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Competition with List Prices

Marco Haan[*] Pim Heijnen[†] Martin Obradovits[‡]

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Abstract

This paper studies the competitive role of list prices. We argue that such prices are often more salient than actual retail prices, so consumers' purchase decisions may be influenced by them. Two firms compete by setting prices in a homogeneous product market. They first set a list price that serves as an upper bound on their retail price. Then, after having observed each other's list price, they set retail prices. Building on the canonical Varian (1980) model, we assume that some consumers observe no prices, some observe all prices, and some only observe list prices. We show that if the latter partially informed consumers use a simple rule of thumb, the use of list prices leads to lower retail prices on average. This effect is weakened if partially informed consumers are rational.

JEL-codes: C72, L13
Keywords: list prices, recommended retail prices, price competition, price dispersion, advertising

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1 Introduction

In many consumer markets, retail prices in stores are frequently lower than the prices that are widely advertised. For example, manufacturers may quote a list price or suggested retail price, but it is hardly a secret that actual retail prices are often much lower.[1] In the Dutch retail gasoline market, majors operate numerous outlets that all charge different prices, but use a recommended retail price that is widely publicized.[2] Consumers know that they will never face a retail price that is higher than the recommended retail price of the brand they visit. In many cases, the price will be significantly lower. Another example is the widespread use of minimum advertised prices (MAP; see Asker and Bar-Isaac (2020) for an extensive discussion). Here, manufacturers set a floor on the price that retailers can advertise. However, this floor does not apply to the actual price retailers can charge: consumers regularly receive in-store discounts. Also there, advertised prices are thus often higher than the prices consumers end up paying. For ease of exposition, we will refer to list prices in the remainder of this paper.

Arguably, list prices are more salient to some consumers than actual retail prices, in particular, when only the former are advertised. The aim of this study is to analyze their pricing implications and welfare effects in a stylized model. In our model, two firms sell a homogeneous product and compete in prices. They play a two-stage game. In the first stage, they simultaneously and independently set list prices. In the second stage, after having observed each other's list price, they simultaneously and independently set retail prices. We build on the seminal Varian (1980) framework, where consumers are either informed or uninformed about retail prices. Informed consumers purchase from the cheapest firm, while uninformed consumers pick a firm at random. We introduce a third type: *partially informed* consumers that are uninformed about retail prices, but *are* informed about list prices, simply because these are more salient.

[1] Indeed, Merriam-Webster defines a list price as "the basic price of an item as published in a catalog, price list, or advertisement before any discounts are taken" (see `https://www.merriam-webster.com/dictionary/list%20price`).

[2] See e.g. `http://www.nu.nl/brandstof`.

Crucially, we assume that list prices constitute an upper bound on the retail prices that can actually be chosen. There can be many reasons for this. Firms may fear reputational losses when surprising consumers with a retail price that exceeds their announced list price, resulting in a drastic decrease of future sales. In many countries, there are laws that prohibit firms from engaging in such misleading advertising.[3] Also, some consumers may outright reject a retail price higher than the list price due to loss aversion, anger, or other behavioral reasons, rendering the practice unprofitable.[4] Although the use of list prices restricts firms' ability to set high retail prices, the struggle to attract partially informed consumers may still lead firms to use them, and has non-trivial implications on their pricing and profits.

In our baseline analysis, we assume that partially informed consumers are myopic and simply go to the firm with the lower list price. For some combinations of list prices, however, this implies that they end up visiting the firm with the *higher* expected retail price. We therefore also consider the case in which the partially informed are rational. Whenever their myopic counterparts end up visiting the firm with the higher expected retail price, these consumers then randomize which firm to visit such that firms' expected retail prices are equalized.

Our main results are as follows. In the myopic case, the equilibrium has firms playing mixed strategies when setting list prices: the equilibrium distribution does not contain any atoms or gaps and extends up to consumers' willingness to pay. It is hard to explicitly characterize this distribution, though we can provide a semi-analytic solution when the share of informed consumers is sufficiently large. In all other cases, the equilibrium can be approximated numerically. Firms always use *effective* list prices, i.e. list prices that are lower than consumers' willingness to pay. Firms essentially face a prisoners' dilemma: each firm has an individual incentive to use list prices, yet when both do, their expected profits are lower. When discounts are given, the firm with the higher list price offers the most frequent and deepest discounts. When firms' list prices are sufficiently close to each

[3]See e.g. Rhodes and Wilson (2018) for a discussion of false-advertising regulations in the US and the European Union.

[4]See Bruttel (2018) for experimental evidence that demand tends to drop sharply for prices that exceed a recommended price, even if the latter has no informational content.

other, the firm with the higher list price even sets a lower retail price on average. There are often search externalities in the sense that having better informed consumers leads to lower average prices for all. This is the case when uninformed consumers become either partially or fully informed. When partially informed consumers become fully informed, the effect is ambiguous.

In the case where partially informed consumers are rational, we find that firms will not use effective list prices if there are sufficiently many informed consumers. Otherwise, list prices are again chosen via mixed strategies. Technically, the lack of a pure strategy equilibrium in list prices is no longer caused by the profit function being discontinuous, but rather by it failing to be quasi-concave. We show numerically that the equilibrium distribution of list prices may involve multiple mass points and gaps, depending on parameter values. Interestingly, compared to the myopic case, average prices are now higher and firms benefit. In the terminology of Armstrong (2015), we thus have a *ripoff externality* when consumers become more strategically savvy and better understand the game being played.

Overall, we have a two-stage game where firms often set both list prices and subsequently discounted retail prices via mixed strategies. To our knowledge, with the exception of Obradovits (2014) that studies a specific temporal price regulation in a two-period setting, our model is the first to have this feature. Also, in the case of rational consumers, the equilibrium choice of list prices is influenced by the behavior of consumers, as in some pricing subgames part of them strategically choose which firm to visit based on their expectations of actual retail prices. This is also novel.

A small but growing theoretical literature examines competition with list prices that serve as upper bounds on retail prices. Most closely related to our work, Myatt and Ronayne (2019) also consider a two-stage modification of Varian (1980) where firms sequentially set binding list prices and possibly discounted retail prices. Contrary to our setting, their model has no partially informed consumers, so firms cannot use list prices to steer consumers. Their focus is instead on asymmetric pure strategy equilibria that exhibit "stable price dispersion". In equilibrium, firms do not use discounts off list prices.

Gill and Thanassoulis (2016) analyze a two-stage game of list price and stochastic discount competition in an otherwise standard Hotelling duopoly. A share of consumers, called “price takers”, can only purchase at firms’ posted list prices. The remaining share of “bargainers” additionally have a positive probability to obtain an endogenously determined discount.[5] Contrary to our results, the authors find that firms’ ability to stochastically provide discounts increases prices and profits and reduces consumer surplus. This is because competition is softened due to a strategic complementarity between list prices and discount prices.

Díaz et al. (2009), similar in spirit to Myatt and Ronayne (2019), also show that the use of list prices enables pure strategy equilibria in market environments where these otherwise do not exist. However, Díaz et al. do so in the context of Bertrand-Edgeworth competition with capacity constraints. Like Gill and Thanassoulis (2016) and different from us, they find that equilibrium profits are higher when list prices can be used. Committing to a low list price relaxes competition in the discounting stage by allowing the rival to act as a monopolist on the residual demand.

In Anderson et al. (2019), firms can offer personalized discounts from publicly set list prices. They show that “captive consumers” (who strongly prefer some product) receive no discounts and buy their favorite product at the list price, while “contested consumers” receive poaching and retention offers from their top two firms. The discounting stage yields a mixed strategy equilibrium, similar to our model. Yet, different from what we find, there is a pure strategy equilibrium in list prices. The total effect on prices and profits is ambiguous.

Other papers that have binding list prices and possibly lower promotional prices include the following. In Rao (1991), a national brand and a private label first set list prices, then choose the depth of discounts and finally their frequency. In Chen and Rosenthal (1996a,b), firms use a binding ask price as a commitment device to convince potential buyers to further inspect their product. In Banks and Moorthy (1999), firms set regular and promotional prices to price discriminate between consumers with high and low search costs.

[5] This probability is interpreted as bargainers’ success rate of securing discounts, either via direct bargaining or by accessing discount coupons.

There is also a small literature on non-binding recommended or suggested retail prices, where the list (or recommended) price does not serve as an upper bound on retail prices. Some of this work focuses on vertical relations. Buehler and Gärtner (2013) argue that manufacturers are better informed about demand uncertainty and use recommended prices to convey this information to retailers. The explanation in Lubensky (2017) is similar, but there it is consumers rather than firms who are informed about aggregate market conditions. Harrington and Ye (2019) show that intermediate goods producers may collude on high list prices to signal high costs to prospective buyers, thereby weakening their bargaining. Relatedly, Boshoff et al. (2018) point out that non-binding advance price announcements can help sellers achieve higher collusive profits by reducing asymmetric information regarding costs and demand. A variety of other theories are discussed in Boshoff and Paha (2017); see also Andreu et al. (2020).

Our paper further relates to the behavioral industrial organization literature, where firms try to exploit boundedly rational consumers. Puppe and Rosenkranz (2011) note that firms may benefit from recommended prices if consumers are loss averse. In Heidhues and Kőszegi (2014), firms may set a high list price for an extended period, which establishes a high reference price. This boosts demand during a short period of sales, which can increase profits compared to maintaining a constant price level. Paha (2019) exemplifies the profitability of list price collusion in a market with loss-averse consumers whose willingness to pay is anchored to list prices.

Lastly, our framework shares some characteristics with an earlier literature on competitive couponing (Shaffer and Zhang, 1995; Bester and Petrakis, 1996). There, firms set regular prices, but can additionally send out coupons that grant discounted prices to a subset of consumers. In our model, such price discrimination is not available to firms.

The remainder of this paper is organized as follows. In Section 2, we introduce the model. Section 3 analyzes the baseline game with myopic partially informed consumers. In Section 4, we explore the alternative setting where partially informed consumers are rational, and compare results to the baseline scenario. Concluding remarks are provided in Section 5. Several technical proofs are relegated to Appendix A. In Appendix B, we outline our numerical procedure to approximate the equilibrium choice of list prices (and the corresponding equilibrium profits) for the case of myopic partially informed consumers.

2 The game

We consider a market with two risk-neutral, profit-maximizing firms that sell a homogeneous good and compete in prices. For simplicity and without loss of generality, their constant marginal costs of production are normalized to zero. A unit mass of consumers have unit demand and a common willingness to pay that is normalized to one. The following events unfold. First, each firm simultaneously and unilaterally chooses its list price P_i. Second, after having observed all list prices, each firm decides on the retail price p_i that it charges in its store. Reflecting the discussion in the introduction, we impose that a firm's retail price cannot exceed its list price, so $p_i \leq P_i$. Third, consumers make their purchase decisions.

There are three types of consumers. A fraction $1-\lambda-\mu$ is uninformed. These consumers pick a firm at random and buy there, provided that the firm's retail price does not exceed their willingness to pay. A fraction λ is fully informed. These consumers observe all retail prices and buy from the cheapest firm. Hence, these two types of consumers correspond to the uninformed and informed consumers in the classic Varian (1980) model. However, we also assume that a fraction μ of consumers is *partially informed*. These consumers only observe list prices, pick a firm based on that information and buy there, again provided that the retail price does not exceed their willingness to pay. Throughout, we assume that all consumer types have strictly positive measure, so $\lambda > 0$, $\mu > 0$ and $\lambda + \mu < 1$.

We study two scenarios. First, in Section 3, we assume that the partially informed consumers use a simple rule of thumb and go to the firm with the lowest list price. As it turns out, this is however not always the optimal thing to do: in some pricing subgames, the equilibrium then has the firm with the lower list price charging a higher retail price on average. We therefore refer to the partially informed as being myopic in this scenario. In Section 4, we instead modify the analysis by stipulating that the partially informed consumers are rational, such that they do not visit a firm with a higher expected retail price.

3 The case of myopic partially informed consumers

In this section, we analyze the setting where the partially informed consumers are myopic and always visit the firm with the lowest list price. We solve the corresponding game via backward induction. First, in Subsection 3.1, we determine the equilibrium of all possible pricing subgames (stage 2). Then, in Subsection 3.2, we characterize firms' equilibrium choice of list prices (stage 1). Welfare implications are discussed in Subsection 3.3.

3.1 Equilibrium in the pricing subgames

We start by solving stage 2 of the game with myopic partially informed consumers. Given any two list prices P_1 and P_2 that were set in stage 1, we derive the equilibrium in retail prices in the resulting subgames.

Preliminaries. We label the firm with the lower list price in stage 1 as L, and its list price as P_L. The other firm is denoted by H, and its list price by P_H. Define the ratio of list prices as R, i.e.,

$$R \equiv \frac{P_H}{P_L}. \tag{1}$$

By construction, $R \geq 1$. In case $R = 1$, such that $P_L = P_H = P$, the subgame collapses to the standard Varian (1980) model.[6] In the remainder, we thus focus on $R > 1$.

[6]In this case, λ consumers go to the cheapest firm while the remaining $1-\lambda$ pick one firm at random. In equilibrium, both firms set a retail price that is drawn from a probability distribution with cumulative density $F(p)$ on some interval $[\underline{p}, \overline{p}]$. Firm 1's expected profit from charging a price $p \in [\underline{p}, \bar{p}]$ is

$$\pi(p) = \left(\frac{1-\lambda}{2} + \lambda(1 - F(p))\right) p,$$

as it sells to $\frac{1-\lambda}{2}$ uninformed consumers for sure, and the λ informed consumers if its price is lower than its competitor's, which has probability $1 - F(p)$. With the usual arguments, $F(p)$ has no mass points and $\overline{p} = P$. Hence, equilibrium requires that all prices in the support of F yield $\pi^* = \pi(\overline{p}) = \frac{1-\lambda}{2}P$. From the above equation, this implies

$$F(p) = \frac{1 + \lambda - (1-\lambda)P/p}{2\lambda},$$

In this scenario, firm H will definitely attract its share of the $1-\lambda-\mu$ uninformed consumers who pick a firm at random. The share of consumers that is "captive" to firm H can thus be denoted by

$$\alpha_H \equiv \frac{1-\lambda-\mu}{2}. \tag{2}$$

Firm L not only attracts its share of the uninformed for sure, but also the μ partially informed. Hence, its share of captive consumers is given by

$$\alpha_L \equiv \frac{1-\lambda-\mu}{2} + \mu = \frac{1-\lambda+\mu}{2}. \tag{3}$$

The remaining mass $\lambda = 1-\alpha_H-\alpha_L$ of fully informed consumers buys from the firm charging the lowest retail price. Essentially, our subgame analysis is thus a combination of Narasimhan (1988), where firms differ in their number of captive consumers, and Obradovits (2014), where (in the second stage of his model) firms face different upper bounds on the prices they can charge.

Equilibrium characterization. Note first that for firm H, any price $p_H \in (P_L, P_H)$ is strictly dominated by $p_H = P_H$: with $p_L \leq P_L$, firm H cannot possibly attract the fully informed consumers by setting $p_H \in (P_L, P_H)$. Hence, it is better off setting $p_H = P_H$, which attracts its captive consumers anyway. By doing so, H can secure a profit of $\underline{\pi}_H \equiv \alpha_H P_H$. This also implies that H will never charge a price p_H such that $(\alpha_H+\lambda)p_H = (1-\alpha_L)p_H < \underline{\pi}_H$: doing so yields strictly lower profits than setting $p_H = P_H$ even if it attracts the λ informed for sure. Solving for p_H, this implies that in equilibrium, H never sets a price

$$p_H < \underline{p}_H \equiv \frac{\alpha_H}{1-\alpha_L} P_H. \tag{4}$$

With an identical argument, in equilibrium firm L will never set

$$p_L < \underline{p}_L \equiv \frac{\alpha_L}{1-\alpha_H} P_L. \tag{5}$$

We have three possible cases to consider: the case that $\underline{p}_H < \underline{p}_L$, the case that $\underline{p}_L < \underline{p}_H < P_L$, and the case that $\underline{p}_H \geq P_L$. Below, we sketch the derivation of the equilibrium for each of these cases. Details are in the proofs of the respective lemmas.

with support $\left[\frac{1-\lambda}{1+\lambda}P, P\right]$.

Consider first the case that $\underline{p}_H \geq P_L$. From (4) this is true if and only if

$$R \geq R_1 \equiv \frac{1-\alpha_L}{\alpha_H}. \tag{6}$$

From (4), firm H never finds it worthwhile to price below $\underline{p}_H$. As $\underline{p}_H \geq P_L$, this implies that firm H is not willing to compete with firm L and will simply set $p_H^* = P_H$. The best response for L is then to charge $p_L^* = P_L$. Hence we have:

Lemma 1. *If $R \geq R_1$, the pricing subgame has a unique pure strategy equilibrium with $p_H^* = P_H$ and $p_L^* = P_L$. Equilibrium profits are $\pi_H = \alpha_H P_H$ and $\pi_L = (1-\alpha_H)P_L$.*

Consider next the situation where $\underline{p}_H < \underline{p}_L$. This is the case if and only if

$$R < R_0 \equiv \frac{\alpha_L}{1-\alpha_H} \cdot \frac{1-\alpha_L}{\alpha_H}. \tag{7}$$

In this case, firm H can guarantee to capture the informed by slightly undercutting $\underline{p}_L$. This yields a profit of $\pi_H(\underline{p}_L) = \underline{p}_L(\alpha_H + \lambda) = \underline{p}_L(1-\alpha_L)$. Using the definition of $\underline{p}_L$, we immediately have that $\pi_H(\underline{p}_L) > \alpha_H P_H = \pi_H(P_H)$. As $p_H = P_H$ strictly dominates any $p_H \in (P_L, P_H)$, this implies that in equilibrium firm H will never set $p_H > P_L$. Hence both firms choose prices weakly below P_L. An equilibrium in pure strategies now fails to exist. By arguments similar to those in Narasimhan (1988), the unique equilibrium has firms sampling prices from the same convex support $[\underline{p}, \overline{p}] = [\underline{p}_L, P_L]$. Suppose that neither firm had a mass point. If H set $p_H = P_L$, its profits would then be $\alpha_H P_L < \alpha_H P_H$. Hence, in equilibrium, firm L must have a mass point at P_L. It is now straightforward to derive:

Lemma 2. *If $R \leq R_0$, the pricing subgame has the following unique mixed strategy equilibrium. Firm H draws its price from the CDF*

$$F_H(p) = 1 - \frac{\alpha_L\left(\frac{P_L}{p} - 1\right)}{1-\alpha_L-\alpha_H}$$

with support $\left[\frac{\alpha_L}{1-\alpha_H}P_L, P_L\right)$. Firm L sets $p_L = P_L$ with probability

$$\sigma_L = \frac{\alpha_L - \alpha_H}{1-\alpha_H},$$

and with probability $1-\sigma_L$, it draws its price from $F_H(p)$. Expected profits are

$$\pi_H = \frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}P_L \qquad \text{and} \qquad \pi_L = \alpha_L P_L.$$

Proof. See Appendix A. ■

Finally, consider intermediate values of $\underline{p}_H$ such that $\underline{p}_H \in (\underline{p}_L, P_L)$, hence $R \in (R_0, R_1)$. As now $\underline{p}_H > \underline{p}_L$, firm L can guarantee to capture the informed consumers by marginally undercutting $\underline{p}_H$. Doing so yields $\pi_L(\underline{p}_H) = \underline{p}_H(\alpha_L + \lambda) = \underline{p}_H(1 - \alpha_H) > \alpha_L P_L$. It makes no sense for L to charge a lower price while it cannot charge a price higher than P_L. A candidate for the equilibrium thus has both firms mixing on the interval $[\underline{p}_H, P_L]$. Suppose firm H did not put any probability mass above this range. Then, when charging P_L, firm L would earn $\alpha_L P_L$, which however falls strictly short of its profit when setting $\underline{p}_H$. Hence, considering that firm H finds it strictly dominated to price in (P_L, P_H), H must have a mass point at P_H. With the same argument as in the previous case, we also need that firm L has a mass point at P_L. Precisely, we obtain:

Lemma 3. *If $R \in (R_0, R_1)$, the pricing subgame has the following unique mixed strategy equilibrium. Firm H sets $p_H = P_H$ with probability*

$$\sigma_H = \frac{(1-\alpha_H)\alpha_H R}{(1-\alpha_H-\alpha_L)(1-\alpha_L)} - \frac{\alpha_L}{1-\alpha_H-\alpha_L}$$

and with probability $1 - \sigma_H$ it draws its price from the CDF

$$F_H(p) = \frac{1 - \alpha_L - \alpha_H \left(\frac{P_H}{p}\right)}{1 - \alpha_L - \alpha_H R}$$

with support $\left[\frac{\alpha_H}{1-\alpha_L} P_H, P_L\right)$. Firm L sets $p_L = P_L$ with probability

$$\sigma_L = \frac{\alpha_H (R-1)}{1-\alpha_H-\alpha_L}$$

and with probability $1 - \sigma_L$ it draws its price from $F_H(p)$. Expected profits are

$$\pi_H = \alpha_H P_H \qquad \text{and} \qquad \pi_L = \frac{(1-\alpha_H)\alpha_H}{1-\alpha_L} P_H.$$

Proof. See Appendix A. ■

Summing up, we find the following:

Proposition 1. *Suppose that the list prices are P_L and P_H, with $0 < P_L < P_H \leq 1$. The equilibrium of stage 2 is then as follows. Firm $i \in \{L, H\}$ sets a retail price P_i with probability σ_i and otherwise draws its price from some distribution $F(p)$ with support $[\underline{p}, P_L)$, where σ_L, σ_H, $F(p)$, $\underline{p}$, and firms' equilibrium profits π_L and π_H are given by:*

Case for	A $R \leq R_0$	B $R \in (R_0, R_1)$	C $R \geq R_1$
σ_L	$\frac{\alpha_L - \alpha_H}{1-\alpha_H}$	$\frac{\alpha_H(R-1)}{1-\alpha_H-\alpha_L}$	1
σ_H	0	$\frac{(1-\alpha_H)\alpha_H R-(1-\alpha_L)\alpha_L}{(1-\alpha_L)(1-\alpha_H-\alpha_L)}$	1
$F(p)$	$\frac{1-\alpha_H-\alpha_L P_L/p}{1-\alpha_H-\alpha_L}$	$\frac{1-\alpha_L-\alpha_H P_H/p}{1-\alpha_L-\alpha_H R}$	
$\underline{p}$	$\frac{\alpha_L}{1-\alpha_H} P_L$	$\frac{\alpha_H}{1-\alpha_L} P_H$	
π_L	$\alpha_L P_L$	$\frac{(1-\alpha_H)\alpha_H}{1-\alpha_L} P_H$	$(1-\alpha_H)P_L$
π_H	$\frac{(1-\alpha_L)\alpha_L}{1-\alpha_H} P_L$	$\alpha_H P_H$	$\alpha_H P_H$

with $R = P_H/P_L$; $R_0 = \frac{\alpha_L(1-\alpha_L)}{\alpha_H(1-\alpha_H)}$; $R_1 = \frac{1-\alpha_L}{\alpha_H}$; $\alpha_L = \frac{1-\lambda+\mu}{2}$; $\alpha_H = \frac{1-\lambda-\mu}{2}$.

Properties of the stage 2 equilibrium. The results we derived above already allow us to pin down some interesting implications concerning the frequency and depth of discounts that firms give vis-à-vis their list price.

Result 1. *The minimal discount that firm H offers is $P_H - P_L$.*

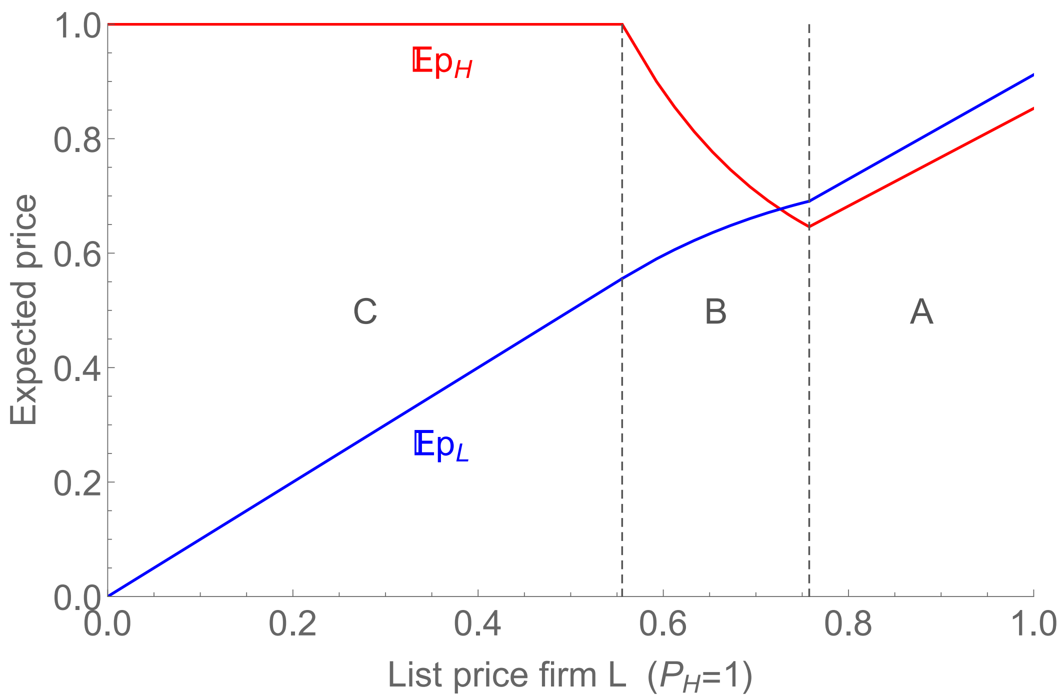
When H, the firm with the higher list price, uses a discount, it will always do so by undercutting the lower list price. This is straightforward. The other firm cannot price above its list price. Hence, H can only possibly attract the fully informed consumers by setting a retail price lower than its rival's list price. Offering any smaller discount would certainly be ineffective.

Result 2. *In cases A and B, firm H is more likely to offer a discount than firm L: $\sigma_H < \sigma_L$.*[7] *In case A, it always offers one.*

[7] In case B, note that $\sigma_H < \sigma_L$ reduces to $R < \frac{1-\alpha_L}{\alpha_H} = R_1$, which is true in the considered case.

Unless we are in case C (where H does not have an incentive to compete for the informed), H is always more likely to offer a discount than L. The latter has more captive consumers and therefore less of an incentive to try to attract the informed consumers. For P_L sufficiently close to P_H, firm L therefore charges a higher price on average. In such a case, the partially informed consumers would be better off buying from firm H instead. Figure 1 illustrates this result for a specific parameter combination. There, it may be observed that the expected retail price of firm L exceeds that of firm H whenever $R = P_H/P_L > R^*$, with R^* falling in the range (R_0, R_1).

Figure 1: Expected retail prices as a function of P_L, with $P_H = 1$.



Expected retail price of firm L (blue line) and H (red line) as a function of P_L ($P_H = 1$, $\lambda = 0.2$, $\mu = 0.3$, dashed lines indicate boundaries between the cases in Proposition 1.

Indeed, we can show that this is always true:

Proposition 2. *There is a unique $R^* \in (R_0, R_1)$ such that the expected retail price of firm H is lower than that of firm L if and only if $R < R^*$.*

Proof. For high R we are in case C where $p_L^* < p_H^*$. For low R we are in case A where $\sigma_H = 0$ and $\sigma_L > 0$ which implies $\mathbb{E}p_L > \mathbb{E}p_H$. For case B we can show that $\mathbb{E}p_L$ strictly increases in P_L, while $\mathbb{E}p_H$ strictly decreases in P_L. By continuity of $\mathbb{E}p_L$ and $\mathbb{E}p_H$, this implies that there must be a unique $P_L \in (P_H/R_1, P_H/R_0)$ where $\mathbb{E}p_L = \mathbb{E}p_H$, which establishes the result. Precisely, from Proposition 1, in case B we have that

$$\begin{aligned} \mathbb{E}p_L &= \sigma_L P_L + (1-\sigma_L)\int_{\underline{p}}^{P_L} p dF(p) \\ &= \frac{\alpha_H}{1-\alpha_L-\alpha_H}\left[P_H - P_L + P_H \log\left(\frac{1-\alpha_L}{\alpha_H}\frac{P_L}{P_H}\right)\right], \end{aligned} \tag{8}$$

while

$$\begin{aligned} \mathbb{E}p_H &= \sigma_H P_H + (1-\sigma_H)\int_{\underline{p}}^{P_L} p dF(p) \\ &= \frac{P_H\left[\alpha_H(1-\alpha_H)P_H/P_L - \alpha_L(1-\alpha_L) + (1-\alpha_H)\alpha_H \log\left(\frac{1-\alpha_L}{\alpha_H}\frac{P_L}{P_H}\right)\right]}{(1-\alpha_L)(1-\alpha_L-\alpha_H)}. \end{aligned} \tag{9}$$

Hence

$$\frac{d\mathbb{E}p_L}{dP_L} = \frac{\alpha_H}{1-\alpha_L-\alpha_H}(P_H/P_L - 1) > 0,$$

and

$$\frac{d\mathbb{E}p_H}{dP_L} = -\frac{P_H}{P_L}\left[\frac{\alpha_H(1-\alpha_H)}{(1-\alpha_L)(1-\alpha_L-\alpha_H)}\right](P_H/P_L - 1) < 0.$$

■

We have thus established that for all combinations of list prices such that $R < R^*$, the partially informed consumers go against their best interest when following the simple rule of thumb and unequivocally frequenting the firm with the lower list price. In Section 4, we will study the equilibrium when the partially informed consumers are instead rational and optimally use their available information. In the next two subsections, we first continue the analysis for the case of myopic partially informed consumers.

3.2 Equilibrium choice of list prices

We now solve for firms' equilibrium first period actions when the partially informed consumers are myopic. First, it is straightforward to show:

Lemma 4. *Suppose that the partially informed consumers are myopic. Then there is no pure strategy equilibrium in the first stage.*

Proof. Note first that no asymmetric pure strategy equilibrium exists: firm L's subgame equilibrium profit is always weakly increasing in P_L, and strictly so for P_L sufficiently close below P_H such that $R \leq R_0$ (compare with Proposition 1). Hence, any putative equilibrium with $P_L^* < P_H^* \leq 1$ fails to exist as firm L has an incentive to set its list price closer to P_H^*. Suppose now that both firms set $P^* > 0$ in a symmetric pure strategy equilibrium. Each then attracts half of the partially informed consumers and obtains an expected profit of $\pi^* = \frac{1-\lambda}{2} P^*$ (compare with Footnote 6). Suppose one firm defects by slightly undercutting P^*. It then ends up as firm L in Case A of Proposition 1, so it can achieve a deviation profit arbitrarily close to $\alpha_L P^* = \frac{1-\lambda+\mu}{2} P^* > \pi^*$, rendering the deviation profitable. But $P^* = 0$ cannot be a symmetric equilibrium either, as each firm can guarantee a positive profit by setting a positive list price. ■

We refer to list prices as being *effective* if they are strictly lower than the consumers' willingness to pay. If that is not the case, they don't have any bite. We now have:

Theorem 1. *If the partially informed consumers are myopic, then in equilibrium, effective list prices are used.*

This follows directly from Lemma 4. Next, we can provide a more detailed characterization of the equilibrium choice of list prices as follows:

Proposition 3. *Suppose that the partially informed consumers are myopic. Any symmetric equilibrium then has firms sampling their list prices from a non-degenerate and atomless CDF $G(P)$ with convex support $[\underline{P}, 1]$, where $\underline{P} \in \left[\frac{\alpha_H}{1-\alpha_H}, \frac{1}{R_0}\right)$.*

Proof. See Appendix A. ■

The proposition follows from fairly standard arguments. $G(P)$ cannot have mass points as slightly undercutting those would increase profits by avoiding ties. Also, $G(P)$ cannot have a gap on some interval (a, b) as setting $P = b$ would yield a higher expected profit than setting $P = a$. For the upper bound of the support of $G(P)$, we need $\overline{P} = 1$: otherwise, defecting to some $P \in (\bar{P}, 1]$ would be profitable. No list price $P < \frac{\alpha_H}{1-\alpha_H}$ will be set, as these are strictly dominated. Finally, with $\overline{P} = 1$, we cannot have $\underline{P} \geq \frac{1}{R_0}$ (that is, $\overline{P}/\underline{P} \leq R_0$): otherwise, setting $\underline{P}$ would yield a higher profit than any other list price in $(\underline{P}, \overline{P}]$.

A firm's profit when setting some $P \in [\underline{P}, 1]$ now depends on whether this list price is higher or lower than that of the competitor and whether case A, B or C of Proposition 1 applies. Using the profit expressions in this proposition, the expected profit equals

$$\Pi(P) = G(P/R_0)\alpha_H P + \frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}\int_{P/R_0}^{P} sg(s)ds + [G(PR_0) - G(P)]\alpha_L P + \frac{(1-\alpha_H)\alpha_H}{1-\alpha_L}\int_{PR_0}^{PR_1} sg(s)ds + [1 - G(PR_1)](1-\alpha_H)P. \quad (10)$$

For an equilibrium, we need that this expression is constant for all $P \in [\underline{P}, 1]$ and weakly lower for all $P < \underline{P}$. Note that latter is certainly satisfied, as for all $P_i < \underline{P}$, the subgame equilibrium profit $\pi_i(P_i, P_j) = \pi_L(P_i, P_j)$ is weakly increasing in P_i, irrespective of the choice of P_j (compare with Proposition 1). Taking the derivative of (10) with respect to P, it is thus necessary and sufficient that

$$\begin{aligned}\Pi'(P) = \quad & G\left(\frac{P}{R_0}\right)\alpha_H + g\left(\frac{P}{R_0}\right)\alpha_H\frac{P}{R_0} - \frac{1}{R_0}\frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}\frac{P}{R_0}g\left(\frac{P}{R_0}\right) + \frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}Pg(P) \\ & +[G(PR_0) - G(P)]\alpha_L + [R_0 g(PR_0) - g(P)]\alpha_L P \\ & -R_0\frac{(1-\alpha_H)\alpha_H}{1-\alpha_L}PR_0 g(PR_0) + R_1\frac{(1-\alpha_H)\alpha_H}{1-\alpha_L}PR_1 g(PR_1) \\ & +[1 - G(PR_1)](1-\alpha_H) - R_1 g(PR_1)(1-\alpha_H)P = 0\end{aligned}$$

for all $P \in [\underline{P}, 1]$. Collecting terms and simplifying, it is thus an equilibrium if for all $P \in [\underline{P}, 1]$ it holds that

$$G\left(\frac{P}{R_0}\right)\alpha_H - \frac{\alpha_L(\alpha_L - \alpha_H)}{1-\alpha_H}Pg(P) + [G(PR_0) - G(P)]\alpha_L + [1 - G(PR_1)](1-\alpha_H) = 0. \quad (11)$$

We thus have to solve a *functional differential equation*, as $g(P)$ depends on $G(P/R_0)$, $G(P)$, $G(PR_0)$ and $G(PR_1)$. In general, this leads $G(P)$ to be piecewise-defined, which makes solving the entire system complicated.

That notwithstanding, we can characterize the solution in case $\underline{P}R_1 \geq 1$ (so case C never occurs in any pricing subgame) and $\underline{P} > 1/R_0^2$. This covers a relatively large part of the parameter space, as we will show below. If these conditions are satisfied, we may proceed as follows. First, we partition the support into three intervals: $\mathcal{I}_1 = [\underline{P}, 1/R_0)$, $\mathcal{I}_2 = [1/R_0, \underline{P}R_0)$ and $\mathcal{I}_3 = [\underline{P}R_0, 1]$. Since we assume that $\underline{P} > 1/R_0^2$, these are non-empty. Denote the distribution function in partition $i \in \{1, 2, 3\}$ by G_i. Using Proposition 3, we must have that $G_1(\underline{P}) = 0$, $G_1(1/R_0) = G_2(1/R_0)$, $G_2(\underline{P}R_0) = G_3(\underline{P}R_0)$, and $G_3(1) = 1$. Note that for prices $P \in \mathcal{I}_1$, we have $PR_0 \in \mathcal{I}_3$ and $P/R_0 < \underline{P}$. Hence, using $\underline{P}R_1 \geq 1$, (11) reduces to

$$G_1(P) + \left(\frac{\alpha_L - \alpha_H}{1 - \alpha_H}\right) P g_1(P) - G_3(PR_0) = 0. \tag{12}$$

For prices $P \in \mathcal{I}_2$, we have $PR_0 > 1$ and $P/R_0 < \underline{P}$. Therefore (11) reduces to

$$1 - G_2(P) - \left(\frac{\alpha_L - \alpha_H}{1 - \alpha_H}\right) P g_2(P) = 0. \tag{13}$$

Finally, for prices $P \in \mathcal{I}_3$, we have $PR_0 > 1$ and $P/R_0 \in \mathcal{I}_1$, so (11) reduces to

$$1 - G_3(P) - \left(\frac{\alpha_L - \alpha_H}{1 - \alpha_H}\right) P g_3(P) + G_1(P/R_0)\frac{\alpha_H}{\alpha_L} = 0. \tag{14}$$

We can now use (13) to solve for G_2. Next, we can use (14) to derive an expression for G_1 in terms of G_3 and g_3 and (after differentiation) a corresponding expression g_1 in terms of g_3 and g_3'. These we plug into (12). That yields a second order differential equation for G_3 which can be solved analytically. Likewise, we can use (12) to derive an expression for G_3 in terms of G_1 and g_1 and a corresponding expression g_3 in terms of g_1 and g_1', which we plug into (14). That again yields a second order differential equation determining G_1 which can be solved analytically. We obtain the following result:

Proposition 4. *Suppose that the partially informed consumers are myopic. For a subset of the parameter space, the symmetric first-stage equilibrium is as follows. Firms draw their list prices from an atomless CDF $G(p)$ with convex support $[\underline{P}, 1]$, where*

$$G(P) = \begin{cases} a + b_1 w \left(R_0 P\right)^{-\frac{1-w}{k}} - b_2 w \left(R_0 P\right)^{-\frac{1+w}{k}} & \textit{if } P \in \left[\underline{P}, \frac{1}{R_0}\right) \\ 1 - \left[\left(1-a\right)\left(1+w\right) - 2b_1 w\right]\left(R_0 P\right)^{-\frac{1}{k}} & \textit{if } P \in \left[\frac{1}{R_0}, \underline{P}R_0\right) \\ a + b_1 P^{-\frac{1-w}{k}} + b_2 P^{-\frac{1+w}{k}} & \textit{if } P \in \left[\underline{P}R_0, 1\right] \end{cases}$$

with

$$w=\sqrt{\tfrac{\alpha_L}{\alpha_H}};\quad a=\tfrac{\alpha_L}{\alpha_L-\alpha_H};\quad k=\tfrac{\alpha_L-\alpha_H}{1-\alpha_H};$$
$$d=(1-a)\,(1+w)\,R_0^{-\frac{1}{k}};\quad e=2wR_0^{-\frac{1}{k}};$$
$$b_1=\frac{(1-a)\left[1-(\underline{P}R_0)^{-\frac{1+w}{k}}\right]-d(\underline{P}R_0)^{-\frac{1}{k}}}{(\underline{P}R_0)^{-\frac{1-w}{k}}-(\underline{P}R_0)^{-\frac{1+w}{k}}-e(\underline{P}R_0)^{\frac{1}{k}}};\quad b_2=1-a-b_1,$$

and where $\underline{P}$ *solves*

$$a+b_1w\,(R_0\underline{P})^{-\frac{1-w}{k}}-b_2w\,(R_0\underline{P})^{-\frac{1+w}{k}}=0. \tag{15}$$

For this solution to hold, it is sufficient (though not necessary) to have $\lambda \geq 0.38$*.*

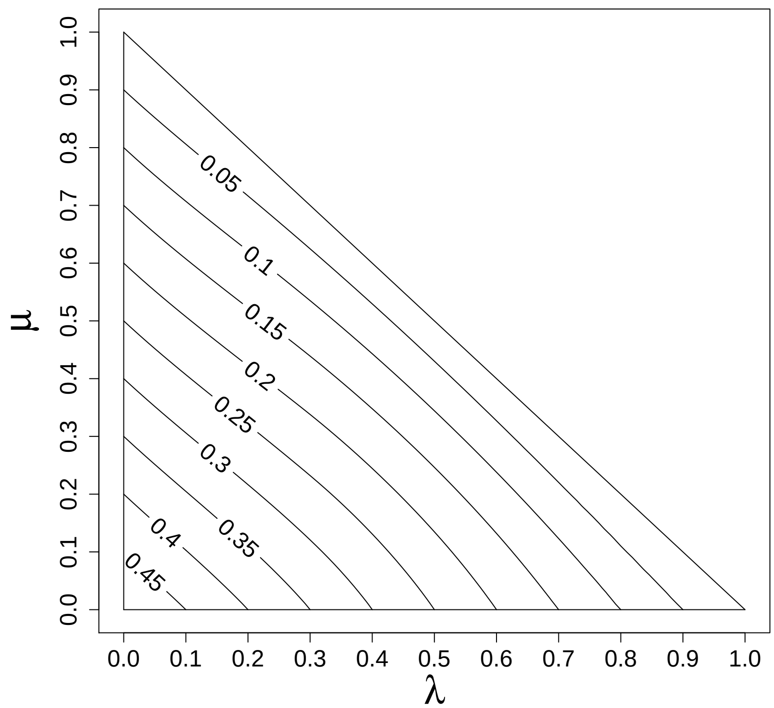
Proof. See Appendix A. ∎

Even in this comparatively simple case, we do not obtain a closed-form solution, as (15) cannot be solved analytically. However, after solving numerically for $\underline{P}$, we can determine $G(P)$ using the proposition. We then have an equilibrium if indeed $\underline{P} \in (1/R_0^2, 1/R_0)$ and $R_1\underline{P} \geq 1$. If that is not the case, an equilibrium of this particular form fails to exist. In Figure 9 in Appendix A, we show numerically for which values of λ and μ this procedure yields an equilibrium. From that analysis, it turns out that it is sufficient to have $\lambda \geq 0.38$. For parameter values not covered by Proposition 4, we use a numerical approximation to find $G(P)$ on a discretized action space. Details to this can be found in Appendix B.

3.3 Welfare effects

We conclude this section by considering the welfare effects of list prices with myopic partially informed consumers. As demand is perfectly inelastic, total welfare is not affected by prices. Hence, we simply have that $CS+2\Pi=1$, where Π denotes the expected equilibrium profit per firm, and CS consumer surplus. In what follows, we focus on the comparative statics effects on profits; the effects on consumer welfare are simply the opposite of that. As an analytical solution fails to exist, we have to solve numerically. Appendix B describes the procedure.

Figure 2: Contour plot of equilibrium profits.



For values $\lambda \in \{0, 0.01, \ldots, 0.98\}$, $\mu \in \{0, 0.01, \ldots, 0.98\}$, $\lambda + \mu \leq 0.98$.

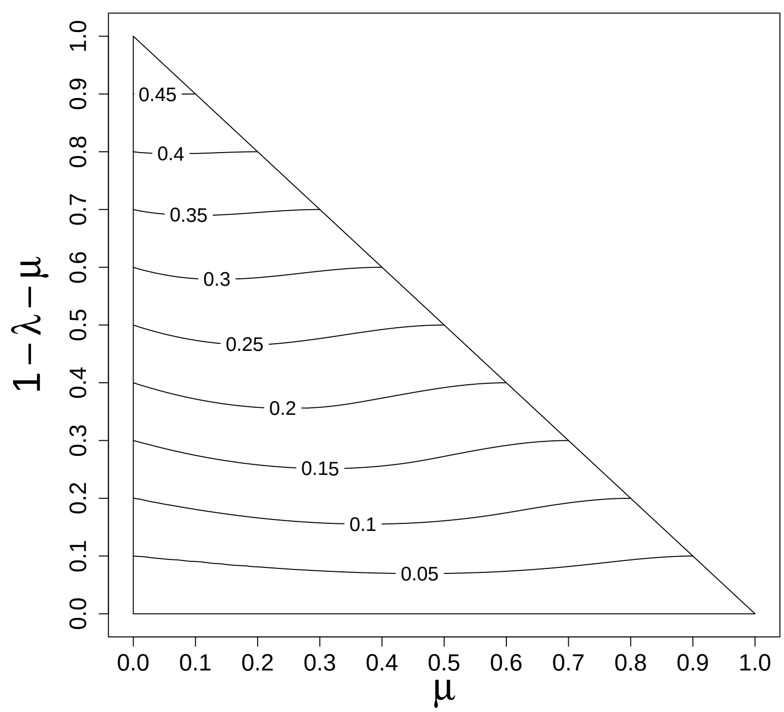
Figure 2 shows a contour plot of the equilibrium profits in (λ, μ)-space. Moving up in this graph thus implies keeping the number of informed (λ) fixed, while increasing the number of partially informed (μ) at the expense of the number of uninformed $(1 - \lambda - \mu)$. Similarly, moving to the right implies keeping the number of partially informed fixed shifting consumers from uninformed to informed.

From the figure, profits are strictly decreasing in λ and μ. Hence, profits decrease as uninformed consumers become either partially or fully informed. When firms do not have the possibility of using list prices, we effectively have $\mu = 0$: all partially informed consumers then act like uninformed consumers. As profits are decreasing in μ, it immediately follows:

Result 3. *When the partially informed consumers are myopic, the possibility of using list prices strictly lowers profits. This effect is stronger with more partially informed consumers.*

The intuition is as follows. In the first stage, firms compete for the partially informed by using list prices. Since these act as an upper bound on retail prices in the second period, this depresses the retail prices that will be set. Firms would like to commit not to use list prices. Hence this is essentially a prisoner's dilemma.

Figure 3: Contour plot of equilibrium profits.



For values $\lambda \in \{0, 0.01, \ldots, 0.98\}$, $\mu \in \{0, 0.01, \ldots, 0.98\}$, $\lambda + \mu \leq 0.98$.

Figure 3 gives the same information as Figure 2, but now in $(\mu, 1 - \lambda - \mu)$-space. Moving down in the graph means that uninformed consumers become fully informed. This decreases profits. Moving to the left instead signifies that partially informed consumers become fully informed. It can be seen from the graph that the effect of this on firm profits is non-monotonic. If the number of partially informed consumers is low, partially informing more consumers at the expense of fully informed consumers increases profits. But if their number is high, partially informing more consumers decreases profits.

Note that with $\lambda = 0$ or $\mu = 0$, we have standard Varian (1980) competition. If $\mu = 0$, there is no competition at the list price level but fierce competition at the retail level. If $\lambda = 0$, there is fierce competition at the list price level but no further competition at the retail level. With intermediate λ and μ, there is intermediate competition at both levels. This benefits firms relative to the case of fierce competition at either level.[8]

Armstrong (2015) gives a general analysis of models with both informed and less informed consumers ("savvy" and "non-savvy" in his more general terminology). In his analysis, there is a *search externality* when each type of consumer is better off when the number of savvy consumers increases. There is a *ripoff externality* if the opposite is true.

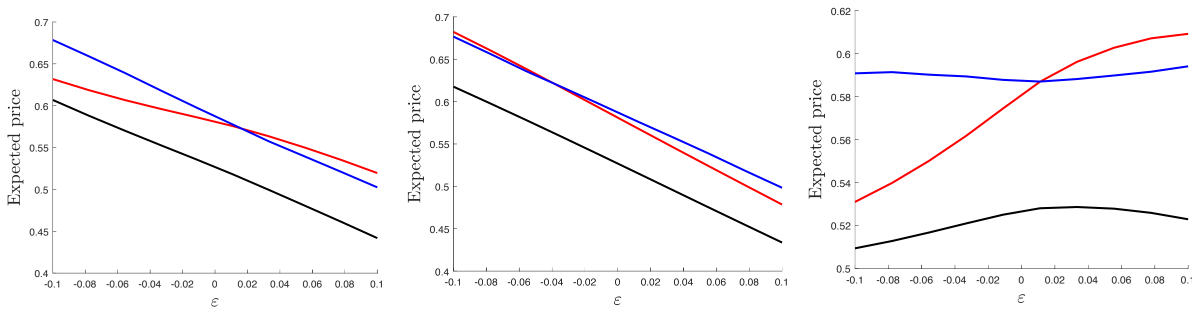
Our model not only has "savvy" and "non-savvy" consumers, but also "partly savvy" ones. It is interesting to see how an increase in savviness affects these consumer types. We do so for one particular parameter configuration in Figure 4.[9] The panels show the effect of fully informing uninformed consumers (a), partially informing uninformed consumers (b), and fully informing partially informed consumers (c). Blue curves give the average price paid by the uninformed, red curves that paid by the partially informed, black curves that paid by the informed.

From the graph, it is apparent that informing uninformed consumers either partially or fully yields a search externality: due to such a change, the average price paid by all types of consumers decreases. Hence, the lower profits (and hence higher consumer surplus) we found in Figure 2 benefit all consumers. The effect of further informing partially informed consumers is ambiguous for each type of consumer though – we already saw that to be the case for the aggregate effect in Figure 3.

[8] From a game-theoretic perspective, this result is straightforward: It is well-known that under Varian (1980) competition, all profits from fully informed consumers are competed away, such that firms' equilibrium profits are given by their min-max profits (that can be achieved by foregoing competition and fully exploiting their loyal consumers). In our model, when keeping the number $1 - \lambda - \mu$ of uninformed consumers fixed (moving on a horizontal line in Figure 3), firms' min-max profits remain constant (at $\alpha_H = \frac{1-\lambda-\mu}{2}$), such that their equilibrium profits can never fall short of their profits with $\mu = 0$ (the leftmost point of any horizontal line in the graph) and $\lambda = 0$ (the rightmost point of any horizontal line in the graph), with Varian (1980) competition.

[9] For other parameter configurations the graphs look qualitatively similar.

Figure 4: The effects of increasing consumer savviness.



(a) Uninformed to full (b) Uninformed to partial (c) Partial to full

Average price paid by the uninformed (blue), partially uninformed (red) and informed (black) for varying λ and μ. Starting from the benchmark $\lambda = 0.25, \mu = 0.2$, the panels show the effect of (a) an increase in the fraction of fully informed by ε while decreasing the fraction of uninformed by ε; (b) an increase in the fraction of partially informed by ε while decreasing the fraction of uninformed by ε; (c) an increase in the fraction of fully informed by ε while decreasing the fraction of partially informed by ε.

From Figure 4 we also have that, depending on the exact parameter values, partially informed consumers may be worse off than uninformed consumers. The uninformed just pick a firm at random, while the partially informed choose the firm with the lower list price, which might charge a higher actual retail price on average.

4 The case of rational partially informed consumers

We now modify the analysis by assuming that the partially informed consumers are rational, such that they will not frequent a firm which sets a higher retail price in expectation. We proceed as follows. First, in Subsection 4.1, we outline how the behavior of the partially informed needs to be adjusted such that the subgame equilibrium characterization of Subsection 3.1 can still be applied. There, we also discuss the effects this has on firms' expected prices and subgame equilibrium profits, relative to the baseline model with myopic partially informed consumers. In Subsection 4.2, we continue by examining firms' equilibrium choice of list prices. Finally, welfare implications, including a comparison to the myopic case, are provided in Subsection 4.3.

4.1 Adjusted pricing subgames

In Section 3, we assumed that partially informed consumers simply frequent the firm with the lowest list price. Yet, as we saw in Proposition 2 and Figure 1, this simple rule of thumb may fail in the sense that the firm with the higher list price may then charge a lower retail price on average. Hence, we now analyze how rational partially informed consumers will adjust their behavior, and how this can be incorporated into the analysis of the full game.

Let θ denote the fraction of partially informed consumers who frequent firm L. So far, we assumed $\theta = 1$, but we now relax that assumption. Denote the expected retail price of L as $\mathbb{E}p_L(\theta)$ and that of H as $\mathbb{E}p_H(\theta)$. These can be found by applying equations (8) and (9) using

$$\begin{aligned} \alpha_L(\theta) &= \frac{1-\lambda-\mu}{2} + \theta\mu \\ \alpha_H(\theta) &= \frac{1-\lambda-\mu}{2} + (1-\theta)\mu. \end{aligned} \tag{16}$$

If $\mathbb{E}p_L(1) > \mathbb{E}p_H(1)$, having $\theta = 1$ cannot be part of an equilibrium with rational consumers. We then need that a fraction $\tilde{\theta} < 1$ visits L such that $\mathbb{E}p_L(\tilde{\theta}) = \mathbb{E}p_H(\tilde{\theta})$.[10] Our approach to deal with rational partially informed consumers is thus as follows:

1. For all pricing subgames where $\mathbb{E}p_L(1) \leq \mathbb{E}p_H(1)$, which is the case if and only if $R = \frac{P_H}{P_L} \geq R^* \in (R_0, R_1)$, the equilibrium characterization of Proposition 1 still fully applies.

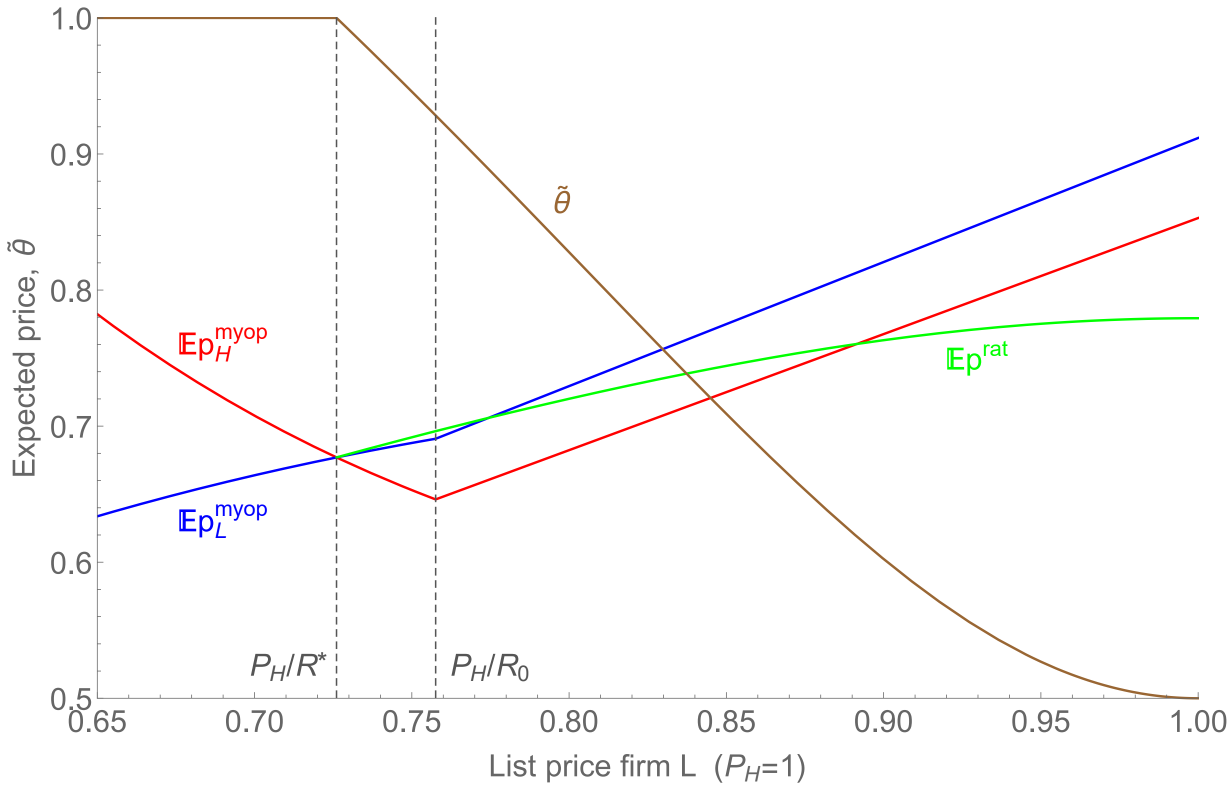
2. For all pricing subgames where $\mathbb{E}p_L(1) > \mathbb{E}p_H(1)$, which is the case if and only if $R = \frac{P_H}{P_L} < R^*$, find the value $\tilde{\theta}$ such that $\mathbb{E}p_L(\tilde{\theta}) = \mathbb{E}p_H(\tilde{\theta})$. Then, case B of Proposition 1 applies, with the adjustment that $\alpha_L = \alpha_L(\tilde{\theta})$ and $\alpha_H = \alpha_H(\tilde{\theta})$.

For this approach to work, we need that such a $\tilde{\theta}$ always exists and is unique. We can show that this is indeed the case:

[10] The only alternative would be to have $\theta = 0$ and $\mathbb{E}p_L(0) > \mathbb{E}p_H(0)$, but that cannot be part of an equilibrium: with $\theta = 0$, firm L would have a lower list price *and* fewer loyal consumers, rendering its pricing more aggressive than its rival's such that $\mathbb{E}p_L(0) < \mathbb{E}p_H(0)$ (see also the proof of Lemma 12 in Appendix A).

Lemma 5. *For any P_L, P_H where $\mathbb{E}p_L(1) > \mathbb{E}p_H(1)$, there is a unique $\tilde{\theta} \in \left(\frac{1}{2}, 1\right)$ such that $\mathbb{E}p_L(\tilde{\theta}) = \mathbb{E}p_H(\tilde{\theta})$.*

Figure 5: Expected prices with myopic and rational partially informed consumers.



Expected price of firm L and firm H as a function of the list price of firm L with myopic partially informed consumers (blue and red line, respectively) and with rational partially informed consumers (green line). Also depicted: equilibrium value $\tilde{\theta}$ (brown line). The parameters used are $P_H = 1$, $\lambda = 0.2$, $\mu = 0.3$.

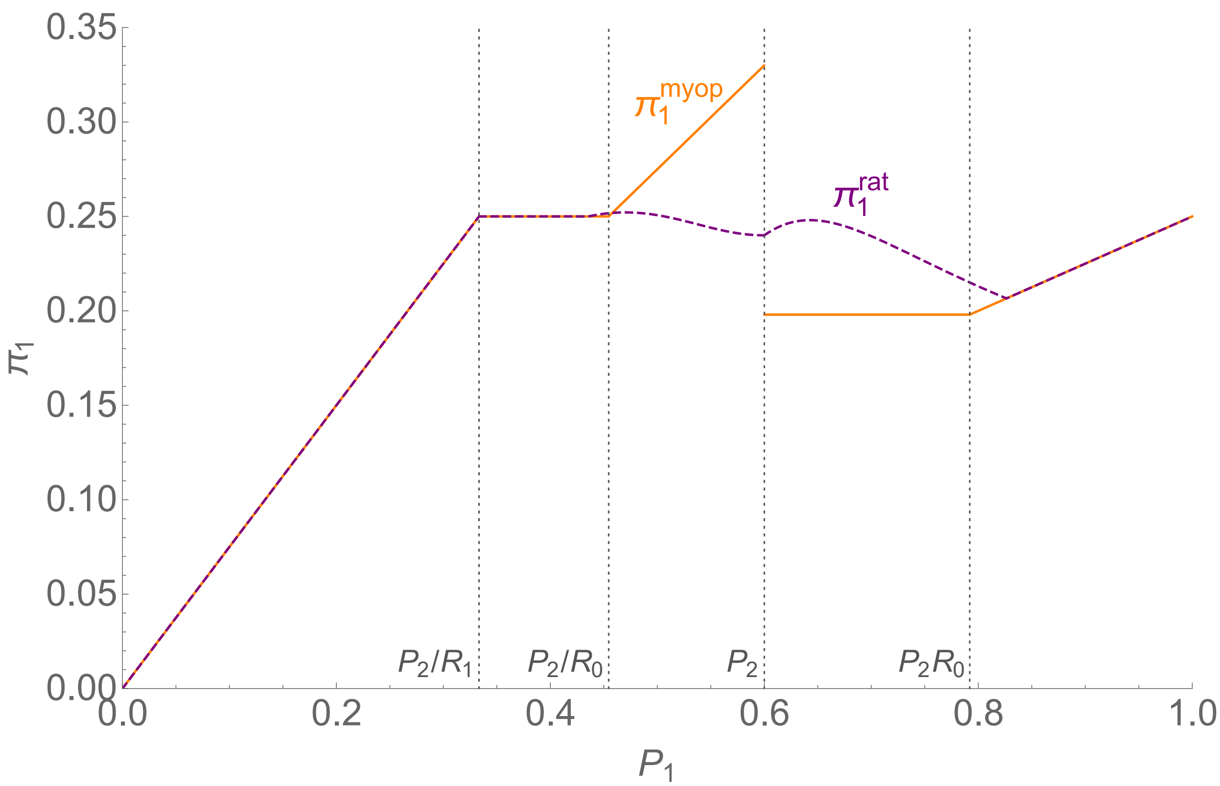
In Figure 5, we use the procedure described above to derive the subgame equilibrium with rational consumers for a range of P_L where $\mathbb{E}p_L > \mathbb{E}p_H$ with myopic partially informed consumers (compare with Figure 1 above). The blue line is the expected retail price of L with myopic partially informed consumers, the red line is that of H. The green line gives expected retail prices for both firms if the partially informed are rational. The brown line gives the equilibrium share of partially informed who visit firm L, $\tilde{\theta}$.

Interestingly, with rational partially informed consumers, expected prices are higher in some pricing subgames but lower in others. This can be understood as follows. First, note that the effect of having rational partially informed rather than myopic partially informed consumers is that firms become more symmetric in their share of captive consumers: with myopic partially informed consumers, all of these will go to L, while when they are rational, only some share $\tilde{\theta} \in (1/2, 1)$ will. If list prices are close to each other, equalizing these market shares leads to more aggressive competition (cf. Narasimhan, 1988, p. 441, point 1.iii): a leveled playing field implies that both firms have a similarly strong incentive to attract the informed consumers and therefore compete aggressively to pursue that goal. Hence, in Figure 5, the green line lies below the other two for P_L close enough to P_H. If the difference in list prices is sufficiently large, however, the opposite is true. As its share of captive consumers increases, it becomes less attractive for firm H to compete for the informed consumers: to do so it has to decrease its retail price below P_L rather than just setting $p_H = P_H$. As a result, L will also compete less aggressively, so the green line lies above the other two for P_L low enough.

To further illustrate the difference between the cases of myopic and rational partially informed consumers, Figure 6 shows the expected profits of firm 1 as a function of its list price P_1, given that firm 2 has set $P_2 = 0.6$, where $\lambda = 0.2$ and $\mu = 0.3$. The orange curve represents the case of myopic partially informed consumers, the purple dashed curve that of rational partially informed.

In the myopic case, slightly undercutting P_2 leads to a discrete upward jump in profits as this attracts *all* partially informed consumers. That is no longer the case with rational partially informed consumers. Slightly decreasing the list price below P_2 then only slightly increases the number of partially informed consumers firm 1 attracts, up to the point where both firms charge the same expected retail price. In the given example, the best reply of firm 1 is now to choose a discretely rather than marginally lower list price than firm 2 to attain the local maximum between P_2/R^* (close below P_2/R_0) and P_2, but for slightly different parameter values, the best reply may also be to price in the range $[P_2/R_1, P_2/R^*]$, to attain the local maximum between P_2 and P_2R^* (close above P_2R_0), or to set no effective

Figure 6: Profits of firm 1 with myopic and rational consumers.



Profits of firm 1 as a function of P_1, given $P_2 = 0.6$ ($\lambda = 0.2, \mu = 0.3$). Orange: myopic partially informed. Purple: rational partially informed.

list price ($P_1 = 1$). For high or low enough P_1, the curves with myopic and rational partially informed consumers coincide as rational partially informed now also collectively frequent the firm with the lowest list price.

As outlined above, with partially informed consumers acting rationally, the demand functions and hence profit functions of both firms are no longer discontinuous: slightly undercutting the other firm no longer leads to a discrete change in demand. Still, as we will see in the next subsection, a (symmetric) pure strategy equilibrium fails to exist for $\lambda < 1/3$. This is instead caused by the profit function failing to be quasi-concave, as exemplified by Figure 6. Indeed, for $\lambda < 1/3$, we can show that $\pi_i(P_i, P)$ has a local minimum at $P_i = P$, which immediately rules out the existence of a symmetric pure strategy equilibrium.

4.2 Equilibrium choice of list prices

We now analyze the equilibrium choice of list prices with rational partially informed consumers, restricting attention to symmetric equilibria. First, we address the question under which circumstances list prices will still be used in that case.

Theorem 2. *Suppose that the partially informed consumers are rational.*

- *If* $\lambda \geq 1/3$*, there is a unique symmetric pure strategy equilibrium in which both firms set* $P = 1$*. Hence, no effective list prices are used.*
- *If* $\lambda < 1/3$*, a symmetric pure strategy equilibrium fails to exist, such that effective list prices are used.*

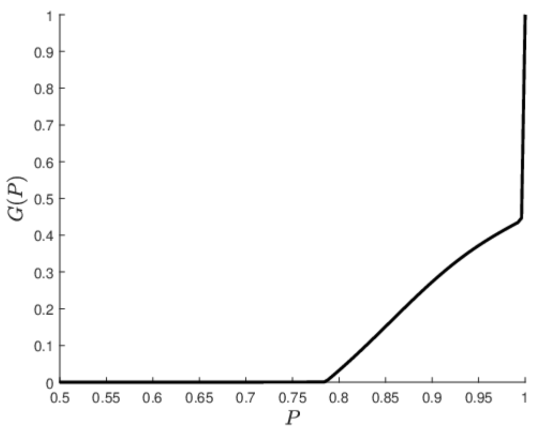
Proof. See Appendix A. ■

Starting from $P_1 = P_2 = 1$, lowering one's list price has two effects. On the one hand, this slightly increases the number of partially informed consumers a firm attracts, which tends to increase its profit. But, different from the myopic case, this is only a second-order effect. On the other hand, this makes competition for the informed consumers more aggressive, which tends to decrease its profit. When the number of informed consumers is high enough, the second effect dominates, leaving $P = 1$ as an equilibrium. Furthermore, a symmetric pure strategy equilibrium with list prices lower than 1 does not exist as firms would then have an incentive to charge a list price slightly *higher* than their competitor.

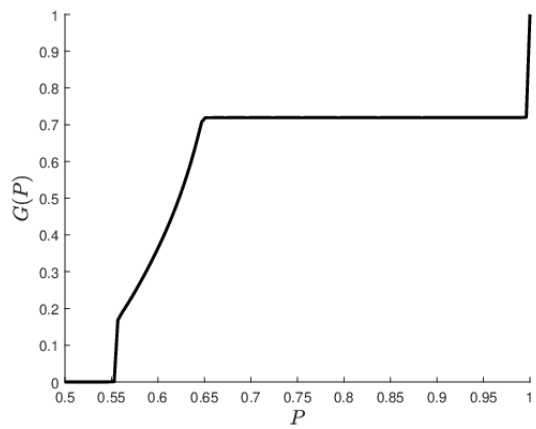
The equilibrium for $\lambda < 1/3$. In this case, it is very hard to characterize the equilibrium choice of list prices. As always, a mixed strategy equilibrium requires that each firm is indifferent between all list prices in its support. But, on top of that, we also need that in all subgames that have list prices sufficiently close to each other, firms' shares of loyal consumers are such that their expected retail prices are equalized. In turn, these endogenously determined shares of loyal consumers affect the subgame equilibrium profits.

We therefore have to resort to a numerical approximation of the equilibrium mixed-strategy choice of list prices. As it turns out, the equilibrium distribution often has mass points and gaps, such that we cannot use the method employed in Section 3.2 (described in Appendix B). Instead, we use a numerical procedure based on Mangasarian and Stone (1964). Roughly, for each parameter combination, we discretize the action space, construct the respective payoff matrix, and numerically solve a quadratic programming problem.[11]

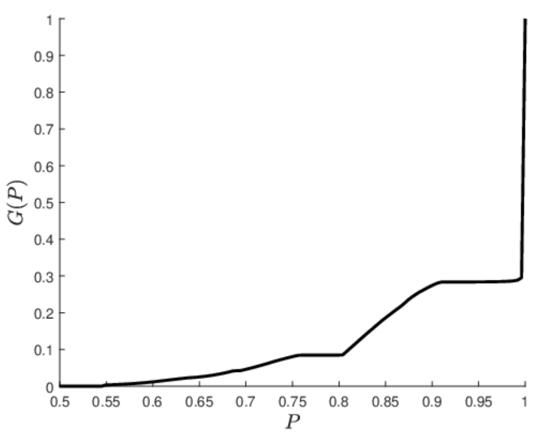
Figure 7: Approximated first-stage equilibrium CDFs.



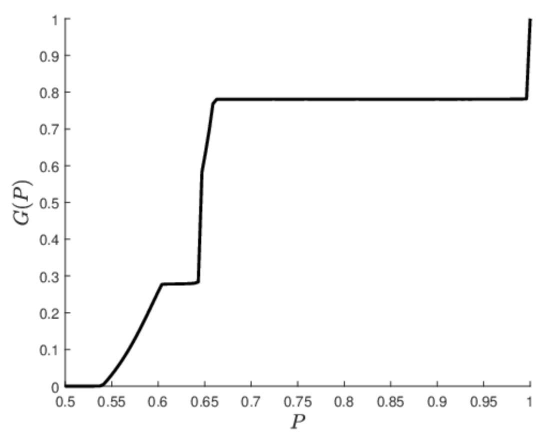
(a) $\lambda = 0.25, \mu = 0.3$



(b) $\lambda = 0.2, \mu = 0.3$



(c) $\lambda = 0.25, \mu = 0.15$



(d) $\lambda = 0.15, \mu = 0.3$

Approximated first-stage equilibrium CDFs for various parameter combinations. In each case, an equidistant grid of size 256 over the interval $[0, 1]$ was used.

[11]Further details can be found in Heijnen (2020). The corresponding Matlab code is available upon request. We also confirmed our results using an alternative, evolutionary algorithm.

To illustrate the complexity, Figure 7 shows the equilibrium CDF $G(P)$ for four sets of parameters. The equilibrium in the top-left panel is fairly well-behaved, but does have a mass point at $P = 1$. The equilibrium in the top-right hand panel has two mass points: one at $P = 1$ and one at roughly $P = 0.55$. Furthermore, the support has a gap at $[0.65, 1)$. In the bottom-left panel, there are two gaps, but only one mass point. The bottom-right panel has two mass points and two gaps.

Even though the parameters are close to each other, the resulting equilibria are qualitatively quite different. This is likely caused by the fact that small changes in parameter values may trigger substantial differences in best replies, as we also saw in Figure 6. A common theme of our numerical results is that even for $\lambda < 1/3$, firms only sometimes use effective list prices (having a mass point at $P = 1$) with rational partially informed consumers. Unfortunately, this seems difficult to prove analytically.

4.3 Welfare effects

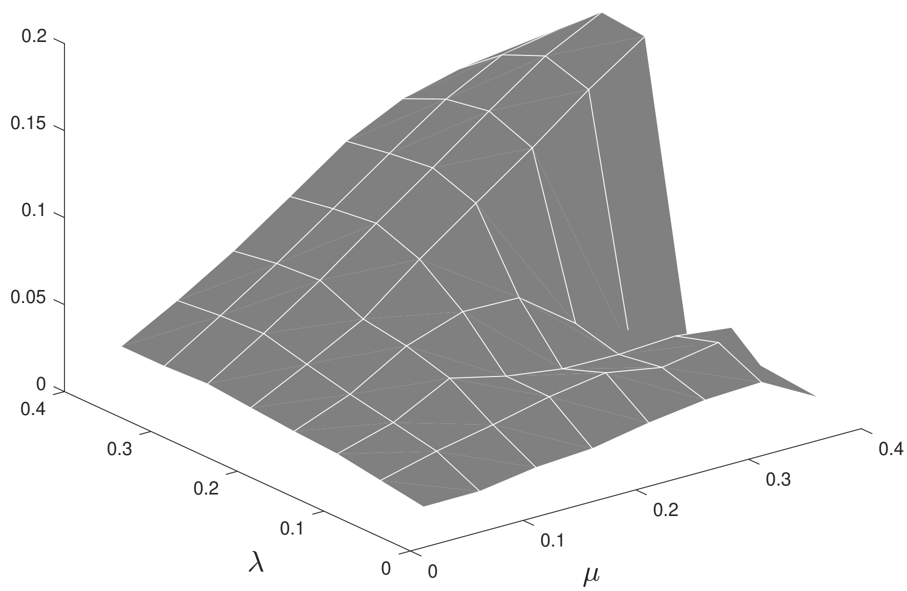
We finally consider the welfare implications of firms' ability to set list prices with rational partially informed consumers. Note first that for $\lambda \geq 1/3$, both firms set $P = 1$, so the second stage collapses to a standard Varian model with λ informed and $1 - \lambda$ uninformed consumers. From Theorem 1, we know that firms *do* set effective list prices when the partially informed consumers are myopic. From Result 3, we then immediately have that profits are higher and consumer surplus is lower when partially informed consumers are rational rather than myopic.

For $\lambda < 1/3$, the comparison is harder. Figure 8 gives the differences in expected profits when the partially informed consumers are rational rather than myopic. As is clear from the picture, this difference is always positive. Hence we find:

Result 4. *Having rational rather than myopic partially informed consumers strictly increases profits and strictly decreases consumer surplus.*

Armstrong (2015) makes a distinction between consumers that are "savvy" since they are well-informed, and those that are *strategically savvy* in the sense that they have a good

Figure 8: Profit differences between the rational case and the myopic case.



For both cases, profits are approximated by solving for the Nash equilibrium of a discretized version of the game. The discretization uses an equidistant grid of size 256 over the interval $[0, 1]$. Positive values mean that profits are higher in the case of rational consumers.

understanding of the game being played in the market. In that terminology, our partially informed consumers are strategically naive if myopic, and strategically savvy if rational. Our analysis then implies that in this dimension there is a ripoff externality: when the partially informed consumers become strategically savvy, all end up paying a higher price on average.[12] Hence, partially informed consumers would be better off if they could commit as a group to use the simple rule of thumb.

[12] In the main text, we only considered the cases where either all partially informed consumers are myopic, or all of them are rational. Of course, it is straightforward to allow for the case that only a fraction, say $\kappa \in (0, 1)$, of the partially informed are rational. Note that in the model with $\kappa = 1$, we have an equilibrium fraction $\tilde{\theta}$ visiting firm L while with $\kappa = 0$ we impose $\theta = 1$. If $1 - \kappa \leq \tilde{\theta}$ the same solution prevails as in the case $\kappa = 1$: having a share $\kappa \geq 1 - \tilde{\theta}$ rational partially informed consumers is enough to reach the fully rational outcome. If $\kappa < 1 - \tilde{\theta}$, we simply get the solution described in Proposition 2, but with $\tilde{\alpha}_L = \frac{1-\lambda-\mu}{2} + (1 - \kappa)\mu$ and $\tilde{\alpha}_H = \frac{1-\lambda-\mu}{2} + \kappa\mu$.

5 Conclusion

In this paper, we have argued that list prices are often more salient than actual retail prices. Therefore, some consumers may decide where to buy based on the lowest list price they observe. We referred to these consumers as partially informed and established that if they use this kind of heuristic, then consumer welfare increases compared to the Varian (1980) benchmark. This is due to intense competition to capture the partially informed consumers via list prices, which in turn serve as upper bounds on the actual retail prices that can be set.

This simple heuristic, where partially informed consumers buy from the firm with the lowest list price, is not always rational. The firm with the lowest list price may then end up setting a higher retail price on average. We show that when the partially informed consumers are rational, then either firms stop using list prices altogether, or competition for the partially informed is less intense. As a result, the positive effects on consumer welfare are lower or even completely vanish. Therefore, consumers (on aggregate) benefit when some consumers make decisions based on heuristics instead of being completely rational.

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Appendix A: Technical Proofs

Proof of Lemma 2. Here, we only prove existence of the characterized equilibrium. Uniqueness can be established via a sequence of additional steps, such as showing that, for $R \leq R_0$, (i) firm H cannot put positive probability mass on prices weakly above P_L in equilibrium; (ii) firms H and L must put positive probability mass into some common interval ranging up to P_L; and (iii) there can be no mass points or gaps in firms' equilibrium price distributions for prices strictly below P_L. Further details to this are available upon request.

Existence. If firm H prices at some $p_H \in \left[\frac{\alpha_L}{\alpha_L+\lambda} P_L, P_L\right)$, it attracts the (full) mass λ of uninformed if and only if $p_L > p_H$, which happens with probability $\sigma_L + (1-\sigma_L)(1-F_L(p_H))$ in the candidate equilibrium. Hence, firm H's expected profit in this range is given by

$$\pi_H(p_H; P_H, P_L) = p_H \left[\alpha_H + \lambda(\sigma_L + (1-\sigma_L)(1-F_L(p_H)))\right] = \frac{(\alpha_H+\lambda)\alpha_L}{\alpha_L+\lambda} P_L = \pi_H,$$

which is indeed firm H's candidate equilibrium profit. Pricing below $\frac{\alpha_L}{\alpha_L+\lambda} P_L$ cannot constitute a profitable deviation since already at this price, firm H attracts the informed with probability 1 (since $F_L(\frac{\alpha_L}{\alpha_L+\lambda} P_L) = 0$). Setting $p_H = P_L$ gives a strictly lower expected profit than setting some $p_H = P_L - \epsilon$ (for ϵ sufficiently low) due to firm L's mass point at P_L. Finally, since H cannot attract the informed when setting $p_H > P_L$, the best possible deviation price above P_L is clearly given by $p_H = P_H$, the highest permissible price for H. This gives a maximal deviation profit of $\pi_H^{dev} = \alpha_H P_H$, which however does not exceed π_H since by assumption $R \leq R_0$. Hence, firm H has no profitable deviation.

If firm L prices at some $p_L \in \left[\frac{\alpha_L}{\alpha_L+\lambda} P_L, P_L\right]$, it attracts the (full) mass λ of informed consumers if and only if $p_H > p_L$, which happens with probability $1 - F_H(p_L)$ in the candidate equilibrium. Hence, firm L's expected profit in this range is given by

$$\pi_L(p_L; P_L, P_H) = p_L \left[\alpha_L + \lambda(1 - F_H(p_L))\right] = \alpha_L P_L = \pi_L,$$

which is indeed firm L's candidate equilibrium profit. Pricing below $\frac{\alpha_L}{\alpha_L+\lambda} P_L$ cannot constitute a profitable deviation, since already at this price, firm L attracts the uninformed with probability 1 (since $F_H(\frac{\alpha_L}{\alpha_L+\lambda} P_L) = 0$). Pricing above P_L is not permissible to firm L. Hence, firm L has no profitable deviation.

Lastly, all equilibrium objects are well-behaved, since clearly $\sigma_L \in (0,1)$, while $F_i(\frac{\alpha_L}{\alpha_L+\lambda} P_L) = 0$, $F_i(P_L) = 1$, and $\frac{dF_i(p)}{dp} = \frac{\alpha_L P_L}{p^2 \lambda} > 0$. ■

Proof of Lemma 3. Here, as in the proof of Lemma 2, we only prove existence of the characterized equilibrium. Uniqueness follows once more from a sequence of additional steps, such as showing that, for $R \in (R_0, R_1)$, in any equilibrium (i) firm H must have a mass point at P_H; (ii) firms H and L must put positive probability mass into some common interval ranging up to P_L; and (iii) there can be no mass points or gaps in firms' equilibrium price distributions for prices strictly below P_L. Again, details are available upon request.

Existence. If firm H prices at P_H, its profit is given by $\alpha_H P_H = \pi_H$, since it cannot attract the informed. If firm H instead prices at some $p_H \in \left[\frac{\alpha_H}{\alpha_H+\lambda} P_L, P_L\right)$, it attracts the (full) mass λ of informed consumers if and only if $p_L > p_H$, which happens with probability $\sigma_L + (1 - \sigma_L)(1 - F_L(p_H))$ in the candidate equilibrium. Hence, firm H's expected profit in this range is given by

$$\pi_H(p_H; P_H, P_L) = p_H \left[\alpha_H + \lambda(\sigma_L + (1 - \sigma_L)(1 - F_L(p_H)))\right] = \alpha_H P_H = \pi_H.$$

Hence, firm H's expected profit indeed equals π_H for any price in its pricing support $\left[\frac{\alpha_H}{\alpha_H+\lambda}P_L, P_L\right) \cup P_H$ of the candidate equilibrium. Pricing below $\frac{\alpha_H}{\alpha_H+\lambda}P_L$ cannot constitute a profitable deviation since already at this price, firm H attracts the informed with probability 1 (since $F_L(\frac{\alpha_H}{\alpha_H+\lambda}P_L) = 0$). Setting $p_H = P_L$ gives a strictly lower expected profit than setting some $p_H = P_L - \epsilon$ (for ϵ sufficiently low) due to firm L's mass point at P_L. Finally, since H cannot attract the informed when setting $p_H > P_L$, the best possible deviation price above P_L is clearly already given by $p_H = P_H$, such that any price in (P_L, P_H) yields a strictly lower profit. Hence, firm H has no profitable deviation.

If firm L prices at some $p_L \in \left[\frac{\alpha_H}{\alpha_H+\lambda}P_L, P_L\right]$, it attracts the (full) mass λ of informed consumers if and only if $p_H > p_L$, which happens with probability $\sigma_H+(1-\sigma_H)(1-F_H(p_L))$ in the candidate equilibrium. Hence, firm L's expected profit in this range is given by

$$\pi_L(p_L; P_L, P_H) = p_L\left[\alpha_L + \lambda(\sigma_H + (1-\sigma_H)(1-F_H(p_L)))\right] = \frac{(\alpha_L+\lambda)\alpha_H}{\alpha_H+\lambda}P_H = \pi_L,$$

which is indeed firm L's candidate equilibrium profit. Pricing below $\frac{\alpha_H}{\alpha_H+\lambda}P_L$ cannot constitute a profitable deviation since already at this price, firm L attracts the informed with probability 1 (since $F_H(\frac{\alpha_H}{\alpha_H+\lambda}P_L) = 0$). Pricing above P_L is not permissible to firm L. Hence, firm L has no profitable deviation.

It remains to verify that all equilibrium objects are well-behaved. First, it is easy to check that $\sigma_H \in (0,1)$ if and only if $R \in (R_0, R_1)$, as assumed. Second, $\sigma_L > 0$ is clearly satisfied due to $R > R_0 > 1$, while $\sigma_L < 1$ follows from $R < R_1$. Lastly, it holds that $F_i(\frac{\alpha_H}{\alpha_H+\lambda}P_L) = 0$, $F_i(P_L) = 1$, and

$$\frac{dF_i(p)}{dp} = \frac{\alpha_H P_H}{p^2[\lambda - \alpha_H(R-1)]} > 0,$$

where the inequality follows from $R < R_1$. ■

Proof of Proposition 3. First of all, note that existence of such an equilibrium follows from Dasgupta and Maskin (1986). To prove Proposition 3, we establish a number of lemmas. First, note that any firm can always choose to set $p_i = P_i = 1$ and sell to at least its captive consumers. Hence

Lemma 6. *Each firm must make an expected profit of at least α_H in equilibrium.*

Also, when having the lower recommended price P_i, a firm sells to at most the $1 - \alpha_H$ consumers not captive to its rival, at a price of at most P_i. For $P_i < \alpha_H/(1-\alpha_H)$, this yields profits lower than the α_H that can be guaranteed by setting $p_i = P_i = 1$. Hence

Lemma 7. *In equilibrium, no firm sets a recommended retail price below $\underline{P}_{min} \equiv \frac{\alpha_H}{1-\alpha_H} > 0$.*

Lemma 8. *$G(\cdot)$ is atomless.*

Proof. Suppose $G(\cdot)$ does have an an atom at some P^*. Then, both firms choose P^* with some probability $\beta > 0$, yielding profits $\frac{1-\lambda}{2}P^*$. Using the same argument as in the proof of Lemma 4, either firm could profitably transfer its probability mass at P^* to some marginally lower recommended retail price $P^* - \epsilon$: doing so would lead to strictly higher profits with probability β. Hence, there can be no atoms in equilibrium. ■

Lemma 9. *Case B can always occur in equilibrium, so $\overline{P}/\underline{P} > R_0$.*

Proof. Suppose to the contrary that $\overline{P}/\underline{P} \leq R_0$. We would then have $\pi_L = \alpha_L P_L$ and $\pi_H = \frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}P_L < \pi_L$. As G is atomless (see Lemma 8), a firm setting $P_i = \underline{P}$ would thus make a profit of $\alpha_L\underline{P}$, which, as every recommended price in the equilibrium support must yield the same expected profit, would equal the equilibrium profit. But then, unless $\underline{P} = 0$, any other recommended price $P_i > \underline{P}$ in the (necessarily non-degenerate) equilibrium support would yield a strictly lower expected profit of $\pi_H = \frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}\underline{P} < \alpha_L\underline{P} = \pi_L$, yielding a contradiction. But $\underline{P} = 0$ cannot be the case either due to Lemma 7. ■

Lemma 10. $\bar{P} = 1$.

Proof. Suppose that $\bar{P} < 1$. Then, if firm i deviates to some $P_i \in (\overline{P}, 1]$, it makes an expected profit of either $\alpha_H P_i$ (if the other firm sets $P_j \leq P_i/R_0$ and we are in case B or C) or $\frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}P_i$ (if $P_j \in (P_i/R_0, \overline{P}]$ and we are in case A). Hence, we can write

$$\pi_i(P_i) = G\left(\frac{P_i}{R_0}\right)\alpha_H P_i + \int_{\frac{P_i}{R_0}}^{\overline{P}} \frac{(1-\alpha_L)\alpha_L}{1-\alpha_H} P g(P) dP.$$

Taking the derivative of this with respect to P_i yields

$$\begin{aligned}\pi_i'(P_i) &= G\left(\frac{P_i}{R_0}\right)\alpha_H + g\left(\frac{P_i}{R_0}\right)\alpha_H\frac{P_i}{R_0} - \frac{1}{R_0}\left[\frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}\right]g\left(\frac{P_i}{R_0}\right)\frac{P_i}{R_0} \\ &= G\left(\frac{P_i}{R_0}\right)\alpha_H.\end{aligned}$$

Hence, $\lim_{\epsilon\downarrow 0}\pi_i'(\overline{P}+\epsilon) = G(\overline{P}/R_0)\alpha_H > 0$, where the inequality follows from Lemma 9. But then, setting P marginally above $\overline{P} < 1$ would be a profitable defection, so this cannot be part of an equilibrium. ■

Lemma 11. *There are no gaps in* $G(\cdot)$*.*

Proof. Suppose G does contain gaps, and the highest is in the interval (a, b), for some $a < b < 1$, with $G(a) = G(b) < 1$. From Proposition 1, if $P_j < P_i$, i's profits are either $\alpha_H P_i$ (if $P_i/P_j \geq R_0$), or $\frac{(1-\alpha_L)\alpha_L}{1-\alpha_H}P_j$ (if $P_i/P_j < R_0$). Hence, conditional on $P_j < P_i$, i's profits are weakly increasing in P_i.

If instead $P_i < P_j$, i's expected profit is either $\alpha_L P_i$ (if $P_j/P_i < R_0$), or $\frac{(1-\alpha_H)\alpha_H}{1-\alpha_L}P_j$ (if $R_0 \leq P_j/P_i < R_1$), or $(1-\alpha_H)P_i$ (if $P_j/P_i \geq R_1$). Again, conditional on $P_j > P_i$, i's expected profit is weakly increasing in P_i.

Hence, as by assumption j never prices in (a, b), i's expected profits must be weakly increasing in P_i on (a, b). But then, it is easy to see that i's expected profit at a would actually be strictly less than its expected profit at b, because for $P_i \in (\max\{a, b/R_0\}, b)$, increasing P_i would increase firm i's expected profit in those cases where firm j prices in the range $[b, P_i R_0)$, which happens with positive probability since by assumption (a, b) is the highest gap in the candidate equilibrium CDF. This cannot be the case in equilibrium. ■

Taken together, the lemmas above establish Proposition 3. ■

Proof of Proposition 4. To establish the result, we continue the discussion above Proposition 4. From (13), G_2 has the form

$$G_2(P) = 1 - B_0 P^{-\frac{1}{k}}, \tag{17}$$

where

$$k = \frac{\alpha_L - \alpha_H}{1 - \alpha_H} \in (0, 1), \tag{18}$$

and B_0 is a coefficient to be determined.

To solve for G_1 and G_3 we proceed as follows. First we introduce the variable $z \equiv P/R_0$, which we substitute in (14) to obtain

$$G_1(z) = \frac{\alpha_L}{\alpha_H}\left[kR_0 z g_3(R_0 z) - (1 - G_3(R_0 z))\right]. \tag{19}$$

Taking the derivative with respect to z and simplifying yields

$$g_1(z) = \frac{\alpha_L}{\alpha_H}\left[R_0 g_3(R_0 z)\,(k+1) + kR_0^2 z g_3'(R_0 z)\right].$$

We then plug these expressions for G_1 and g_1 into (12), which, after simplification, yields a second-order ordinary differential equation for G_3 of the following form:

$$1 - G_3(P)\left(\frac{\alpha_L - \alpha_H}{\alpha_L}\right) - k(2+k)Pg_3(P) - k^2P^2g_3'(P) = 0, \tag{20}$$

We conjecture that $G_3(P)$ has the following functional form:

$$G_3(P) = a + b_1P^{c_1} + b_2P^{c_2},$$

such that $Pg_3(P) = b_1c_1P^{c_1} + b_2c_2P^{c_2}$ and $P^2g_3'(P) = b_1c_1(c_1-1)P^{c_1} + b_2c_2(c_2-1)P^{c_2}$. Substituting these expressions and comparing coefficients, we find

$$a = \frac{\alpha_L}{\alpha_L - \alpha_H}, \tag{21}$$

$$c_{1,2} = -\frac{1}{k}\left(1 \pm w\right),$$

with $w \equiv \sqrt{\frac{\alpha_H}{\alpha_L}}$, while b_1 and b_2 are still unspecified.

Note that c_1 and c_2 are given by $k^2c_i^2 + 2kc_i + \frac{\alpha_L - \alpha_H}{\alpha_L} = 0$, $i = 1, 2$. Now c_1 and c_2 cannot be equal: otherwise $G_3(P) = a + bP^c$, which with just one free parameter b cannot yield a general solution to a second-order ordinary differential equation. For concreteness, let

$$c_1 = -\frac{1-w}{k}, \tag{22}$$

$$c_2 = -\frac{1+w}{k}. \tag{23}$$

Hence we have

$$G_3(P) = a + b_1 P^{-\frac{1-w}{k}} + b_2 P^{-\frac{1+w}{k}}. \tag{24}$$

The requirement $G_3(1) = 1$ pins down the relationship between b_1 and b_2. Using (24),

$$b_2 = b_2(b_1) = 1 - a - b_1. \tag{25}$$

We next introduce the variable $q \equiv PR_0$, which we substitute in (12) to obtain

$$G_3(q) = G_1\left(\frac{q}{R_0}\right) + \frac{kq}{R_0} g_1\left(\frac{q}{R_0}\right). \tag{26}$$

After taking the derivative with respect to q, we obtain

$$g_3(q) = \frac{1}{R_0} g_1\left(\frac{q}{R_0}\right) + \frac{k}{R_0} g_1\left(\frac{q}{R_0}\right) + \frac{kq}{R_0^2} g_1'\left(\frac{q}{R_0}\right).$$

Plugging these expressions for G_3 and g_3 into (14) and simplifying yields a second-order ordinary differential equation for G_1 of the following form:

$$1 - G_1(P)\left(\frac{\alpha_L - \alpha_H}{\alpha_L}\right) - k(2+k)Pg_1(P) - k^2P^2g_1'(P) = 0. \tag{27}$$

This ordinary differential equation coincides with that for $G_3(P)$ above. Hence, we must have

$$G_1(P) = a + \beta_1 P^{c_1} + \beta_2 P^{c_2},$$

with a, c_1 and c_2 as specified above. Using (24) and (19), we find that, conditional on b_1,

$$G_1(P) = a + \left[b_1 R_0^{c_1} w\right] P^{c_1} + \left[-b_2(b_1) R_0^{c_2} w\right] P^{c_2},$$

which pins down β_1 and β_2 as functions of b_1:

$$\begin{aligned} \beta_1(b_1) &= b_1 R_0^{c_1} w; \\ \beta_2(b_1) &= -b_2(b_1) R_0^{c_2} w. \end{aligned} \tag{28}$$

The requirement that $G_1(1/R_0) = G_2(1/R_0)$ pins down B_0 as a function of b_1,

$$B_0(b_1) = \frac{1 - a - \beta_1(b_1) R_0^{-c_1} - \beta_2(b_1) R_0^{-c_2}}{R_0^{\frac{1}{k}}}.$$

Inserting $\beta_1(b_1)$, $\beta_2(b_1)$ and using $b_1 + b_2(b_1) = 1 - a$ then yields

$$B_0(b_1) = \frac{(1-a)(1+w) - 2b_1 w}{R_0^{\frac{1}{k}}}. \tag{29}$$

The requirement that $G_2(\underline{P}R_0) = G_3(\underline{P}R_0)$, yields an equation for b_1, conditional on $\underline{P}$:

$$1 - B_0(b_1) \cdot (\underline{P}R_0)^{-\frac{1}{k}} = a + b_1(\underline{P}R_0)^{c_1} + (1-a-b_1)(\underline{P}R_0)^{c_2}.$$

As this is linear in b_1, we can directly solve for b_1, given $\underline{P}$:

$$b_1(\underline{P}) = \frac{(1-a)[1-(\underline{P}R_0)^{c_2}] - d(\underline{P}R_0)^{-\frac{1}{k}}}{(\underline{P}R_0)^{c_1} - (\underline{P}R_0)^{c_2} - e(\underline{P}R_0)^{-\frac{1}{k}}}, \tag{30}$$

where

$$d = (1-a)(1+w)\, R_0^{-\frac{1}{k}}; e = 2wR_0^{-\frac{1}{k}}. \tag{31}$$

The final step to solve for equilibrium is the consistency requirement that

$$G_1(\underline{P}; a, \beta_1(b_1(\underline{P})), \beta_2(b_1(\underline{P}))) = 0. \tag{32}$$

Taken together, this implies the result.

Figure 9 shows for which part of the parameter space the above procedure indeed yields a solution for the first-stage equilibrium price distribution. In particular, it can be observed that the procedure works for all λ sufficiently large ($\lambda \gtrapprox 0.38$), irrespective of μ. ■

Proof of Lemma 5. We first establish the following:

Lemma 12. *If $\tilde{\theta}$ exists, it is such that $\tilde{\alpha}_H$ is a root of*

$$h(\tilde{\alpha}_H; R) = \left(1 - \frac{1-\tilde{\alpha}_H}{\lambda+\tilde{\alpha}_H}\right)\log\left(\frac{\lambda+\tilde{\alpha}_H}{\tilde{\alpha}_H R}\right) + \frac{1-\lambda}{\tilde{\alpha}_H} - \frac{1}{R} - \frac{1-\tilde{\alpha}_H}{\lambda+\tilde{\alpha}_H}R.$$

Moreover, it holds that (1) $\tilde{\theta} > 1/2$, (2) $\frac{\partial h}{\partial \tilde{\alpha}_H} < 0$, (3) $\frac{\partial h}{\partial R} < 0$, and (4) $\frac{\partial^2 h}{\partial \tilde{\alpha}_H \partial R} > 0$.

Proof. As noted, we need $\mathbb{E}p_L(\tilde{\theta}) = \mathbb{E}p_H(\tilde{\theta})$. Equating (8) and (9) and simplifying, we thus need $\tilde{\theta}$ to be such that

$$1 - \frac{1}{R} - \frac{\tilde{\alpha}_L - \tilde{\alpha}_H}{1-\tilde{\alpha}_L}\log\left(\frac{1-\tilde{\alpha}_L}{\tilde{\alpha}_H}\frac{1}{R}\right) - \frac{1-\tilde{\alpha}_H}{1-\tilde{\alpha}_L}R + \frac{\tilde{\alpha}_L}{\tilde{\alpha}_H} = 0.$$

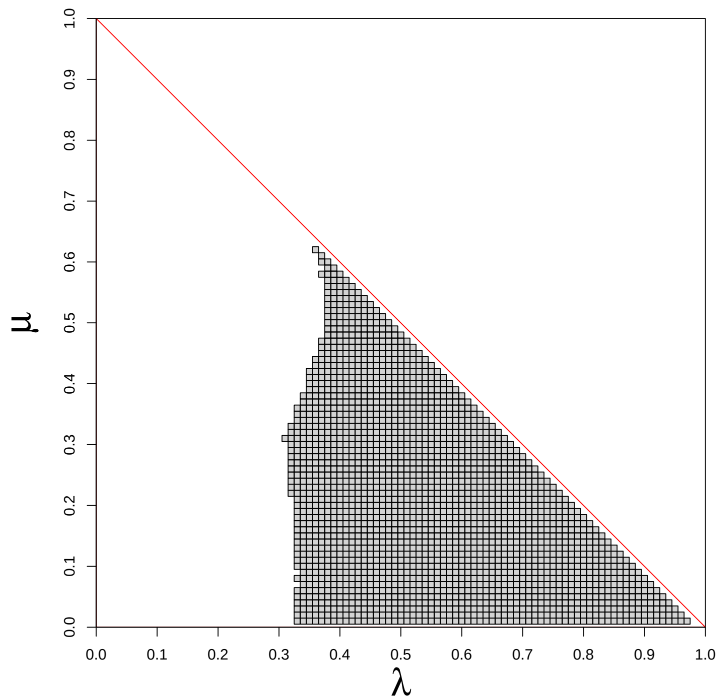

Figure 9: Parameter combinations ($\lambda \in \{0.01, 0.02, ..., 0.97\}$, $\mu \in \{0.01, 0.02, ..., 0.97\}$, $\lambda + \mu \leq 0.98$). Each square corresponds to a feasible parameter combination, centered at the respective parameters. Black squares indicate parameter combination for which Proposition 4 yields a valid solution.

Using the fact that $\tilde{\alpha}_L = 1 - \lambda - \tilde{\alpha}_H$ yields the expression for $h(\tilde{\alpha}_H; R)$.

To prove claim (1) we show that for $\theta \leq \frac{1}{2}$, necessarily $\mathbb{E}p_L(\theta) < \mathbb{E}p_H(\theta)$. In case C of Proposition 1, this is always true since both firm charge the recommended retail price. In case B it holds that

$$\mathbb{E}p_L(\theta) = (1 - \sigma_L) \int_{\underline{p}}^{P_L} p dF(p) + \sigma_L P_L$$

$$\mathbb{E}p_H(\theta) = (1 - \sigma_H) \int_{\underline{p}}^{P_L} p dF(p) + \sigma_H P_H.$$

Since $P_H > P_L$, it follows that if $\sigma_H \geq \sigma_L$, then $\mathbb{E}p_L(\theta) < \mathbb{E}p_H(\theta)$. Now $\sigma_H \geq \sigma_L$ requires

$$(1 - \tilde{\alpha}_H)\tilde{\alpha}_H R - (1 - \tilde{\alpha}_L)\tilde{\alpha}_L \geq (1 - \tilde{\alpha}_L)\tilde{\alpha}_H R - (1 - \tilde{\alpha}_L)\tilde{\alpha}_H,$$

which implies

$$(\tilde{\alpha}_L - \tilde{\alpha}_H)\tilde{\alpha}_H R \geq (\tilde{\alpha}_L - \tilde{\alpha}_H)(1 - \tilde{\alpha}_L).$$

With $\theta \leq 1/2$, we have $\tilde{\alpha}_L - \tilde{\alpha}_H \leq 0$, so this implies

$$R \leq \frac{1 - \tilde{\alpha}_L}{\tilde{\alpha}_H} = \tilde{R}_1,$$

which is true since we are in Case B.

To prove the other claims, note that

$$\frac{\partial h}{\partial R} = -\frac{(R-1)\left(R\left(1-\alpha_H\right)+\lambda+\alpha_H\right)}{R^2\left(\lambda+\alpha_H\right)} < 0$$

and hence

$$\frac{\partial^2 h}{\partial \tilde{\alpha}_H \partial R} = \frac{(1+\lambda)(R-1)}{R\left(\lambda+\tilde{\alpha}_H\right)^2} > 0,$$

which establishes claims (3) and (4). Note next that

$$\frac{\partial h}{\partial \tilde{\alpha}_H} = \frac{\lambda - \lambda^2 - 2\lambda\tilde{\alpha}_H}{\tilde{\alpha}_H\left(\lambda+\tilde{\alpha}_H\right)^2} + \left(\ln\frac{\lambda+\tilde{\alpha}_H}{\tilde{\alpha}_H R}\right)\frac{1+\lambda}{\left(\lambda+\tilde{\alpha}_H\right)^2} - \frac{1}{\tilde{\alpha}_H^2}(1-\lambda) + R\frac{1+\lambda}{\left(\lambda+\tilde{\alpha}_H\right)^2}.$$

Claim (4) then implies that if $\partial h/\partial\tilde{\alpha}_H$ is negative at R_1, then it is negative for all $R \in (R_0, R_1)$. We thus need[13]

$$\left.\frac{\partial h}{\partial \tilde{\alpha}_H}\right|_{R=R_1} = \frac{\lambda - \lambda^2 - 2\tilde{\alpha}_H\lambda}{(\lambda+\tilde{\alpha}_H)^2} - \frac{1-\lambda}{\tilde{\alpha}_H} + \frac{1+\lambda}{\lambda+\tilde{\alpha}_H} < 0.$$

Multiplying by $\tilde{\alpha}_H(\lambda+\tilde{\alpha}_H)^2$, we require

$$\tilde{\alpha}_H(\lambda - \lambda^2 - 2\tilde{\alpha}_H\lambda) - (1-\lambda)(\lambda+\tilde{\alpha}_H)^2 + \tilde{\alpha}_H(1+\lambda)(\lambda+\tilde{\alpha}_H) < 0,$$

which simplifies to $(2\tilde{\alpha}_H - 1) + \lambda < 0$. Using the fact that $1 - \lambda = \tilde{\alpha}_L + \tilde{\alpha}_H$, this simplifies to $\tilde{\alpha}_H < \tilde{\alpha}_L$ which is true for $\tilde{\theta} > \frac{1}{2}$. ■

To establish Lemma 5, note that from the proof of Lemma 12, if $\theta < \frac{1}{2}$, we have $\mathbb{E}p_L(\theta) < \mathbb{E}p_H(\theta)$. By construction, $\mathbb{E}p_L(1) > \mathbb{E}p_H(1)$. Since $\mathbb{E}p_L(\theta)$ and $\mathbb{E}p_H(\theta)$ are continuous in θ, this establishes existence.

[13] Note that the term containing the logarithm drops at $R = R_1$.

To establish uniqueness we need to show that $\mathbb{E}p_L - \mathbb{E}p_H$ is monotonic in θ for $\theta \in (\frac{1}{2}, 1)$. Note that

$$\frac{dh}{d\tilde{\theta}} = \frac{dh}{d\tilde{\alpha}_H}\frac{d\tilde{\alpha}_H}{d\tilde{\theta}} = -\mu\frac{dh}{d\tilde{\alpha}_H},$$

where we use the fact that $d\tilde{\alpha}_H/d\tilde{\theta} = -\mu$. Hence it is sufficient to have that h is monotonic in $\tilde{\alpha}_H$, which is true from Claim 2 in Lemma 12. ■

Proof of Theorem 2. We check whether both firms setting the same list price P can be an equilibrium. The expected profit per firm would then be $\frac{1-\lambda}{2}P$. We proceed with the following steps:

1. Suppose firm i deviates to a lower list price with a relatively large deviation such that $R = P/P_i \geq R^*$. From Proposition 2, i then has the lower expected transaction price, so all partially informed consumers visit i. Firm i's profits are thus given by

$$\Pi_i^d(P_i; P) = \begin{cases} (1-\alpha_H)P_i & \text{if} \quad P_i \leq P/R_1 \\ \frac{(1-\alpha_H)\alpha_H}{1-\alpha_L}P & \text{if} \quad P_i \in (P/R_1, P/R^*]. \end{cases} \tag{33}$$

   With $(1-\alpha_H)P_i$ strictly increasing in P_i, it is never a best reply to price strictly below P/R_1. Hence, the best possible defection in this range yields a deviation profit of $\Pi_i^d = \frac{(1-\alpha_H)\alpha_H}{1-\alpha_L}P$. This is weakly lower than $\frac{1-\lambda}{2}P$ whenever $\lambda \geq \frac{1-\mu}{3}$. Hence, for $\lambda \geq \frac{1-\mu}{3}$, firm i (weakly) prefers setting $P_i = P$ over any $P_i \leq P/R^*$.

2. Suppose firm i deviates to a lower list price with a relatively small deviation such that $R = P/P_i < R^*$. From Proposition 2, not all partially informed consumers go to i. Moreover, i and j must have the same expected transaction price. Following (16), i's profits in this interval are

$$\Pi_i^d(P_i; P) = \frac{(1-\tilde{\alpha}_H)\tilde{\alpha}_H}{1-\tilde{\alpha}_L}P = \frac{(1-\tilde{\alpha}_H)\tilde{\alpha}_H}{\tilde{\alpha}_H+\lambda}P.$$

   This implies that

$$\frac{d\Pi_i^d(P_i;P)}{dP_i} = \frac{\partial\Pi_i^d(P_i;P)}{\partial\tilde{\alpha}_H}\frac{d\tilde{\alpha}_H(P_i)}{dP_i} = -\left[1 - \frac{(1+\lambda)\,\lambda}{(\lambda+\tilde{\alpha}_H)^2}\right]P\frac{d\tilde{\alpha}_H}{dP_i}. \tag{34}$$

Using the implicit function theorem,

$$\frac{d\tilde{\alpha}_H}{dR} = -\frac{\partial h/\partial R}{\partial h/\partial \tilde{\alpha}_H} < 0,$$

as follows from claims (2) and (3) of Lemma 12. With $R = P/P_i$, it therefore holds that

$$\frac{d\tilde{\alpha}_H}{dP_i} = \frac{d\tilde{\alpha}_H}{dR}\frac{dR}{dP_i} > 0.$$

Hence, we have that $\frac{d\Pi_i^d(P_i;P)}{dP_i} \geq 0$ for all $P_i \in (P/R^*, P)$ if and only if the squared term in (34) is weakly negative over this range. As this term strictly increases in $\tilde{\alpha}_H$, which in turn strictly increases in P_i by the previous result, this requires that $\lim_{P_i \to P}\left[1 - \frac{(1+\lambda)\lambda}{(\lambda+\tilde{\alpha}_H)^2}\right] \leq 0$. As $\lim_{P_i \to P} \tilde{\alpha}_H = \frac{1-\lambda}{2}$, this condition is equivalent to

$$1 - \frac{4\,(1+\lambda)\,\lambda}{(1+\lambda)^2} \leq 0,$$

which reduces to $\lambda \geq 1/3$. Hence, $\frac{d\Pi_i^d(P_i;P)}{dP_i} \geq 0$ for all $P_i \in (P/R^*, P)$ if and only if $\lambda \geq 1/3$. In this case, firm i thus clearly prefers setting $P_i = P$ over any $P_i \in (P/R^*, P)$. On the other hand, for $\lambda < 1/3$, it holds that $1 - \frac{4(1+\lambda)\lambda}{(1+\lambda)^2} > 0$ and hence that $\frac{d\Pi_i^d(P_i;P)}{dP_i} < 0$ for all P_i sufficiently close below P, such that firm i would like to deviate downward starting from $P_i = P$.

3. Suppose that for $P < 1$ firm i deviates to a higher list price with a relatively small deviation such that $R = P_i/P < R^*$. That yields $\Pi_i^d(P_i;P) = \tilde{\alpha}_H P_i$, so

$$\begin{aligned}\frac{d\Pi_i^d(P_i;P)}{dP_i} &= \frac{d\tilde{\alpha}_H}{dP_i}P_i + \tilde{\alpha}_H \\ &= \frac{d\tilde{\alpha}_H}{dR}\frac{dR}{dP_i}P_i + \tilde{\alpha}_H \\ &= -\frac{\partial h/\partial R}{\partial h/\partial \tilde{\alpha}_H}\frac{P_i}{P} + \tilde{\alpha}_H.\end{aligned}$$

Evaluated at $P_i = P$, it can now be checked that the first term is zero, hence

$$\left.\frac{d\Pi_i^d(P_i;P)}{dP_i}\right|_{P_i=P} = \frac{1-\lambda}{2} > 0.$$

4. Consider $\lambda \geq 1/3$. With $P = 1$, the only feasible deviation is one to a lower list price. Steps 1 and 2 then imply that $P = 1$ is an equilibrium. Step 3 implies that any $P < 1$ cannot be an equilibrium as it would be profitable to deviate to a slightly higher list price.

5. Consider $\lambda < 1/3$. From step 2, we immediately have that any firm wants to deviate from any symmetric equilibrium.

■

Appendix B: Numerical analysis

Our numerical approach proceeds as follows. For any (λ, μ), we discretize the relevant action space by breaking down the candidate support $[\underline{P}_{min}, 1]$ into l actions $a_1, ..., a_l$, where a_k ($k \in \{1, ..., l\}$) amounts to choosing $P = \underline{P}_{min} + (k-1)\left(\frac{1-\underline{P}_{min}}{l-1}\right)$. We then use Proposition 1 to construct a $l \times l$ payoff matrix A, where a_{ij} gives i's expected profit when choosing a_i, while j chooses a_j. We set $a_{ii} = \frac{(1-\alpha_L)\alpha_L}{1-\alpha_H} a_i$ on the main diagonal. Hence the row player is treated as having a strictly higher recommended retail price in case of a tie. This slightly increases players' incentives to compete, but improves accuracy by creating just a single discontinuity in payoffs around $a_i = a_j$.

Let f_k denote the $(l-k+1) \times 1$ vector describing the frequency distribution of actions $(a_k, ..., a_l)$. Let ι_k denote a vector of ones of corresponding length. Finally, let A_k be the $(l-k+1) \times (l-k+1)$ submatrix of A with rows k to l and columns k to l. Then, for given k, the following linear system in f_k is a candidate equilibrium with expected profit γ:

$$A_k f_k = \gamma \cdot \iota_k \tag{35}$$

$$\iota_k' f_k = 1. \tag{36}$$

Here, a_k serves as a guess for the lower bound $\underline{P}$ of $G(P)$. Equation (35) then states that for given support $\{a_k, ..., a_l\}$, each action must yield the same payoff γ (using the fact that $G(P)$ cannot contain gaps), while (36) requires that the frequencies sum to one.

To numerically approximate the equilibrium, we use the following algorithm. First, take $k = 1$. Second, solve the above linear system of $l - k + 2$ equations in $l - k + 2$ unknowns for f_k and γ. If A_k is invertible and $\iota_k' A_k^{-1} \iota_k \neq 0$ a unique solution exists and is given by[14]

$$\gamma = \frac{1}{\iota_k' A_k^{-1} \iota_k} \tag{37}$$

$$f_k = \frac{A_k^{-1} \iota_k}{\iota_k' A_k^{-1} \iota_k}. \tag{38}$$

If $f_k > 0$, we have a solution. If not, increase k by 1 and repeat the procedure. The fact that $\underline{P} < 1/R_0$ provides a further robustness check: the algorithm should terminate for some k such that $a_k < 1/R_0$. Otherwise, it fails to find the equilibrium.

Figure 10 gives an example of the approximation of the density function for $\lambda = 0.4$ and $\mu = 0.2$. For these parameter values, we can also use Proposition 4. This allows us to check the performance of our numerical procedure. With $l = 201$ grid points, our algorithm stops at $k = 78$ for an estimated lower bound of $\underline{P} = 0.53875$. The frequency distribution appears to be comprised of three different parts, with transitions at around $0.67 \approx 1/R_0$ and $0.81 \approx \underline{P} R_0$.[15] This is indeed what is also implied by Proposition 4. Figure 11 shows the corresponding CDF.

[14]To see this, note that we may first multiply (35) by $\iota_k' A_k^{-1}$ from the left (if A_k is invertible), resulting in $\iota_k' f_k = \gamma \cdot \iota_k' A_k^{-1} \iota_k$. Substituting $\iota_k' f_k$ from equation (36) and dividing through $\iota_k' A_k^{-1} \iota_k$ then yields (37). Plugging this back into $f_k = \gamma \cdot A_k^{-1} \iota_k$ (as obtained from (35)) finally gives f_k.

[15]The apparent discontinuity between the first and second price in the discretized support is an artifact of the discretization. It vanishes as the grid size l increases.

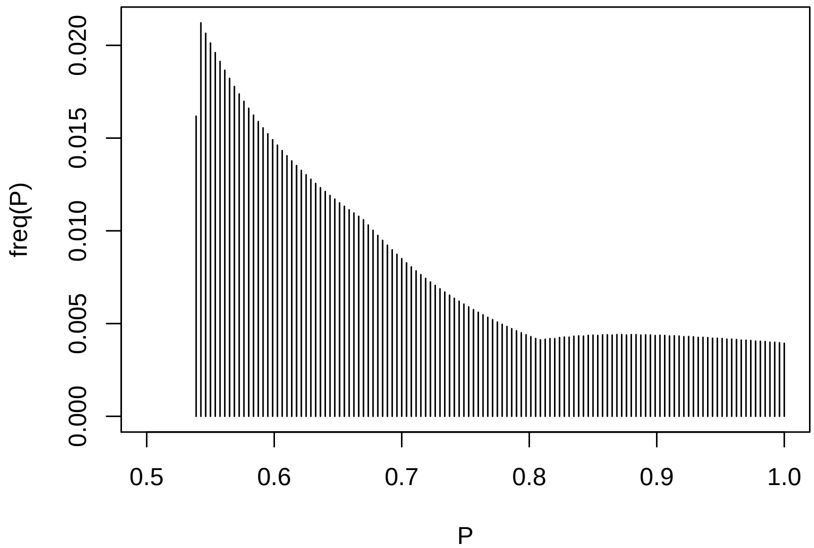

Figure 10: Approximated equilibrium frequency distribution ($\lambda = 0.4$, $\mu = 0.2$).

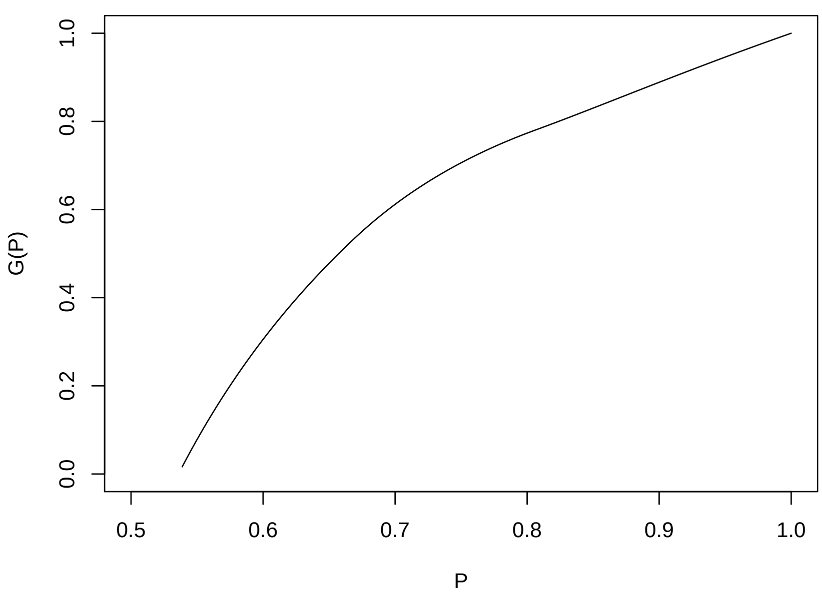

Figure 11: Approximated equilibrium CDF ($\lambda = 0.4$, $\mu = 0.2$).

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Marco Haan, Pim Heijnen, Martin Obradovits

Competition with List Prices

Abstract
This paper studies the competitive role of list prices. We argue that such prices are often more salient than actual retail prices, so consumers' purchase decisions may be influenced by them. Two firms compete by setting prices in a homogeneous product market. They first set a list price that serves as an upper bound on their retail price. Then, after having observed each other's list price, they set retail prices. Building on the canonical Varian (1980) model, we assume that some consumers observe no prices, some observe all prices, and some only observe list prices. We show that if the latter partially informed consumers use a simple rule of thumb, the use of list prices leads to lower retail prices on average. This effect is weakened if partially informed consumers are rational.

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