about product quality even if they are costless to transmit?

[2]Asymmetric information about quality was also studied by Kim (2012). While the present model assumes a finite number of firms (modeled by a duopoly), the number of buyers and sellers in his model tends towards infinity. This gives rise to partially separating equilibria where a share of low-quality firms sends a truthful signal about product quality while others pool with the high-quality firms.

And why have customers been observed to make list price comparisons? Comparing list prices may be informative if the qualities of different products are correlated. But what if the product qualities of different manufacturers are uncorrelated as is assumed in this model? The article complements the literature on recommended retail prices that is reviewed in Section 2. This literature typically studies the effect of intrabrand price comparisons where a customer compares the actual retail price of a product, which is set by the retailer, to the recommended retail price, which is suggested by the manufacturer. The present article, however, focuses on interbrand comparisons where a customer compares the list prices set by different manufacturers.

The list price chosen by one firm serves as a reference price for the list price of the other product. Such reference price comparisons have been well-documented, for example, in marketing (Rajendran and Tellis, 1994). A reference price "separates [a] domain into regions of desirable outcomes (gains) and undesirable ones (losses)" (Kahneman, 1992, p. 296), and buyers often are averse to losses (Tversky and Kahneman, 1991; Kalyanaram and Winer, 1995). A similar effect may be inferred from a strand in the marketing literature suggesting that customers dislike price unfairness (Xia et al., 2004). Therefore, the customer in the present model is assumed to be averse to a manufacturer's list price being higher than the one set by another firm.

The article shows as a benchmark that in case of costless signals and uncorrelated qualities list prices are uninformative about product quality for a rational consumer. The article then demonstrates as its central result that this is different if the customer is subject to observed behavioral biases, in particular, if she anchors her willingness to pay on the list price of the goods and if she compares their list prices. A behavioral consumer of this type can learn information about product quality that is unattainable by a rational consumer. The model suggests that behavioral biases play an important role as heuristics that allow an economic agent to attain a surplus above that earned when behaving purely rational.

Further literature is reviewed in Section 2. The model is presented in Section 3 before discussing signaling in Section 4. The behavioral heuristics are introduced in Section 5. Section 6 demonstrates the list pricing equilibria and the central results. The article is concluded in Section 7. Proofs are provided in the appendix.

2 Literature Review

This article contributes to the literature in behavioral industrial organization (see Ellison, 2006, for a review). It explores to what extent list prices and especially interbrand comparisons of those list prices can help a consumer to infer information about product quality. Although the specification of the model makes it impossible for a rational consumer to learn product quality from list prices, it is shown how list prices can be informative for a behavioral consumer who anchors her willingness to pay on them.

Kahneman (1992, p. 308) defines anchoring as "cases in which a stimulus or a message that is clearly designated as irrelevant and uninformative nevertheless increases the normality of a possible outcome." Northcraft and Neale (1987) show that professional real estate agents overestimate the fair price of a house after having been exposed to an excessive list price. Ritov (1996) found in her bargaining experiment that a seller and a buyer typically settle on a higher price if the seller starts the negotiation with a higher initial price. Beggs and Graddy (2009) show empirically for a dataset on art auctions that paintings, which were sold at higher prices in the past, are typically also sold at higher prices in the present, even if one controls for their observable characteristics. Bruttel (2018) found from a laboratory experiment that buyers anchor their willingness to pay on recommended retail prices even if these recommendations are uninformative about product characteristics.

Related to this observation of anchoring effects, the marketing literature provides evidence of sellers using the distinction between external reference prices (also referred to as suggested, list, or regular prices) and actual prices for raising their profits (Mayhew and Winer, 1992). In the economics literature, a similar concept was employed, for example, by Armstrong and Chen (2019) in a two-period model. They assume that the initial price charged in the first period may be taken as a signal about an unobserved product characteristic by second-period buyers.

Several contributions have shown that sellers use prices as signaling devices for unobserved product characteristics, and that they are interpreted by customers accordingly. For example in the marketing literature, Rao and Monroe (1989) have established empirically that customers use the price of a product as one of several cues to infer product quality (also see the literature reviewed by Kim, 2012). In this context, the sellers may decide whether to use actual prices (as in Wolinsky, 1983) or list prices for doing so.

For example, Cooper and Ross (1984) show that actual prices may convey information about product quality in a model where only some buyers are uninformed about product quality and only some firms try to exploit this by offering a lower than the full-information product quality. In my model, a representative consumer is uninformed about quality, and the manufacturers in the duopoly model try to exploit this asymmetric information.

Observing *that* manufacturers use list prices / suggested retail prices as signaling devices for unobserved product characteristics does not answer *why* they do so. More research is needed to explain why the firms use list prices to signal quality on a monetary scale rather than signaling quality directly on a quality scale. As one hypothesis, the use of list prices might facilitate both intrabrand and interbrand comparisons of the signals. The list price of one product is readily comparable to the list price of another product, whereas it is not clear that the manufacturers measure quality also on the same scale.

In any case, Rao and Monroe (1989, p. 356) observe: "When buyers do infer a positive relationship between price and product quality, they are likely to compare the price of the product against another price (price in memory or price of an alternative option)." The literature on reference price formation (for example, Monroe, 1973; Rajendran and Tellis, 1994; Mazumdar et al., 2005) suggests that customers form their reference price based on the prices charged for the same good in the past (intrabrand, temporal comparisons) and/or based on the prices charged contemporaneously for products in the same category (interbrand, contextual comparisons). The present article focuses on interbrand comparisons of *list prices*. Interbrand comparisons of *actual prices* were analyzed by Azar (2013). Intrabrand comparisons were studied, for example, by Greenleaf (1995), Kopalle et al. (1996), Heidhues and Köszegi (2008), Spiegler (2012), Heidhues and Köszegi (2014), and Ahrens et al. (2017). They are beyond the scope of the present article.

Intrabrand price comparisons also feature prominently in the literature on recommended retail prices, which may serve a similar purpose as list prices. Puppe and Rosenkranz (2011) show that recommended retail prices help firms to solve the double marginalization problem when the manufacturer sells the product to the retailer at a linear wholesale price. If consumers exhibit loss aversion with regard to the recommended retail price, it serves as an upper bound to the actual retail price set by the retailer. The manufacturer can raise its profit by recommending a retail price that eliminates double marginalization. Fabrizi et al. (2016) extend this model to a downstream duopoly where a share of consumers has standard preferences without loss aversion. Different from those articles, who focused on double marginalization, I study the role of list prices in the presence of asymmetric information.

This analysis complements Buehler and Gärtner (2013) where a manufacturer possesses private information about both marginal production costs and a demand parameter, which are unobserved by the retailer. In their dynamic game, the retailer can employ trigger strategies such that the manufacturer recommends a retail price that is informative about demand and maximizes joint profits. The manufacturer refrains from understating its costs if the firm is made the residual claimant of joint profits. While their study assumes asymmetric information between the manufacturer and the retailer, I analyze a situation where manufacturers' superior information harms the uninformed final customer.

The article also relates to literature on collusion in list prices such as Gill and Thanassoulis (2016) and Harrington and Ye (2019). My model differs from Harrington and Ye (2019) by studying asymmetric information about quality whereas they study asymmetric information about costs. My model compares to theirs as follows: Similar to the anchoring effect in the present model, they assume that customers are willing to accept a higher actual price once observing a higher list price (*bargaining effect*). In their model, a high list price reduces a firm's chance of being invited to submit a bid (*inclusion effect*). In my model, a high list price is punished by the customer's loss aversion. Finally, they assume a market for an industrial / intermediate product that is sold via an auction. I analyze a posted price market for a consumer good.

3 The Model

Consider a market for an industrially produced, branded consumer good such as apparel, sportswear, electronic articles, watches etc. Market structure is depicted by Figure 1: Each of two symmetric upstream manufacturers indexed by $i, j \in \{1, 2\}$ produces one variant of a horizontally and vertically differentiated product at costs of zero. Every manufacturer sells its product to a representative consumer exclusively through one of two downstream retailers. This setup with two manufacturer-retailer pairs allows analyzing the effect of interbrand list price comparisons.

The article studies a multi-stage, signaling game with the manufacturers

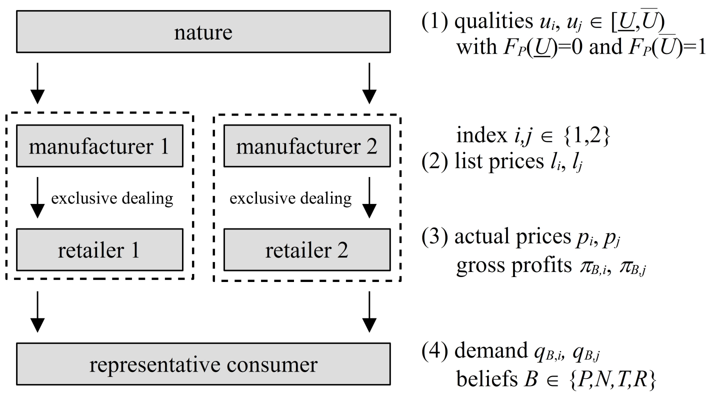

Figure 1: Timing and the supply chain

as the informed principals and the representative consumer as the uninformed agent. The qualities u_i, u_j are drawn in stage 1. In the second stage, the manufacturers send signals l_i, l_j about product quality. In the third stage, the retailers simultaneously choose actual retail prices p_i, p_j with the objective of maximizing their individual profits taking into account the consumer's beliefs B. Finally, in the fourth stage, the representative consumer demands the quantities maximizing her expected utility given the actual prices, the signals, and her beliefs.

The product qualities u_i, u_j are independent and identically distributed realizations of the random, continuous variable $U \in [\underline{U}, \overline{U})$ with $\underline{U} \geq 1$. They were drawn by 'nature' from the probability density function $f_P(U)$ in stage 1, and they cannot be affected by the firms. The cumulative distribution function $F_P(U)$ satisfies the properties $F_P(\underline{U}) = 0$ and $F_P(\overline{U}) = 1$. The qualities u_i, u_j define the manufacturers' types. They are mutually observed by the manufacturers and the downstream retailers but not by the representative consumer. In case of the consumer goods assumed in this model, it is typically easy for a manufacturer to purchase a unit of another manufacturer's product, determine its quality, and convey this information to its retailer.

For the representative consumer, however, the goods are experience goods (Nelson, 1970) so that the qualities u_i and u_j can only be learned *ex post* after buying the goods. Verifying quality *ex ante* is assumed to be prohibitively costly, which is a reasonable assumption for consumer goods whose price is only a small fraction of the consumer's income. This models an industry where, for example, new fashion collections or models of an electronic product are introduced before the representative consumer makes a repeated purchase of this type of product. It suffices studying the representative consumer's decision in the stage game if in an alternative, dynamic game the qualities are uncorrelated over time so that each new draw of the qualities may reverse the quality ranking of the firms.

The demand function is obtained from the representative consumer's utility function (1).

$$v = q_0 + a(q_i + q_j) - \frac{b}{2}\left(\frac{q_i^2}{u_i^2} + \frac{q_j^2}{u_j^2}\right) - \theta b \frac{q_i}{u_i}\frac{q_j}{u_j} \tag{1}$$

The parameter $\theta \in [0;1)$ measures horizontal product differentiation with $\theta = 0$ modeling unrelated products. The variable q_0 denotes the consumption of the numeraire good, and q_i, q_j stand for the quantities produced by the firms i, j. Utility function (1) was proposed by Sutton (1997) and analyzed, for example, by Symeonidis (1999, 2000, 2003); Bos and Marini (2019); Bos et al. (2020). It proves convenient because it adds the quality dimension to the well-known, linear utility function proposed by Bowley (1924), and it is computationally equally tractable. It also assumes that the buyer may purchase several units of each product, which is in line with the purchasing behavior in the consumer goods markets that motivated this model. There is no indication that the main effects of the model are sensitive to the choice of this particular utility function. The derivation of demand function (2) is presented in the Appendix.

$$q_{B,i} = \frac{x_{B,j}(a-p_i) - \theta z_B(a-p_j)}{b(x_{B,i}x_{B,j} - \theta^2 z_B^2)} \quad \text{with} \quad x_{B,i} = E_B(1/u_i^2), x_{B,j} = E_B(1/u_j^2) \quad \text{and} \quad z_B = E_B\left(\frac{1}{u_i}\frac{1}{u_j}\right) \tag{2}$$

The demand function satisfies the consumer's perfection condition because it was obtained by maximizing her expected utility while considering the signals l_i, l_j and the posterior distribution $f_B(u_i|l_i, l_j)$ of quality given her beliefs B. The beliefs show up in the expected values $x_{B,i}$, $x_{B,j}$, and z_B.

In the third stage, every retailer chooses the price p_i of its product to individually maximize its profits given demand function $q_{B,i}$ and the wholesale contract concluded with the manufacturer. Each retailer is assumed to enter into an exclusive dealing contract with one manufacturer. I assume that the firms agree on a two-part tariff where manufacturer i sets a wholesale price equaling its marginal costs of production (zero) and receives a share s_i of retailer i's gross profits $\pi_{B,i}$. The process of determining the manufacturer's share s_i is not modeled explicitly. It could be the result of any bargaining model.

These assumptions ensure that the manufacturer and the retailer of product i are both interested in maximizing the profits $\pi_{B,i}$. Preventing any conflict of interest between the manufacturer and the retailer makes the main points of this article, which is concerned with the information asymmetry between the firms and the representative consumer, easier to see.[3] Exclusive dealing contracts are commonly used in markets for branded consumer goods. This is, however, not necessarily the case for two-part tariffs. Yet, Jeuland and Shugan (1983) and Kolay et al. (2004) have shown that the computationally more tractable two-part tariffs can substitute for the empirically observed quantity discount schemes that have been employed quite frequently in wholesale markets for consumer goods (Iyer and Villas-Boas, 2003; Villas-Boas, 2007). Two-part tariffs and quantity discounts have the same economic properties: They eliminate double marginalization, and they transfer profits from downstream retailers to upstream manufacturers.

It is straightforward to show that the Bertrand-Nash equilibrium price $p^*_{B,i}$, quantity $q^*_{B,i}$, and gross profit $\pi^*_{B,i}$ of retailer i (i.e., before paying the fee $s_i \cdot \pi^*_{B,i}$ to the manufacturer) are given by (3) to (5). Equilibrium values are indicated by an asterisk.

$$p^*_{B,i} = a \cdot \frac{x_{B,i}(2x_{B,j} - \theta z_B) - \theta^2 z_B^2}{4x_{B,i}x_{B,j} - \theta^2 z_B^2} \tag{3}$$

$$q^*_{B,i} = \frac{a x_{B,j}}{b(x_{B,i}x_{B,j} - \theta^2 z_B^2)} \cdot \frac{x_{B,i}(2x_{B,j} - \theta z_B) - \theta^2 z_B^2}{4x_{B,i}x_{B,j} - \theta^2 z_B^2} \tag{4}$$

$$\pi^*_{B,i} = \frac{a^2 x_{B,j}}{b(x_{B,i}x_{B,j} - \theta^2 z_B^2)} \cdot \left[\frac{x_{B,i}(2x_{B,j} - \theta z_B) - \theta^2 z_B^2}{4x_{B,i}x_{B,j} - \theta^2 z_B^2}\right]^2 \tag{5}$$

[3] The model would be the same for two vertically integrated firms who set list prices in the first and transaction prices in the second stage.

4 Signaling

Given that the qualities u_i and u_j are unobservable by the representative consumer, demand (2) coincides with its complete information counterpart only by chance. This gives rise to an adverse selection problem similar to Akerlof's (1970) lemons problem: A retailer benefits if the customer's demand under incomplete information is above her demand under complete information. The retailer is harmed if the customer's demand is suboptimally low. The customer is harmed in both cases. She either buys too much of a low quality good or too little of a high quality good.

There are typically three ways to solve asymmetric information problems; none of which is fully applicable here: Mechanism design analysis suggests that the buyer might enter into a contract with each manufacturer-retailer pair. She would propose a menu specifying quantity-payment combinations. If the menu satisfies each manufacturer-retailer pair's participation and incentive compatibility constraints they would reveal their qualities truthfully in return for an information rent. The transaction costs of implementing such a mechanism would, however, be prohibitively high given the type of consumer products that inspired this model. Implementing a mechanism would also be far from trivial given that the menu specified for every firm i would have to depend not only on one unobserved parameter u_i, as is often assumed in the mechanism design literature, but on an additional unobserved parameter u_j.

Asymmetric information concerning several types of sellers may also be addressed by a customer in the form of conducting an auction. This is a second option for solving games of asymmetric information. However, auctions cause non-negligible transaction costs, too. They are used when firms or authorities procure large quantities of a good while being uncommon when consumers purchase rather small quantities.

As a third option, the firms might try to signal product quality as is assumed in this article. Therefore, in the second stage, both manufacturers send messages l_i, l_j of product quality to the representative consumer before she makes her purchase. Each manufacturer chooses its signal with the objective of maximizing gross profit (5). Section 6 shows that signaling qualities is individually rational for the manufacturers. However, the current model was purposefully defined to preclude the existence of a separating Perfect Bayesian Equilibrium (PBE): Neither manufacturer incurs any costs for signaling an incorrectly high quality. The qualities u_i, u_j are also uncorrelated so that one must not expect a comparison of the signals l_i, l_j to be informative about the true qualities u_i, u_j either.

The article shows that in this situation, where transaction costs preclude an auction or a mechanism, and where a separating PBE in a signaling game may not be expected, behavioral biases as are observed in practice and presented in Section 5 can increase a consumer's surplus. This result is in the spirit of the well-known *reputation game* (for example, see the review by Fudenberg and Tirole, 1991, p. 326) where the reputation of non-rational behavior allows a player to earn a higher payoff than the payoff earned when behaving rationally.

Section 5 shows that comparisons of l_i, l_j play an important role in the resulting equilibrium with a behavioral consumer. Before turning there, note that the messages were denoted l_i, l_j because it is the list price that shall serve as a signal about product quality. More specifically, I assume that product quality is transformed linearly into the monetary dimension by a function $l_i = L \cdot u_i$. Without loss of generality, the scaling factor is assumed to take a value $L = 1$.

5 Updating Rules

Firms' choices of l_i, l_j and p_i, p_j depend on the representative consumer's beliefs about the posterior distribution $f_B(u_i|l_i, l_j)$ after observing l_i, l_j. I analyze three candidates for the customer's posterior beliefs $B \in \{P, N, R\}$. As is standard, the consumer may disregard the signals l_i, l_j and stick to the prior P, according to which she knows the minimum and maximum level of quality $(\underline{U}, \overline{U})$ and the distribution $f_P(U)$ but cannot observe the realizations u_i, u_j. Alternatively, and at the core of this article, she may make an interbrand comparison of the signals l_i and l_j, where l_j serves as a reference price for l_i and *vice versa* (hence the index R).

The case with a naive consumer (indexed by N) is provided as a benchmark and for introducing notation. The beliefs N are restricted forms of the beliefs R. A naive customer is assumed to form her beliefs according to the discrete probability mass function $f_N(u_i|l_i)$ in (6) that makes use of the probability mass functions $f_n(u_i|l_i)$ and $f_{nn}(u_i)$ as are defined by (7) and (8).

$$f_N(u_i|l_i) = \begin{cases} f_n(u_i|l_i) & \text{if } l_i < \overline{U} \\ f_t(u_i) & \text{if } l_i = \overline{U} \end{cases} \tag{6}$$

$$f_n(u_i|l_i) = \begin{cases} 1 & \text{if } u_i = l_i \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

$$f_{nn}(u_i) = \begin{cases} 1 & \text{if } u_i = \underline{U} \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

The properties of those beliefs can be seen best based on the expected quality $E_N(u_i|l_i)$ that is implied by them.

$$E_N(u_i|l_i) = \begin{cases} l_i & \text{if} \quad l_i < \overline{U} \\ \underline{U} & \text{if} \quad l_i = \overline{U} \end{cases} \tag{9}$$

If $l_i < \overline{U}$, the representative consumer believes the signal ($E_N(u_i|l_i) = l_i$) by putting mass 1 on l_i according to $f_n(u_i|l_i)$. Otherwise, if $l_i = \overline{U}$, the representative consumer disbelieves the signal by putting mass 1 on $\underline{U}$ according to $f_{nn}(u_i)$, which results in $E_N(u_i|l_i) = \underline{U}$. This assumption is made because even a naive consumer may be aware that the manufacturers have an incentive to overstate the quality of their products. For example, experimental results by Kirmani (1990) and Kopalle and Lindsey-Mullikin (2003) show that customers reduce their willingness to pay once a message about product quality exceeds a certain threshold. This is parsimoniously implemented by assuming that the representative consumer's quality expectation falls all the way down to $\underline{U}$ if $l_i = \overline{U}$.

Because there is no cost for the manufacturers to signal excessive qualities it is straightforward to prove Lemma 1.

Lemma 1. *Forming beliefs according to $f_N(u_i|l_i)$ is not part of a separating PBE. The manufacturers signal $l_{N,i} = \overline{U} - \epsilon, l_{N,j} = \overline{U} - \epsilon$ (with $\epsilon > 0$ and $\epsilon \to 0$) irrespective of their types u_i, u_j.*

Proof. See the Appendix. □

Given Lemma 1, a rational consumer would stick to her prior P. It is not evident either why, in practice, one should observe a naive consumer, given that she may have encountered untrustworthy signals in other markets before. This is however different if the representative consumer compares the list prices l_i, l_j to each other. The evidence presented in Sections 1 and 2 suggests that real customers make interbrand price comparisons, using the list prices set by other manufacturers as reference prices when evaluating how good a deal some product is. Section 6 of this article demonstrates that for a behavioral customer of this type list prices can be informative about product quality. This result may be unexpected given that the qualities u_i, u_j are uncorrelated. Moreover, the behavioral consumer can even earn a higher consumer surplus than a rational consumer.

To see this, consider a representative consumer who forms her beliefs R based on an interbrand comparison of the signals l_i, l_j as follows. As before, the representative consumer forms her conditional beliefs according to $f_n(u_i|l_i)$ as long as the signal l_i is below both the upper threshold $\overline{U}$ and the list price l_j of the rival. The consumer puts mass 1 on l_i and expects a quality equaling l_i. If the list price l_i equals the upper threshold $\overline{U}$, the representative consumer uses the conditional distribution $f_{nn}(u_i)$. She disbelieves the signal $l_i = \overline{U}$ and expects the product to be of the lowest quality $\underline{U}$ instead. These considerations are captured by the first and third lines in (10) and (11) that show the posterior beliefs $f_R(u_i|l_i, l_j)$ and the expected quality $E_R(u_i|l_i, l_j)$. The new parameter ℓ will be explained below in this section.

$$f_R(u_i|l_i,l_j) = \begin{cases} f_n(u_i|l_i) & \text{if} & & l_i \leq l_j & \text{and} & l_i < \overline{U} \\ f_r(u_i|l_i,l_j) & \text{if} & l_j < & l_i \leq l_j + \frac{\underline{U}-l_j}{1-\ell} & \text{and} & l_i < \overline{U} \\ f_{nn}(u_i) & \text{if} & & l_i > l_j + \frac{\underline{U}-l_j}{1-\ell} & \text{or} & l_i = \overline{U} \end{cases} \tag{10}$$

$$E_R(u_i|l_i,l_j) = \begin{cases} l_i & \text{if} & & l_i \leq l_j & \text{and} & l_i < \overline{U} \\ l_i - \ell(l_i - l_j) & \text{if} & l_j < & l_i \leq l_j + \frac{\underline{U}-l_j}{1-\ell} & \text{and} & l_i < \overline{U} \\ \underline{U} & \text{if} & & l_i > l_j + \frac{\underline{U}-l_j}{1-\ell} & \text{or} & l_i = \overline{U} \end{cases} \tag{11}$$

The main novelty is in the second lines: The beliefs $f_R(u_i|l_i, l_j)$ and $E_R(u_i|l_i, l_j)$ are conditional not only on the list price l_i of manufacturer i any more but also on the list price l_j sent by manufacturer j. Rajendran and Tellis (1994) find empirical support for mainly two types of reference prices. The first adopts the notion that the reference price is established as the *average* list price of all brands other than brand i. The second variant of the reference price refers to buyers using the *lowest* list price that can be observed in the market. For a duopoly, both types yield the same threshold $l_i > l_j$. In this case, the representative consumer distorts the expected quality downwards by forming her beliefs based on the probability mass function $f_r(u_i|l_i, l_j)$ as defined in (12), which puts mass 1 on $u_i = l_i - \ell(l_i - l_j)$.

$$f_r(u_i|l_i,l_j) = \begin{cases} 1 & \text{if } u_i = l_i - \ell(l_i - l_j) \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

The new parameter $\ell > 1$ measures the strength of a downward distortion of expected quality $E_R(u_i|l_i, l_j)$ once $l_i > l_j$. It can be interpreted as a measure of loss aversion. In fact, specification (11) resembles the specification of loss aversion in the seminal model of Putler (1992) closely: The representative consumer adjusts the expected quality of product i and, thus, her expected utility downwards when perceiving the purchase of this product as a loss relative to the other product ($l_i > l_j$). The positive relationship between the list price l_i and the expected quality $E_R(u_i|l_i, l_j)$ for $l_i < \overline{U}$ might be interpreted as anchoring.

Before turning to the manufacturers' choice of list prices in Section 6, two technical remarks shall be made. Firstly, the term $l_i - \ell(l_i - l_j)$ may take values below $\underline{U}$. Solving the requirement $l_i - \ell(l_i - l_j) \geq \underline{U}$ for l_i yields the threshold $l_i \leq l_j + (\underline{U} - l_j)/(1 - \ell)$. Therefore, $E_R(u_i|l_i, l_j)$ is censored at $\underline{U}$ for $l_i \leq l_j + (\underline{U} - l_j)/(1 - \ell)$. Secondly, the values of ℓ are restricted to $\ell > 1$ because the threshold $l_j + (\underline{U} - l_j)/(1 - \ell)$ is undefined for $\ell = 1$ and, more importantly, because the proof of Proposition 1 in Section 6 presents an intuitive result: If the downward distortion is weak, which is the case for $\ell < 1$, the list pricing equilibrium is essentially the same as the one already presented in Lemma 1. Therefore, assuming $\ell > 1$ merely precludes this less relevant result while facilitating notation as well as the further analysis.

6 List Prices and Consumer Surplus

This section presents the manufacturers' choice of list prices if the representative consumer forms her (behavioral) beliefs using $f_R(u_i|l_i, l_j)$. The section demonstrates that the equilibrium list prices convey information about product quality so that a behavioral consumer may enjoy a higher consumer surplus than a rational consumer. Yet, the beliefs $f_R(u_i|l_i, l_j)$ are not part of a PBE because they do not follow from Bayes' rule. Therefore, as in Puppe and Rosenkranz (2011) and Fabrizi et al. (2016), the manufacturers choose Nash equilibrium list prices subject to a behavioral customer.

Proposition 1 presents the manufacturers' choice of list prices and the resulting gross profits. The proposition shows a central result: The manufacturers play a coordination game where they set symmetric list prices that can be below those set in the presence of a naive consumer (i.e., $l_i, l_j < \overline{U} - \epsilon$; see Lemma 1).

Proposition 1. *If the manufacturers compete in list prices by individually choosing the signals* l_i, l_j *to maximize the gross profits* $\pi^*_{R,i}(l_i, l_j), \pi^*_{R,j}(l_j, l_i)$ *of their products, the equilibrium values* $l_{R,i}, l_{R,j}$ *depend on the value of* ℓ *as is shown by* (13)*. The ensuing equilibrium profits are given by* (14)*.*

$$l_{R,i} = l_{R,j} = \begin{cases} l_R \in [\underline{U}, \overline{U}) & \text{if} \quad 1 < \ell < \frac{2-\theta^2}{\theta} \\ \underline{U} & \text{if} \quad \frac{2-\theta^2}{\theta} \leq \ell \end{cases} \tag{13}$$

$$\pi^*_{R,i}(l_{R,i}, l_{R,j}) = \frac{a^2}{b[1-\theta^2]} \cdot \left[\frac{1-\theta}{2-\theta}\right]^2 \cdot {l_R}^2 \tag{14}$$

For $1 < \ell < (2-\theta^2)/\theta$ *the game takes the form of a coordination game with multiple equilibria. All symmetric combinations of list prices in the interval* $[\underline{U}, \overline{U})$ *constitute equilibria of the game.*

Proof. See the Appendix □

Proposition 1 demonstrates that the list prices chosen by the firms depend on the representative consumer's loss aversion parameter ℓ. The proof shows that, on the one end of the spectrum, for $\ell < 1$ the distortion is so weak that the equilibrium would be the same as the one shown in Lemma 1 for the case without list price comparisons. This uninteresting case was precluded by assuming $\ell > 1$. On the other end of the spectrum, if ℓ is too large ($\ell \geq (2-\theta^2)/\theta$) the consumer's distortion upon observing $l_i \neq l_j$ is quite strong. By signaling $l_i < l_j$ manufacturer i can induce the representative consumer to distort her expectation of the quality of product j downwards perceptibly. This lowers demand for product j and, given the (imperfect) substitutability of products i and j, the representative customer purchases more of product i. This increases the gross profit made with product i as opposed to setting $l_i = l_j$. Since it is a best response for each manufacturer to set a list price below that of the other firm, one finds $l_{R,i} = \underline{U}, l_{R,j} = \underline{U}$ for all u_i, u_j.

Most importantly, Proposition 1 suggests that for intermediate values of ℓ it is profitable for manufacturer i to match but not exceed manufacturer j's list price. Both firms would want to set the same list prices $l_i = l_j$ in the interval $[\underline{U}, \overline{U})$. Because there are infinitely many symmetric combinations of list prices in this interval, the stage game takes the form of a coordination game with multiple symmetric equilibria. This gives rise to an equilibrium selection problem for the firms.[4]

Schelling (1960) suggested that players can solve coordination games non-cooperatively by choosing their strategies based on focal points, which might be defined as points of convergence for expectations (Sugden and Zamarrón, 2006, p. 610). Although "[game] theory lacks [...] a formal theory of focal points" (Janssen, 2001, p. 119), four list prices stand out as potential focal points in the context of the present model with symmetric list prices in equilibrium: Each manufacturer might signal the lowest quality $\underline{U}$. It might signal almost the highest quality $\overline{U}-\epsilon$ as in Lemma 1. The two manufacturers might signal l_P where l_P is defined by condition $\pi^*_{R,i}(l_P, l_P) = \pi^*_{P,i}$, i.e., the gross profit is the same as if the customer relied on her prior P. Finally, the manufacturers might signal the highest quality observable in the market $l_{R,i} = l_{R,j} = u_{max}$ with $u_{max} = \max(u_i, u_j)$. Proposition 2 shows that a customer with beliefs R can potentially learn the higher of the two qualities u_{max}.

Proposition 2. *The manufacturers choose* $l_{R,i} = l_{R,j} = \max(u_{max}, l_P)$ *if, firstly,* $1 < \ell < (2 - \theta^2)/\theta$ *and, secondly, there is no obvious candidate for* $\overline{U} - \epsilon$*.*

As is standard with focal points, Proposition 2 cannot be proven formally, whereas its plausibility can be assessed: Following Proposition 1, the condition $1 < \ell < (2-\theta^2)/\theta$ is required for the list pricing subgame to take the form of a coordination game. The candidate $\underline{U}$ may be dismissed because of being payoff-dominated by $l_{R,i} = l_{R,j} = l_P$, which again is payoff-dominated by $l_{R,i} = l_{R,j} = u_{max}$ if $u_{max} > l_P$. Setting $l_{R,i} = l_{R,j} = u_{max}$ is feasible because the manufacturers mutually observe u_i, u_j. The focal point is determined by the larger of the two qualities, and the firm with $\min(u_i, u_j)$ generates higher profits by signaling u_{max} instead of its true product quality.

One may ask why the firms should find it difficult to tacitly coordinate on $\overline{U} - \epsilon$. Why should it be impossible for them to set a list price an ϵ below the maximum $\overline{U}$? While this task appears straightforward in the

[4] Proposition 1 also demonstrates the relevance of assuming both vertical *and* horizontal product differentiation. For homogeneous goods ($\theta = 1$) the threshold $(2 - \theta^2)/\theta$ takes a value of 1. As a consequence, the equilibrium with list prices in the interval $[\underline{U}, \overline{U})$ vanishes for homogeneous goods. In this case, competition among the firms is so intense that they both would want to signal $l_{R,i} = l_{R,j} = \underline{U}$ for all $\ell \geq 1$. The coordination game, thus, only emerges for horizontally differentiated goods.

model it may be much more difficult in practice. For example, it may not be clear how to define ϵ specifically. Moreover, the representative consumer might only have a *very good* understanding of the maximum quality $\overline{U}$ rather than knowing it *exactly*. This means she bases her beliefs $f_R(u_i|l_i, l_j)$ on a somewhat inaccurate proxy $\tilde{U}$ in the vicinity of $\overline{U}$. While this leaves the main mechanism of the reference price comparisons and the results of Proposition 1 intact, it greatly complicates manufacturers' task of coordinating on $\tilde{U} - \epsilon$ if they cannot observe $\tilde{U}$.

Note that there need not be an inconsistency between the assumption of manufacturers' finding it difficult to observe the demand parameter $\tilde{U}$ while, at the same time, being able to observe the loss aversion parameter ℓ. Even though the model presented in this article is static, it can easily be thought of as the stage game of a dynamic game where new realizations of the utilities u_i, u_j are drawn in every period. If ℓ was unobservable in this dynamic game, it would take the firms just one period to learn its value: The manufacturers would merely have to set some arbitrary values of l_i and l_j. And the retailers would have to set some arbitrary prices p_i, p_j. The value of ℓ could then be inferred from the representative consumer's quantity choice. It would, however, be much more costly for the firms to learn $\tilde{U}$ because it would take the firms several periods of setting non-optimal list prices to narrow down the interval for $\tilde{U}$.

Lemma 2 establishes participation of the manufacturers in the signaling game.

Lemma 2. *It is individually rational for the manufacturers to send quality signals l_i, l_j.*

Proof. As their outside option, the manufacturers might refuse to send quality signals. The representative consumer would then rely on her prior P, and every manufacturer-retailer pair would make the gross profit $\pi^*_{P,i}$. This illustrates why the manufacturers only signal $l_{R,i} = l_{R,j} = u_{max}$ if $u_{max} > l_P$ (and l_P otherwise). This guarantees that they receive at least the profit $\pi_{R,i}(l_P, l_P) = \pi^*_{P,i}$, which ensures manufacturers' participation in the signaling game. □

Lemma 3 finally proves a feature of the model that was implemented by construction.

Lemma 3. *The beliefs R are not part of a PBE.*

Proof. The beliefs $f_R(u_i|l_i, l_j)$ do not follow from Bayes' rule: For symmetric list prices ($l_i = l_j = l$) the definition of $f_R(u_i|l, l)$ in (12) causes the consumer to put mass $f_N(u_i|l) = 1$ on $u_i = l$. A rational consumer would, however, infer that $u_i = l$ only applies with a 50% chance, i.e., if firm i offers a higher quality than firm j. The rational consumer's Bayesian beliefs $f_{RR}(u_i|l)$ are shown by (15), which allow for the possibility that firm i is the lower-quality firm whose true quality is distributed in the interval $[\underline{U}, l]$.

$$f_{RR}(u_i|l) = 0.5 \cdot f_N(u_i|l) + 0.5 \cdot \left[\frac{f_P(u_i)}{F_P(l)}\right]_{\underline{U}}^{l} \tag{15}$$

Because the beliefs $f_R(u_i|l_i, l_j)$ do not follow from Bayes' rule, they cannot be part of a Bayesian equilibrium. □

This raises the question whether there is a benefit to making interbrand price comparisons, as are observed in practice, even if they are not part of a PBE? As one answer, such comparisons help to economize on effort costs. More importantly, a behavioral consumer, who builds beliefs according to $f_R(u_i|l_i, l_j)$, may receive a higher consumer surplus than a rational consumer.

To demonstrate the effort cost savings, recall that a rational consumer needs to calculate the expected values of the inverse qualities subject to her beliefs B if she wants to determine her demand optimally, i.e., she needs to calculate $x_{B,i} = E_B(1/u_i^2)$, $x_{B,j} = E_B(1/u_j^2)$, and $z_B = E_B(1/(u_i u_j))$. This is a non-trivial task given the non-linearities of both demand and the posterior distribution of qualities. Marketing literature such as Zeithaml (1988) and Steenkamp (1990) indicates that, in practice, buyers reduce this complexity by basing their purchasing decisions on the expected product quality instead. And indeed, by putting mass 1 on a single quality, the posterior beliefs $f_R(u_i|l_i, l_j)$ allow writing the terms $x_{R,i}$, $x_{R,j}$, and z as functions of the expected product quality (for example, $x_{R,i} = 1/E_R(u_i)^2$). For symmetric list prices, the expected product quality can be obtained easily without any further calculations. One finds $E_R(u_i|l_i, l_j) = l_i$ if $l_i = l_j$. Therefore, the posterior beliefs $f_R(u_i|l_i, l_j)$, which were defined based on empirical evidence, reduce complexity and, thus, effort costs.

More importantly, by learning the higher of the two qualities, a behavioral consumer, who builds beliefs according to $f_R(u_i|l_i, l_j)$, may receive a higher consumer surplus than a rational consumer. This is shown by Proposition 3.

Proposition 3. *Condition* (16) *defines the increase in consumer surplus for specific combinations of u_i and u_j when forming beliefs according to R instead of P.*

$$\Delta CS(u_i, u_j) = CS_R(u_i, u_j) - CS_P(u_i, u_j) \tag{16}$$

Condition (17) *defines the increase in consumer surplus expected by a customer who knows $f_P(U)$ but cannot observe u_i, u_j.*

$$E(\Delta CS) = \int_{\mu_i=\underline{U}}^{\overline{U}} \int_{\mu_j=\underline{U}}^{\overline{U}} f_P(\mu_i) f_P(\mu_j) \Delta CS(\mu_i, \mu_j) d\mu_i d\mu_j \tag{17}$$

One finds $E(\Delta CS) > 0$ if the variance of $f_P(U)$ is below a critical value, which is determined by the shape of $f_P(U)$ and utility function v.

Proof. Given the non-linearities of utility function (1) and of most distribution functions, Proposition 3 is demonstrated in the Appendix using a numerical example. □

The intuition for Proposition 3 is as follows: Using reference price comparisons R to learn the higher of the two qualities does not necessarily raise the consumer's surplus in comparison to her prior P. This is because the manufacturer with the lower-quality product still exaggerates this product's quality to the consumer's disadvantage.

A positive effect on consumer surplus occurs however if the utilities of both firms are identical ($u_i = u_j$) so that the representative consumer learns the exact qualities of both goods. This effect remains positive also for asymmetric qualities as long as u_i and u_j are sufficiently symmetric. Rather symmetric qualities can be observed more frequently if the variance of $f_P(U)$ is sufficiently low.

These considerations demonstrate that interbrand reference price comparisons in combination with behavioral heuristics (anchoring and loss aversion) reduce a consumer's effort costs and allow her to achieve a surplus that is unattainable by a rational consumer. This result shows that interbrand reference price comparisons can benefit a consumer even in situations where the qualities themselves are uncorrelated. This also demonstrates why manufacturers set list prices (or recommended retail prices) even if none of the goods is ultimately sold at these prices.

7 Conclusion

This article contributes to the literature in industrial organization, behavioral economics, and marketing. It develops a formal model of setting list prices and asks why manufacturers set a list price for their products even if the retailers are free to decide about the retail price, and if no consumer purchases the product at the list price. Based on evidence suggesting that list prices potentially serve as signals about quality, the article shows that list prices can be informative about quality – but only to a behavioral consumer.

The list prices are informative about product quality if the representative consumer compares the list prices to each other, even if the qualities themselves are uncorrelated. The reference price comparisons cause list price competition, which prevents the firms from setting excessive list prices. The firm with the higher-quality product reveals its quality truthfully, and the firm with the lower-quality product matches this signal. Therefore, list prices can be informative about product quality even if they are costless to transmit. Consumer surplus rises if the variance of the qualities is moderate.

Future research should extend the analysis in several directions. It will be interesting to analyze list price collusion in addition to list price competition. The model should also be extended to more than two firms, different utility functions, and bargaining and/or auction models. While none of these extensions may be expected to change the main outcomes of the model fundamentally, further research should also go beyond the present model: It will be interesting to explore why customers infer information about product quality from list prices instead of relying on more immediate quality signals. Moreover, this article along with other literature treats list, recommended, regular prices etc. synonymously. It should be studied under which circumstances this is justified.

Appendix

Derivation of demand function (2). With utility function (1), the consumer's perfection condition is satisfied if she demands the quantities q_i, q_j that maximize her expected utility $E_B(v)$ shown by (A.1) given the signals l_i, l_j and her posterior beliefs $f_B(u_i|l_i, l_j)$.

$$E_B(v) = \int_{\mu_i=\underline{U}}^{\overline{U}} \int_{\mu_i=\underline{U}}^{\overline{U}} f_B(\mu_i|l_i,l_j) f_B(\mu_j|l_i,l_j) \left[q_0 + a(q_i+q_j) - \frac{b}{2}\left(\frac{q_i^2}{\mu_i^2} + \frac{q_j^2}{\mu_j^2}\right) - \theta b \frac{q_i}{\mu_i}\frac{q_j}{\mu_j} \right] d\mu_i d\mu_j \tag{A.1}$$

Maximizing (A.1) subject to the budget constraint $y = q_0 + \sum q_i p_i$ (with $p_0 = 1$, and y denoting the buyer's budget) gives inverse demand (A.2), which can be solved for demand as is stated in (2).

$$p_{B,i} = a - \int_{\mu_i=\underline{U}}^{\overline{U}} \int_{\mu_i=\underline{U}}^{\overline{U}} f_B(\mu_i|l_i,l_j) f_B(\mu_j|l_i,l_j) \left[\frac{b}{\mu_i}\frac{q_i}{\mu_i} + \theta \frac{b}{\mu_i}\frac{q_j}{\mu_j} \right] d\mu_i d\mu_j \tag{A.2}$$

□

Proof of Lemma 1. Given the definition of $f_N(u_i|l_i)$ in (6), the customer puts all mass on a single expected quality $E_N(u_i|l_i)$ for each product. For $l_i, l_j < \overline{U}$, one can thus write $x_{N,i} = 1/l_i^2$, $x_{N,j} = 1/l_j^2$, and $z_N = 1/(l_i l_j)$. After plugging these terms in profit function (5) one finds $\partial \pi^*_{N,i}/\partial l_i > 0 \forall l_i < \overline{U}$. Given $E_N(u_i|l_i) = \underline{U}$ for $l_i = \overline{U}$, it is a dominant strategy for the manufacturers to signal almost the maximum quality ($l_{N,i} = \overline{U} - \epsilon, l_{N,j} = \overline{U} - \epsilon$ with $\epsilon > 0$ and $\epsilon \to 0$) irrespective of their types u_i, u_j. The naive consumer's information set would, thus, be the same when using $f_N(u_i|l_i)$ or $f_P(u_i)$ so that the rational consumer's conditional beliefs would still be $f_P(u_i)$. Therefore, forming beliefs according to $f_N(u_i|l_i)$ is not part of a separating PBE. A pooling PBE results where the customer sticks to the prior P and the firms set their profit-maximizing prices accordingly. □

Proof of Proposition 1. Note that $f_R(u_i|l_i, l_j)$ puts all mass on one level of quality so that $E_R(1/u_i) = 1/E_R(u_i)$ applies. This allows to set $x_{R,i} = 1/E_R(u_i)^2$, $x_{R,j} = 1/E_R(u_j)^2$, and $z_R = 1/[E_R(u_i)E_R(u_j)]$. The gross profit $\pi^*_{R,i}(l_i, l_j)$ can be written as a function of the list prices because $E_R(u_i)$ and $E_R(u_j)$ are fully defined by l_i and l_j. Maximizing the manufacturer's profit $(1 - s_i) \cdot \pi^*_{R,i}(l_{R,i}, l_{R,j})$ gives the same solution as maximizing the gross profit $\pi^*_{R,i}(l_{R,i}, l_{R,j})$ itself.

The profit $\pi^*_{B,i}$ from (5) can be restated as in (A.3) after plugging in the functional forms of $x_{R,i}$, $x_{R,j}$, and z_R given $E_R(u_i|l_i, l_j)$ from (11).

$$\pi^*_{R,i}(l_i,l_j) = \begin{cases} \frac{a^2}{b[1-\theta^2]} \cdot \left[\frac{[(2-\theta^2)-\theta\ell]l_i - \theta(1-\ell)l_j}{4-\theta^2}\right]^2 & \text{if } l_i \le l_j \text{ and } l_j \le l_i + \frac{\underline{U}-l_i}{1-\ell} \text{ and } l_i, l_j < \overline{U} \\ \frac{a^2}{b[1-\theta^2]} \cdot \left[\frac{(2-\theta^2)(1-\ell)l_i + [(2-\theta^2)\ell - \theta]l_j}{4-\theta^2}\right]^2 & \text{if } l_i > l_j \text{ and } l_i \le l_j + \frac{\underline{U}-l_j}{1-\ell} \text{ and } l_i, l_j < \overline{U} \\ \frac{a^2}{b[1-\theta^2]} \cdot \left[\frac{(2-\theta^2)l_i - \theta\underline{U}}{4-\theta^2}\right]^2 & \text{if } l_i < l_j \text{ and } l_j > l_i + \frac{\underline{U}-l_i}{1-\ell} \text{ and } l_i < \overline{U} \\ \frac{a^2}{b[1-\theta^2]} \cdot \left[\frac{(2-\theta^2)\underline{U} - \theta l_j}{4-\theta^2}\right]^2 & \text{if } l_i > l_j \text{ and } l_i > l_j + \frac{\underline{U}-l_j}{1-\ell} \text{ and } l_j < \overline{U} \\ \frac{a^2}{b[1-\theta^2]} \cdot \left[\frac{(2-\theta^2)\underline{U} - \theta\underline{U}}{4-\theta^2}\right]^2 & \text{if } l_i, l_j = \overline{U} \end{cases} \tag{A.3}$$

Using the first and the second line in (A.3), it is a dominant strategy for firm i to choose a list price higher than that of firm j (i.e., $l_i = l_j + \epsilon$ with $\epsilon > 0$) if $\pi^*_{R,i}(l_j + \epsilon, l_j) > \pi^*_{R,i}(l_j, l_j)$. Re-arranging this inequality gives $\ell < 1$. The firms would choose $l_{R,i} = l_{R,j} = \overline{U} - \epsilon$ if $\ell < 1$ was not precluded by assumption.

Alternatively, for $\ell > 1$, one finds $\pi^*_{R,i}(l_j + \epsilon, l_j) < \pi^*_{R,i}(l_j, l_j)$ so that firm i's profit is given by the first line in (A.3). Deriving the profit function for l_i yields reaction function (A.4).

$$l_{R,i}(l_j) = \max\left(\underline{U}, \frac{\theta(1-\ell)}{(2-\theta^2) - \theta\ell} l_j\right) \tag{A.4}$$

Firm i would not set a list price below $\underline{U}$, which already signals the lowest conceivable quality level $\underline{U}$. Moreover, for any combination of θ and ℓ, the reaction functions $l_{R,i}(l_j)$ and $l_{R,j}(l_i)$ only intersect at $l_i, l_j = 0$, which is ruled out by $l_i, l_j \in [\underline{U}, \overline{U}]$. One can see from the first line in (A.3) that $\pi^*_{R,i}(l_i, l_j)/\partial l_i \leq 0$ applies for $\ell \geq (2-\theta^2)/\theta$ so that firm i would set $\underline{U}$ as is shown in the second line of (13). Alternatively, for $\ell < (2-\theta^2)/\theta$, one finds $\pi^*_{R,i}(l_i, l_j)/\partial l_i > 0$ so that firm i would want to set $l_i = l_j$, which proves that the firms set identical list prices in equilibrium.

All symmetric list prices $l_i = l_j = l_R \in [\underline{U}, \overline{U})$ constitute equilibria of this game as is shown in the first line of (13). The list prices $l_{R,i}, l_{R,j} = \overline{U}$ is not chosen by the firms because the customer would expect $E_R(u_i|l_i, l_j) = \underline{U}$ in this case, and the manufacturer can raise its profit by remaining somewhat below $\overline{U}$. The symmetry property of the equilibrium list prices illustrates why the inequalities $l_i \lesseqgtr l_j + (\underline{U} - l_i)/(1-\ell)$ and $l_j \lesseqgtr l_i + (\underline{U} - l_j)/(1-\ell)$ need not be considered any further. □

Proof of Proposition 3. Consumer surplus is shown by equation (A.5). It depends on the true qualities u_i, u_j, which are learned after purchasing the products, and on the beliefs B, which determine the equilibrium prices and quantities.

$$CS_B(u_i, u_j) = (a - p^*_{B,i})q^*_i + (a - p^*_{B,j})q^*_j - \frac{b}{2}\left(\frac{{q^*_{B,i}}^2}{u_i^2} + \frac{{q^*_{B,j}}^2}{u_j^2}\right) - \theta b \frac{q^*_{B,i}}{u_i}\frac{q^*_{B,j}}{u_j} \tag{A.5}$$

Quality u_i is assumed to be distributed according to a truncated normal distribution whose density function $f_P(u_i)$ was derived from an (uncensored) normal distribution with mean η and variance σ^2 as is shown by (A.6), where ϕ denotes the probability density function and Φ the cumulative density function of a standard normal distribution with mean 0 and standard deviation 1. The mean η_P and variance σ_P^2 of the truncated distribution $f_P(u_i)$ are given by (A.7) and (A.8).

$$f_P(u_i) = \frac{1}{\sigma}\frac{\phi\left(\frac{u_i - \eta}{\sigma}\right)}{\Phi\left(\frac{\overline{U}-\eta}{\sigma}\right) - \Phi\left(\frac{\underline{U}-\eta}{\sigma}\right)} \tag{A.6}$$

$$\eta_P = \eta + \sigma \cdot \frac{\phi\left(\frac{\underline{U}-\eta}{\sigma}\right) - \phi\left(\frac{\overline{U}-\eta}{\sigma}\right)}{\Phi\left(\frac{\overline{U}-\eta}{\sigma}\right) - \Phi\left(\frac{\underline{U}-\eta}{\sigma}\right)} \tag{A.7}$$

$$\sigma_P^2 = \sigma^2 \cdot \left[1 + \frac{\left(\frac{\underline{U}-\eta}{\sigma}\right) \cdot \phi\left(\frac{\underline{U}-\eta}{\sigma}\right) - \left(\frac{\overline{U}-\eta}{\sigma}\right) \cdot \phi\left(\frac{\overline{U}-\eta}{\sigma}\right)}{\Phi\left(\frac{\overline{U}-\eta}{\sigma}\right) - \Phi\left(\frac{\underline{U}-\eta}{\sigma}\right)} - \left(\frac{\phi\left(\frac{\underline{U}-\eta}{\sigma}\right) - \phi\left(\frac{\overline{U}-\eta}{\sigma}\right)}{\Phi\left(\frac{\overline{U}-\eta}{\sigma}\right) - \Phi\left(\frac{\underline{U}-\eta}{\sigma}\right)} \right)^2 \right] \tag{A.8}$$

To parameterize the model, I assume $a = 1$, $b = 1$, $\theta = 0.5$, $\underline{U} = 1$, $\overline{U} = 10$, $\eta = 4$, and $\sigma = 0.2$.

The panel on the left in Figure 2 shows the representative consumer's surplus $CS_P(u_i, u_j)$ if the she acts according to her prior $f_P(u_i)$. The figure shows that $CS_P(u_i, u_j)$ can be negative if at least one of the qualities u_i, u_j is sufficiently low. In this situation, the customer overestimates quality and purchases too much of the low quality good(s) at an excessive price.

The panel on the right shows consumer surplus $CS_R(u_i, u_j)$ if the consumer updates her beliefs using $f_R(u_i|l_i, l_j)$. Following Proposition 2, consumer surplus is the same as before if $u_{max} < l_P$: Signaling u_{max} would result in $\pi^*_{R,i}(u_{max}, u_{max}) < \pi^*_{R,i}(l_P, l_P)$ so that the manufacturers rather signal l_P instead of u_{max}. For $u_{max} \geq l_P$ the manufacturers signal u_{max}. Consumer surplus $CS_R(u_i, u_j)$ is above $CS_P(u_i, u_j)$ if the qualities are sufficiently symmetric. Yet, one finds $CS_R(u_i, u_j) < CS_P(u_i, u_j)$ if the qualities are sufficiently asymmetric so that the positive effect of learning $\max(u_i, u_j)$ is overcompensated by the lower-quality firm exaggerating the quality of its product.

Figure 3 summarizes these effects by showing the change in consumer surplus $\Delta CS(u_i, u_j)$ as was defined in (16). One finds $E(\Delta CS) > 0$ if the variance of $f_P(U)$ is sufficiently low, which means that high probabilities are assigned to the rather symmetric combinations of u_i and u_j causing $\Delta CS(u_i, u_j) > 0$, while only small probabilities are assigned to the fairly asymmetric combinations of u_i and u_j that cause $\Delta CS(u_i, u_j) < 0$. This is shown by Figure 4.

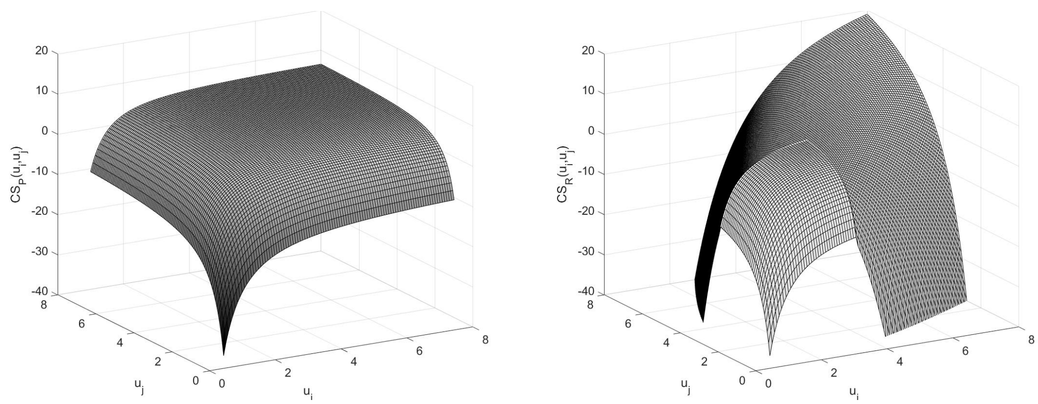

Figure 2: $CS_P(u_i, u_j)$ (left) and $CS_R(u_i, u_j)$ (right)

Figure 4 shows that $E(\Delta CS)$ is not monotonically decreasing in σ_P. The expected change in consumer surplus initially rises in σ_P before starting to fall because of the mechanisms described above. To explain this initial increase, consider that for low values of the standard deviation, the qualities u_i and u_j are distributed quite narrowly around their expected value so that building expectations according to the prior $f_P(u_i)$

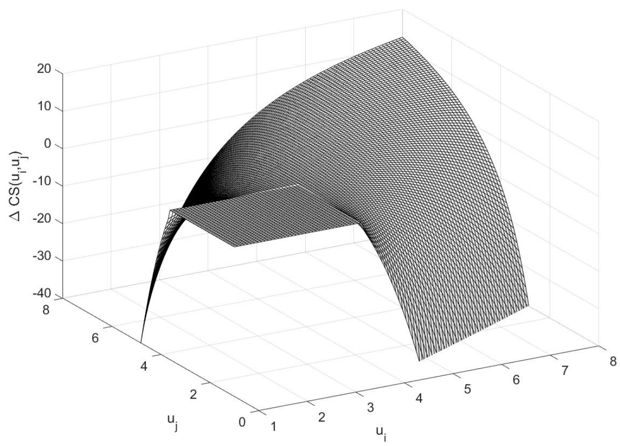

Figure 3: Change in consumer surplus $\Delta CS(u_i, u_j)$

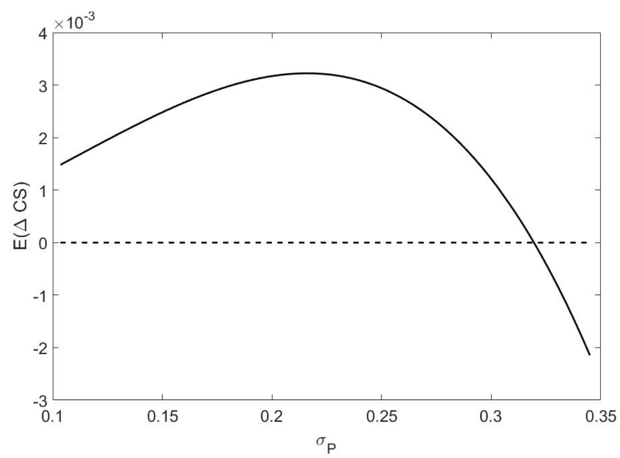

Figure 4: $E(\Delta CS)$ as a function of σ_P

approximates the true qualities well. Using the conditional distribution $f_R(u_i|l_i, l_j)$ thus generates an increase in expected consumer surplus especially for more intermediate values of the standard deviation σ_P. Yet, for σ_P sufficiently large, the prevalence of asymmetric qualities, and thus the negative effect of the lower-quality firm overstating its product's quality overtakes this positive effect until $E(\Delta CS)$, eventually, becomes negative. $\square$

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