Price vs. Product Features obfuscation by competing firms.

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Abstract

In this paper we study market outcomes in a setting where competing firms can influence the shopping behavior of consumers. When choosing the best deals consumers look for the best combination of price and product features. We allow for the possibility to separate price information from product feature information and study the incentives of firms to obfuscate each dimension separately. In equilibrium firms randomize in their price choice over some interval. We characterize several outcomes depending on the assumptions as to consumer purchasing behavior. In general, the firms that charge higher prices are more likely to limit consumers' ability to price shop but at the same time encourage product comparison, by making their product features transparent and keeping their niche customers. By contrast firms that compete by choosing low prices tend to make it easier for consumers to compare prices, but would choose to increase their demand beyond their niche consumers by making their product features more difficult to compare across firms. Increasing competition, via more competitors in the market, forces firms to choose more often the strategy of high and hardly comparable prices with transparent products. We then aim to test these theoretical predictions as to equilibrium market outcomes in the laboratory setting.

Introduction

In standard models of competition consumers are assumed to be perfectly able to compare several offers and to choose the one with the highest value to them. Empirically, however, studies have shown that consumers do not always choose the best offer. Consumers experience challenges when comparing different offers, which may be explained both by various psychological biases and by the fact that consumers face a cost of comparing several offers. Consumers might not readily observe either the price or the product characteristics of a good, or both of them. Firms have the power to affect the consumers' cost of comparing offers, by making their own offers more complex, ensuring that it is hard to perceive and compare the real value of their goods.

One way that this could be done is by presenting products and prices in different framing or measurement units, which are costly for consumers to convert into a single dimension for comparison. Examples of complex prices and products can be seen in various sectors including credit offers in finance, mobile phone tariffs, the airline industry and electricity contracts as well as high tech products, computers, mobile phones, cameras, etc. Consider a rather simple choice example of purchasing a shampoo from a large retailer. Each shampoo is suited to a particular hair type: however some brands make their characteristic more explicit than the others, i.e. they make it easier for a consumer to understand the specific features of their product while the other brands leave it to a consumer to find out their characteristics and whether their product is suitable for this particular consumer, by emphasizing only one feature, or by putting the detailed product description in a small print, or by claiming that the shampoo is suitable for all types of hair. At the same time the price frames of several shampoo brands differ substantially: price per different volume of a bottle, various bundles with other beauty products, various promotion events and so on. Therefore it becomes costly for consumers to compare and understand the actual matching value and price of an even relatively simple product when faced with costly comparison on both dimensions: price and product characteristics. Costly comparison may affect what kind of information consumers acquire prior to their purchasing decision. If market prices are too complex to understand consumers may abandon the idea of price comparison and select a product with the highest matching value. On the other hand if product features are difficult to understand consumers might just invest in price comparison and buy the cheapest product. As a result of costly information acquisition prior to purchasing consumers can make suboptimal choices

Manufacturers and retailers invest a considerable amount of time and money into opportunities to differentiate their products, leverage their brands, set strategic prices, and reduce the effectiveness of consumer search. The UK's Office of Fair Trading launched a high profile study in October 2009 in an attempt to understand what kind of pricing practices are more likely to harm consumers and what are the relevant policies that can minimize this harm. The question that we address is the following: if firms can influence consumers' shopping behavior by making price or product features or both easy or hard to compare with the products of their competitors, which dimension wil theyl choose to obfuscate and under which conditions? Would the market outcome result in more complex and incomparable prices and product features or would competition, in the sense of more firms in the market, correct for consumer biases and lead to more transparent pricing and product characteristics.

In this paper we study market outcomes in a setting where competing firms can influence the proportion of consumers that shop using price comparison and the proportion of consumers that shop using product comparison. We also consider richer consumer shopping behavior but the qualitative results are identical to the base line model. We enrich the price complexity game of Carlin (2009) by introducing heterogeneous products into the setting. When shopping for the best deals, consumers look for the best combination of price and matching value. We allow for the possibility to separate price information from product feature information, and we study the incentives of firms to obfuscate each dimension separately, by choosing the level of complexity of both dimensions. At equilibrium firms randomize in their price choice over some interval. The firms that charge higher prices are more likely to limit the consumers' ability to price shop but at the same time encourage product comparison, by making their product features transparent and keeping their niche customers. By contrast, firms that compete by choosing low prices tend to make it easier for consumers to compare prices, but would choose to increase their demand beyond their niche consumers by making their product features more difficult to compare across the firms. Increasing competition, via more competitors in the market, forces firms to choose more often the strategy of high and hardly comparable prices with transparent products. Followig this, we study the effect of entry and regulation of the levels of complexity. More firms in the market leads to firms choosing complex prices and transparent products more often and increases the average market price. Imposing a cap on price complexity leads to lower prices but a more frequent choice of complex prices by competing firms, whereas imposing a cap on product complexity leads to lower and more transparent prices but to more frequent choice of product complexity. As a result, introducing a cap on both types of complexity leads to more transparent market prices and products.

Furthermore, we extend the basic model by allowing firms to vertically differentiate their products. Complexity represents the amount of time and effort it takes to perceive the actual price and quality of the offer and how difficult it is to make a comparison across the offers.

At equilibrium, firms that charge higher margins adopt high complexity and firms that charge lower margins compete by adopting low complexity. Depending on the shape of preferences and the cost function, high complexity is adopted by firms that provide low or high quality. The existence of product variety is a result of the strategic use of complexity by the firms. An example of such a mixed strategy can be seen in the presence of a broad choice of different mobile phone contracts, when there is no difference in real economic value between them, but the contracts are hardly comparable.

The rest of the paper is organized as follows. Section 2 discusses the related literature. In section 3 we introduce the basic model set-up. In our model heterogeneous firms compete for market share by choosing their price and how easy it is to compare their price and product characteristics with that of a competitor. Consumers are divided into two groups: price experts and product experts. Price experts can easily compare prices but do not observe the corresponding matching values, while product experts observe easily all the matching values but do not observe prices of the firms. The equilibrium proportion of both types is determined by the aggregate market complexity level. Each firm, therefore, by its own complexity choice, exerts an externality on other firms by affecting the aggregate market complexity and therefore the proportion of both types of consumers.

The proportion of product experts increases with aggregate price complexity and decreases with aggregate product complexity.

In section 4 we provide a discussion of the main results.

In section 5 we extend the basic model by introducing the possibility for the firms to vertically differentiate their products.

Finally section 6 concludes.

Related Literature

Our work is related to three main classes of literature: a literature on price dispersion when search is costly, a literature on consumer obfuscation by limiting the extent of price comparison and a literature on obfuscation when the the product features are costly to evaluate.

Several lines of research have addressed the issue of price dispersion and consumers not buying the cheapest product in markets with homogeneous goods. The presence of consumers that do not search at equilibrium softens price competition and results in prices higher than marginal costs. Moreover increasing the number of firms might lead to higher market prices.

The main examples of these works include the "search-theoretic" models of Stigler (1961), Rothschild (1973), Burdett and Judd (1983), and Stahl (1989, 1996) and the "information clearing house" models of Salop and Stiglitz (1977), Varian (1980), Rothenthal (1980), Morgan, Orzen and Sefton (2001). In these models, price dispersion and positive mark-ups exist due to the fact that some proportion of consumers, either exogenously given or endogenously determined,do not search for the best value product. The introduction of a simple clearing house, such as the internet, where consumers could obtain the information about all the prices, eliminates the problem completely.

Dubovik (2009) introduces quality to the above analysis and studies the market outcome when an exogenous proportion of consumers with homogeneous preferences over quality observe neither price nor quality before purchasing. He shows that at equilibrium there is price and quality dispersion. The mixed strategy of the firms over price and quality takes the same form as the mixed strategy over the prices found by Varian (1980), if the price is replaced by the margin, and all the results of Varian (1980) remain valid. He finds that depending on the shape of consumer preferences and the cost function of the firms, in equilibrium there is under or over provision of quality, and quality dispersion exists due to the fact that some consumers are uninformed. Alternatively Armstrong and Chen (2008) study the market outcome with some consumers being inattentive to product qualities. The equilibrium results in the provision of both low and high quality goods, even when the low quality goods are not socially desirable. In equilibrium firms earn positive profits due to the existence of the inattentive consumers. Increasing the number of attentive consumers brings the prices and qualities closer to the competitive level and increases consumers welfare.

Several works are concerned with how firms can influence the searching cost of consumers. This literature in turn can be divided into two blocks: firms with homogeneous goods that can influence price comparison by consumers, and firms with horizontally or vertically differentiated products that can affect product comparison. The closest to our work in terms of modelling is Carlin (2009). In his price complexity game it is costly for consumers to compare several offers when faced with complex tariffs. The costs in his model increase in the aggregate market complexity. Thus, prior to a decision of whether to compare prices and choose the best offer or to buy randomly, a consumer learns the aggregate market price complexity, which determines his purchasing behavior. In this model firms' individual choice of price complexity affects the buyers' costs of comparison, and therefore exerts an externality on the demand of other firms. This shifts the proportion of consumers that choose to be informed and, therefore, the profits of all the firms in the market. At equilibrium price dispersion arises because the firms compete strategically for market share from both types of consumers. The firm with the lowest price captures the entire share of the informed consumers. All of the firms, however, share the demand from the uninformed consumers. Piccione and Spiegler (2009), consider a setting with homogeneous goods, where firms choose different frameworks for their price presentation, from simple to compare to harder to compare. The choice of framework affects the number of price informed consumers. The qualitative results are similar to Carlin (2009).

A number of works considers a setting with heterogeneous goods, allowing for the possibility for firms to obfuscate on the product information dimension. Scitovsky (1950) argued that sellers might have an incentive to confuse buyers by emphasizing the extent to which products differ and by stressing their technical, chemical or functional complexity. Perloff and Salop (1985) show that price-cost margins are increasing in the degree of product differentiation, and that this holds irrespective of whether the differences between products are "real" or "spurious". Anderson and Renault (1999) study the role of product differentiation and search costs in such an environment. In the limit, their model yields the Diamond paradox (as product differentiation vanishes), monopolistic competition (as search cost become negligible) and the Bertrand paradox (as search costs and differentiation disappears). Gabaix and Laibson (2004) extend this analysis by showing that firms have incentives to make products inefficiently complex. Similarly Spiegler (2006) demonstrates that if goods have multiple dimensions and consumers cannot evaluate all of them, firms will have incentives to make it hard from consumers to compare the value of the goods. In these models limiting the extend to which the products are complex benefits consumers and restores a competitive outcome. Increasing the number of competing firms may or may not, depending on the setting, result in more competitive pricing. Moreover, the firm supplies consumers with either full information about its product or no information at all before they start searching.

Bar-Isaac et al. (2011) study firms' product design choices in a competitive environment with sequential search. Their results suggest that low quality firms choose extremal designs with large taste heterogeneity whereas high quality firms try to appeal to a broad mass of consumers.

The literature on advertising addresses the related issue of limited information of consumers.

Lewis and Sappington (1994) show that a monopolist either perfectly informs consumers about their valuation for its product or provides no information at all.

Anderson and Renault (2000) in their work "Product Characteristics and Price Advertising with Consumer Search" propose a framework to analyze the incentives for firms to provide various types of information. This work is closely related with our analysis but in the context of a single seller. In the equilibrium, price-only and price-and-characteristic, advertising can arise depending on the relative strength of product differentiation and consumer search costs. When the search costs are large and the firm must advertise to bring in consumers, the firm may still prefer to keep consumers in the dark about how much they like the product. Even when the firm finds it optimal to inform consumers of both their match values and the price charged, the level of advertising is too small because the firm only accounts for its private benefit per consumer informed when determining how much to advertise, and not the extra benefit to consumers of making a valuable match

Our work contributes to the existing literature by enriching the model of Carlin (2009) by introducing exogenous product heterogeneity in order to allow firms to obfuscate price and product features at the same time. Our paper is the first to our knowledge to analyze the incentives of firms to obfuscate on the price vs. product dimension, and to study the conditions for which obfuscation on one dimension is preferable to obfuscation on another. We then extend the basic set-up by introducing vertical differentiation and study the incentives of firms to obfuscate the net value of a product as well as to differentiate their products. We further analyze the impact of policies targeted on regulation of market complexities.

Basic model

There are n single-product firms, for which marginal production costs are zero. The firms choose their prices and how difficult is to compare their product and prices across the firms.

Consumers

There is a continuum of ex-ante identical consumers. The utility of a representative consumer from buying product i at price p_i is of the form:

$$u_i = v - p_i + \mu\varepsilon_i$$

The parameter μ is a scale parameter that captures the heterogeneity of consumer tastes and ε_i is the realization of a random variable with distribution G and a continuously differentiable density g whose support is an interval $[a, b]$ of the extended real line. The term $\mu\varepsilon_i$ can be interpreted as a match value between the consumer and product i, and these match values are assumed to be independent across consumers and products. The match value can be viewed as a non-monetary utility to a consumer. The monetary valuation (income) of each consumer us given by v (limited liability), i.e. the highest price that consumers can pay is given by v.

Consumers are divided in 2 types: *price experts*, and *product experts*. The qualitative results hold when allowing for more types of consumers: those who do not compare at all and net-value experts. However for the ease of exposition we present a simplified model with these two types.

Price experts only observe prices but do not observe matching value and therefore choose the product with the lowest price. *Product experts* observe the matching value of all the products but do not observe prices and therefore choose the product with the highest matching value for them. The proportion of price experts consumers is given by λ^p and the proportion of product experts is thus given by $(1 - \lambda^p)$.

Firms

Firms choose their prices as well as the complexity of their price structures (k_i^p) and the complexity of their product features (k_i^ε). The choice of k is costless. The price complexity choice represents how difficult it is to compare several prices and product complexity represents how difficult it is to compare across different matching values. Price complexity can be thought of as the amount of individual fees the price structure is divided into. Product complexity can be thought of the number of features the product consists of and how easily these features are compared with other products.

The aggregate complexity of the market price (K^p) and of the products (K^ε) determine the resulting proportion of different types of consumers. The aggregate complexities are given by the sum of firms' individual complexities choices, $K^{p,\varepsilon} = \sum_i^n k_i^{p,\varepsilon}$. The proportion of price experts λ^p is determined by the multivariate map

$$\lambda^p : [(k_L^p, k_H^p) \times (k_L^\varepsilon, k_H^\varepsilon)]^n \to [0, 1]$$

Assumption 1

$$\frac{d\lambda^p}{dk_i^p} < 0; \frac{d\lambda^p}{dk_i^\varepsilon} > 0; \frac{d^2\lambda^p}{dk_i^p dk_j^p} = \frac{d^2\lambda^p}{dk_i^\varepsilon dk_j^\varepsilon} = 0;$$

The proportion of price experts decreases with the firm's individual choice of its price complexity and increases with the firm's choice of product complexity. Each firm when choosing its complexity levels exerts an externality on other firms, by influencing the resulting proportion of price and product experts. If the product comparison becomes harder with respect to price comparison, more consumers will shop based on price comparison, and vice versa. The last assumption is adopted for simplicity.

Timing

In period 1 each firm i chooses its price, $p_i \in [0, v]$ as well as the complexity of the price and of the product, $k_i^d \in [k_L^d, k_H^d]$. The aggregate complexity levels determine the resulting proportion of price and product experts, λ^p and $1 - \lambda^p$. In period 2 matching values are realized and consumers make their purchase decision. *Price experts* observe all prices but do not observe product characteristics while *product experts* learn product characteristics, but do not observe prices.

Equilibrium

Let $\Sigma_i = [0, v] \times [k_L^p, k_H^p] \times [k_L^\varepsilon, k_H^\varepsilon]$ be the strategy space of firm i and $\sigma_i \in \Sigma_i$ be its (mixed) strategy. In any $Nash$ equilibrium the strategies of the firms are given by the vector $\sigma^* = [\sigma_1^*, \sigma_2^*, ..., \sigma_n^*]$.

Let $F_i(p)$ be the equilibrium probability distribution of prices of firm i, with $F_i(p)$ equal to one being a pure strategy, i.e. firm i chooses price p with probability 1.

Then, the profit of the firm i is given by:

$$\Pi_i = p_i(\prod_{j \neq i}[1 - F_j(p)]\lambda^p + G(\varepsilon_i)^{n-1}(1 - \lambda^p)$$

where $\prod_{j \neq i}[1 - F_j(p)]$ is the probability that firm i has the lowest price out of n firms and thus gets the whole fraction of price experts and $G(\varepsilon_i)^{n-1}$ is the probability that firm i has the highest realized matching value and thus gets the whole fraction of product experts.

Denote $\Gamma(k_i^p, k_i^\varepsilon | \sigma_{-i})$, the conditional expectation of λ^p given a choice of k_i^p and k_i^ε for firm i and the strategies of the other firms.

Thus, firm $i's$ expected profit can be written as:

$$\Pi_i(k_i^p, k_i^\varepsilon, p_i | \sigma_{-i}) = p(\prod_{j \neq i}[1 - F_j(p)]\Gamma + \Pr(\varepsilon_i > \max \varepsilon_j)(1 - \Gamma)$$

Assumption 2 Consumers do not observe the individual choice of firms' complexities, nor do they observe the identity of firms.

This assumption states that even though consumers rationally anticipate the equilibrium prices and complexities distribution, product experts cannot identify which firm charges which price and therefore all the firms have ex-ante the same expected price, and thus product experts make their purchase decision solely based on the observed matching values. Therefore the ex-ante probability for each firm to attract product experts given its price and complexity choice is the same for each firm and is given by:

$$\Pr(\varepsilon_l > \max \varepsilon_j) = \int_a^b G(\varepsilon)^{n-1} g(\varepsilon) d\varepsilon = \frac{1}{n}$$

Therefore the profit of firm i becomes:

$$\Pi_i(k_i^p, k_i^\varepsilon, p_i|\sigma_{-i}) = p(\prod_{j\neq i}[1 - F_j(p)]\Gamma + \frac{1}{n}(1 - \Gamma)).$$

Proposition 1 *There is no pure strategy equilibrium.*

Proof. 1. No symmetric equilibrium

Suppose all firms charge $c < p^* \leq v$. Then firm i has incentives to lower its price by ϵ to get all the demand from price experts and increase its profits.

Suppose all firms charge price $p^* = c$. In this case firms have zero profits and always have incentives to deviate to $p = v$ which generates positive profits.

2. No asymmetric equilibrium

Assume that there exists a unique price p_i^* that each firm chooses in equilibrium such that $p_i^* \neq p_j^*$. Then the firm that does not have the lowest price is getting the same demand that the firm charging higher price. Therefore there is always a profitable deviation to $p = v$. Assume that $n-1$ firms charge price v and 1 firm charges $p < v$ and gets all the demand of price experts. In this case the firm with the lowest price can always increase its price to $v - \epsilon$ and have strictly greater profits. So this cannot be an equilibrium.

Assume half of the firms charge $p = v$ and half charge $p < v$. Then firms that charge lower prices would undercut each other until $p = c$, which leads to lower profits than under $p = v$. So this also cannot be an equilibrium.

Therefore there exists no pure strategy equilibrium. ■

Consider now firm i charging $p = p_L$ or $p = v$. Let $p = p_L$ be the lowest price charged by a firm i,

Proposition 2 *There exists a symmetric mixed strategy Nash equilibrium of this game where firms:*

1) choose their prices according to equilibrium distribution function $F^*(p)$ on $[p_L, v]$:

$$F^*(p) = 1 - [\frac{v(1 - \Gamma^L) - p(1 - \Gamma)}{np\Gamma}]^{\frac{1}{n-1}}$$

$$where\ p_L = \frac{v(1 - \Gamma^L)}{(n-1)\Gamma^H + 1}$$

2) and choose the complexity levels as a deterministic function of their price:

$$\begin{Bmatrix} k^p = k_L \ and\ k^\varepsilon = k_H & for\ p < \widehat{p} \\ k^p = k_H \ and\ k^\varepsilon = k_L & for\ p > \widehat{p} \end{Bmatrix}$$

$$where\ \widehat{p} = F^{*-1}[1 - \frac{1}{n}]^{\frac{1}{n-1}}$$

where

$$\begin{aligned}\Gamma &= E[\lambda^p(k_i^p(p), k_i^\varepsilon(p); \sigma_{-i})] \\ \Gamma^L &= E[\lambda^p(k_H^p, k_L^\varepsilon; \sigma_{-i})] \\ \Gamma^H &= E[\lambda^p(k_L^p, k_H^\varepsilon; \sigma_{-i})]\end{aligned}$$

Proof. 1. The highest price that firm i can charge is v. At this price firm i has no price expert consumers and its demand consists of product experts only. So firm i chooses k^p and k^ε so as to maximize the expected proportion of product experts: $k^p = k_H^p$ and $k^\varepsilon = k_L^\varepsilon$. Therefore the expected proportion of product experts for firm i when charging $p_i = v$ given the strategies of other firms is given by (1- Γ^L). When instead the firm chooses p_L it gets all the price experts, and therefore it maximizes the proportion of price experts by choosing $k^p = k_L^p$ and $k^\varepsilon = k_H^\varepsilon$. The expected proportion of price experts for firm i when charging $p_i = p_L$ given the strategies of other firms is given by Γ^H ∎

From the fact that the expected profit of firm i should be the same as when charging price v, we get :

$$p([1-F(p)]^{n-1}\Gamma + \frac{1}{n}(1-\Gamma)) = v[(1-\Gamma^L)\frac{1}{n}]$$

Therefore the equilibrium $F(p)$ solves:

$$\begin{aligned}F(p) &= 1 - (\frac{v[(1-\Gamma^L) - p(1-\Gamma)]}{np\Gamma})^{\frac{1}{n-1}} \\ p_L &= \frac{v(1-\Gamma^L)}{(n-1)\Gamma^H + 1}\end{aligned}$$

2. Choice of complexity levels of price and product:

The profit of firm i can be expressed as a function of its choice of complexity levels:

$$\begin{aligned}\Pi_i(k_i^p, k_i^\varepsilon, p_i|\sigma_{-i}) &= p([1-F(p)]^{n-1}\widehat{\Gamma}(k_i^p, k_i^\varepsilon) + \frac{1}{n}(1-\widehat{\Gamma}(k_i^p, k_i^\varepsilon))) \qquad (1)\\ &= \frac{p}{n} + p\widehat{\Gamma}(k_i^p, k_i^\varepsilon)([1-F(p)]^{n-1} - \frac{1}{n}) \\ \text{where } \widehat{\Gamma}(k_i^p, k_i^\varepsilon) &= E[\lambda^p(k_i^p, k_i^\varepsilon; \sigma_{-i})]\end{aligned}$$

Choosing k_i^p and k_i^ε so as to maximize 1 amounts to:
maximizing $\widehat{\Gamma}(.)$ when

$$1 - F(p)]^{n-1} - \frac{1}{n} > 0$$

and minimizing $\widehat{\Gamma}(.)$ when

$$1 - F(p)]^{n-1} - \frac{1}{n} < 0$$

Therefore

$$\begin{aligned}
when\ [1-F(p)]^{n-1} &> \frac{1}{n} \text{ then } k^P = k^p_L \text{ and } k^\varepsilon = k^\varepsilon_H \\
when\ [1-F(p)]^{n-1} &< \frac{1}{n} \text{ then } k^p = k^p_H \text{ and } k^\varepsilon = k^\varepsilon_L \\
when\ [1-F(p)]^{n-1} &= \frac{1}{n} \text{ then } k^p \in [k^p_L, k^p_H] \text{ and } k^\varepsilon \in [k^\varepsilon_L, k^\varepsilon_H]
\end{aligned}$$

On the one hand, when a firm charges a low price, the probability of attracting all price experts is relatively high and this gives the firm incentives to maximize the share of price experts by choosing a transparent pricing structure and therefore decreasing the aggregate market price complexity. At the same time, making product comparison more difficult also increases the proportion of price experts. Therefore the firm chooses a high complexity level for its product in order to maximize the proportion of price experts.

On the other hand when a firm charges a high price, the probability of attracting a price expert becomes small and a firm's demand is coming mainly form product experts. Therefore the firm would maximize the amount of product experts by making its product transparent, thereby decreasing aggregate market product complexity and encouraging consumers to shop based on matching value, attracting its niche customers. At the same time the firm would make its price complex in order to discourage price comparison and maximize the proportion of product experts.

Basically when firms charge low prices they engage in price competition and do not want to disclose the niche of their products in order to encourage price shopping, whereas when firms charge higher prices, in order to soften price competition they disclose their niche and keep their captive consumers that prefer their product over the product of others in terms of matching value.

When the number of firm increases the price competition becomes more intense, i.e. the probability of having the lowest price decreases but at the same time the demand from captive product experts decreases as the probability of having the highest matching value decreases simultaneously. The effect on the choice of the complexity levels is summarized in the following proposition.

Proposition 3 *:ENTRY EFFECT: When the number of firms increases, the frequency with which firms choose complex prices and transparent matching values increases. In the limit when n tends to infinity firms make the matching values of products transparent for consumers and prices complex for comparison.*

Proof. The firms choose complex prices and transparent matching values with ex-ante probability given by:

$$1-F^{*}(\widehat{p})=\frac{1}{n}^{\frac{1}{n-1}} \tag{2}$$

■

The derivative of 2 is:

$$-\frac{\left(\frac{1}{n}\right)^{\frac{n}{-1+n}}\left(-1+n+n\mathrm{Log}\left[\frac{1}{n}\right]\right)}{(-1+n)^{2}} \tag{3a}$$

This probability is increasing with n, as 3 is greater than zero. Moreover

$$\lim_{n\longrightarrow\infty}\frac{1}{n}^{\frac{1}{n-1}}=1$$

When the number of competitors increases, the probability of having the lowest price and therefore attracting all the price shoppers decreases faster than the ex-ante probability of having the highest matching value. Therefore firms put more weight on the strategy that limits price comparison and encourages shopping based on matching value comparison, i.e. firms choose high price complexity and transparent matching values more often. If the number of firms is sufficiently large we would observe transparent niche products with complex pricing structures. The aggregate market price complexity increases with the number of firms while the aggregate product complexity decreases.

The following propositions explore how regulation in the form of a complexity ceiling (lower k^{H}) or a complexity floor (higher k_{L}) would affect the price distribution and the aggregate market complexity.

Proposition 4 *:Complexity Regulation.*

1.The price distribution with a smaller upper bound k_{H}^{p} or lower bound k_{L}^{p} of the price complexity interval (or a higher k_{H}^{ε} and k_{L}^{ε} of the product complexity interval) first order stochastically dominates that of with a higher k_{H}^{p} or k_{L}^{p}(or smaller k_{H}^{ε} and k_{L}^{ε}).

2.The frequency of choosing complex prices and transparent products decreases with the upper and lower bound of price complexity and increases with the upper and lower bound of product complexity. Introducing a complexity ceiling for either prices or products lowers both the aggregate market price and product complexity levels.

Proof. The equilibrium price distribution, $F^{*}(p)$ is decreasing with Γ^{H} and Γ^{L}. Note that by construction Γ^{H} and Γ^{L} decrease with k_{H}^{p} and k_{L}^{p} and increase with k_{H}^{ε} and k_{L}^{ε}. ■

According to *Proposition 4* if a regulator wants to decrease market prices the best policy would be to set a ceiling on price complexity, i.e. how complex can firms go in their price structures, or to set a product complexity floor, i.e. to limit the extent to which firms can make their product transparent. Setting instead a ceiling on product complexity results in an adverse effect on price distribution and market prices consequently increase.

An interesting observation is that the policy targeted on lower market prices leads to firms choosing complex prices and transparent products more often, although the aggregate market price complexity still decreases and aggregate product complexity still decreases. The intuition is that when the ceiling for price complexity is introduced, the price competition becomes more fierce and firms have more incentives to minimize the fraction of price experts and maximize that of product experts. As a result, due to the limit on individual price complexity, the aggregate market price complexity decreases, and, due to the increased incentives of firms to limit price comparison, the aggregate product complexity decreases. However the decrease in aggregate market price complexity outweighs the decrease in product complexity, and as a result there are more price shoppers, which decreases market prices.

Consider now a ceiling on the product complexity. As the policy decreases the aggregate market product complexity it encourages consumers to shop more based on matching value comparison which in turn decreases the proportion of price shoppers. For a given proportion of price shoppers, the prices increase, which gives firms incentives to maximize the proportion of product experts and therefore they choose complex products more often than complex prices. As a result both market price and product complexities decrease, with aggregate product complexity decreasing more and shifting the incentives to comparison shop away from price comparison.

Numerical Example:

Let

$$K^p = \sum_{i=1}^{n} (k_i^p - k_i^\varepsilon)$$

and let

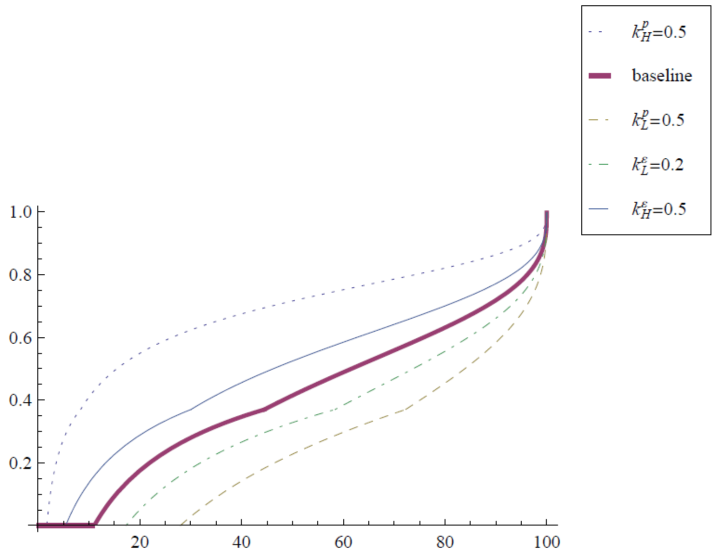
$$\lambda^p = \min[1 - (\frac{\sum_{i=1}^{n} (k_i^p - k_i^\varepsilon)}{n}, 1].$$

Then

$$\begin{aligned}
\Gamma^L &= 1 - \frac{n - 1(\int_{p_L}^{\widehat{p}} (k_L^p - k_H^\varepsilon) f(p)dp + \int_{\widehat{p}}^{v} (k_H^p - k_L^\varepsilon) f(p)dp) + k_H^p - k_L^\varepsilon}{n} \\
\Gamma^H &= 1 - \frac{n - 1(\int_{p_L}^{\widehat{p}} (k_L^p - k_H^\varepsilon) f(p)dp + \int_{\widehat{p}}^{v} (k_H^p - k_L^\varepsilon) f(p)dp) + k_L^p - k_H^\varepsilon}{n}
\end{aligned}$$

Regulation of complexity levels

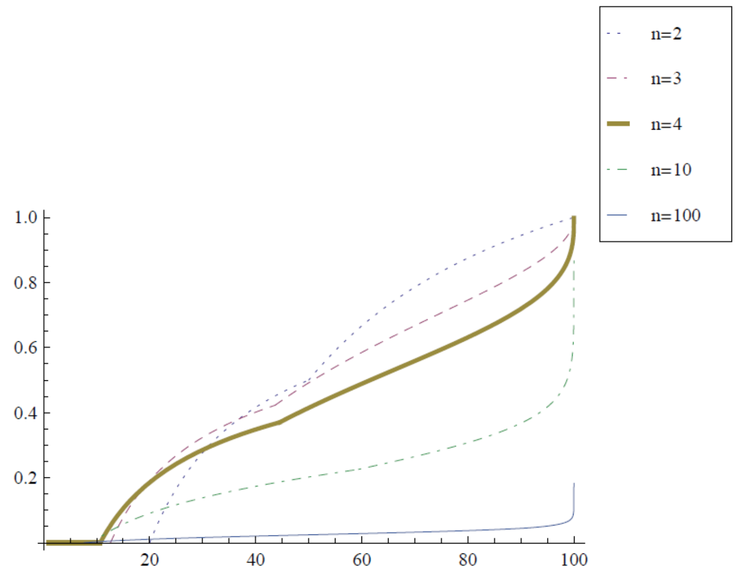
Below is the plot of $F^*(p)$ for $n = 4, v = 100$ and different values of k_H^p, k_H^ε and k_L^p, k_L^ε. We take as a baseline $k_H^p = k_H^\varepsilon = 1$ and $k_L^p = k_L^\varepsilon = 0$.



As seen from the graph above the price distribution shifts up (prices decrease) as the cap on price complexity or a floor on product complexity is imposed. The threshold price for complexity choice shifts left. When the cap is imposed on product complexity instead or a floor on price complexity, the price distribution shifts down (prices increase) and the threshold price shifts right.

Change in number of firms

We run a numerical simulation to analyze the effect of an increase in number of firms on market prices.



The graph above plots the equilibrium price distribution for different numbers of firms on the market. For n greater than four the equilibrium price distribution shifts upwards and therefore prices decrease. For n smaller than four prices increase in the lower part of support and decrease in the upper part. The competition for price experts forces firms to price more aggressively, therefore the minimum price decreases while the average price still increases.

Thus this numerical example demonstrates that increasing number of firms in this setting leads to higher and more complex prices and transparent product characteristics.

General Discussion

This simple framework allows us to analyze the incentives of firms to obfuscate price or product features and to predict the change of the market structure as a result of new entries or regulatory interventions. However the model is based on particular assumptions on the shopping behavior of consumers. The first assumption is that complexity affects the proportion of price experts and product experts. Alternatively consumers can be thought to be heterogeneous in their costs of obtaining price and product information. The costs of obtaining price and product information (c^p and c^ε) are identically and independently distributed across the population of consumers. Aggregate market complexity may alter the distribution of consumers' costs, in a way that affects the equilibrium proportion of price and product shoppers in the similar manner to our assumption. However, due to the analytical complexity of the setting with heterogeneous consumers we adopt a simplified version of the model, where the proportion of price experts is solely determined by the firms' choice of how easy it is to compare their offer with the offers of competitors. In this we abstract from the analysis of the individual consumer searching decision. However we believe that fully endogenizing the decision of consumers about information acquisition would give similar qualitative predictions.

The fact that consumers choose to learn either the price or the matching value and not both is supported by assumption that the marginal increase in expected utility from learning both price and matching value is lower than the additional cost of learning a single dimension:

$$E_p E_\varepsilon \max u_i - (c^p + c^\varepsilon) < \max[E_p \max U - c^p, E_\varepsilon \max U - c^\varepsilon]$$

To gain further intuition as to why it might be optimal to learn and thus compare only one dimension, i.e. price or matching value, consider a simple example of consumer incentives to learn and compare different offers.

Example: Consider 2 firms selling horizontally differentiated goods: $i = 1, 2$

Consumer has a utility from purchasing good from firm i:

$$u_i = v + \varepsilon_i - p_i$$

with ε_i being the matching value of firm i.

Firm 1 charges $p_1 = p_L$ and $\varepsilon_1 = \varepsilon_L$, while Firm 2 charges $p_2 = p_H$ and $\varepsilon_2 = \varepsilon_H$.Assume that the benefit from choosing the lowest price is higher than the benefit from choosing a proper match, i.e. $\triangle p > \triangle\varepsilon$, and $\varepsilon_L > p_H$

If prices and matching values were perfectly observable, a consumer would optimally choose to purchase from Firm 1.

However in the presence of imperfect information, consumers do not or cannot observe and compare prices and matching values. Consumers know that with equal probability ($\pi = \frac{1}{2}$) each firm can have price equal to p_H or p_L and matching value equal to ε_H or ε_L.

Consumers can either incur costs c^p to compare prices, or costs c^ε to compare matching values, or both ($c^p + c^\varepsilon$). Assume $c^p = c^\varepsilon = c$.

Expected utilities from the different strategies are as following:

- No comparison on either dimension:

$$Eu = E\varepsilon - Ep = \frac{1}{2}(\varepsilon_L + \varepsilon_H) - \frac{1}{2}(p_L + p_H)$$

- Comparison of prices:

$$Eu = E\varepsilon - p_L = \frac{1}{2}(\varepsilon_L + \varepsilon_H) - p_L - c$$

- Comparison of matching values:

$$Eu = \varepsilon_H - Ep = \varepsilon_H - \frac{1}{2}(p_L + p_H) - c$$

- Comparison of both dimensions:

$$Eu = \frac{1}{2}(\varepsilon_H - p_L) + \frac{1}{2}(\varepsilon_L - p_L) = \frac{1}{2}(\varepsilon_L + \varepsilon_H) - p_L - 2c$$

The table below summarizes the marginal benefit for consumers from learning additional dimensions.

Marginal benefit of searching:	no comparison (p)	comparison (p)
no comparison (ε)	$\frac{1}{2}(\varepsilon_L + \varepsilon_H - p_L - p_H)$	$\frac{1}{2}\triangle p$
comparison (ε)	$\frac{1}{2}\triangle\varepsilon$	0

It is clear from the table that in this case consumers would choose to compare only the price dimension. In fact it is never optimal in this example for consumers to obtain information on both dimensions.

We also solve the model allowing for a richer consumer behavior. Appendix A provides an analysis when consumers can be of 4 types: price experts, product experts, net-value experts and uninformed. However the qualitative prediction of the analysis are similar to those of the base line model with two types.

Vertical differentiation and complexity

Model set up

Consider a market with n firms, which sell a unit good to consumers and compete in price and quality. The firms face marginal cost $w(q)$ per unit of good of quality q, $\partial w/\partial q > 0$ and have no capacity constraints. Let (p_i, q_i), $i \in \{1, ..., N\}$, be the offer of firm i. Firms choose price and quality and how complicated it is to compare their net value to that of competitors, k_i.

In the market, there is a continuum of consumers of unit mass who each have a unit demand. The preferences of consumers over pair (p, q) are represented by utility function $U(p, q)$.

Assumption 1: The utility function is strictly decreasing in p, strictly increasing in q, continuous in (p, q).

The outside option is given by $U(p^r, q^r)$. Consumers will purchase a good i if

$$U(p_i, q_i) \geq \max\left[U(p^r, q^r), U(p_j, q_j)\right].$$

Consumers are divided into two groups: informed (λ) and uninformed (1-λ). The aggregate complexity of the market (K) determines the resulting proportion of different types of consumers. Consumers do not observe the individual choice of complexity by each firm. The aggregate complexity is given by the sum of firms' individual complexities choices, $K = \sum_i^n k_i$. The proportion of experts λ is determined by the multivariate map

$$\lambda : [(k_L, k_H)]^n \to [0, 1]$$

with

$$\frac{d\lambda}{dk_i} < 0; \frac{d^2\lambda}{dk_i dk_j} = 0;$$

The proportion of experts decreases with the firm's individual choice of its complexity . Each firm when choosing its complexity levels exerts an externality on other firms, by influencing the resulting proportion of experts.

Consider the following three stage game:

In the first period ($t = 1$), the firms simultaneously choose the price and quality of their good. Each firm chooses $p_j \in \left[p_L, p^H\right]$ and $q_j \in \left[q_L, q^H\right]$ and complexity of their net-value $k_i \in [k_L, k_H]$.

The aggregate market complexity is realized and λ is determined. In the second period ($t = 2$) consumers make their purchasing decisions. Consumers do not observe firm's individual pair (p_i^*, q_i^*), but form rational expectations about the equilibrium distribution. Experts choose the product with the highest net-value and uninformed consumers shop based on their information about net-value distribution.

Equilibrium

In this section the firm's maximization problem is considered. We show that an equilibrium results in a positive price mark-up over the marginal costs. We find the symmetric equilibrium in which firms randomize between pairs (p, q) and show that there is always price dispersion and quality dispersion (except if the utility function is quasi-linear in quality, then a unique quality level would prevail on the market).

Let consumers be *endogenously* divided into two groups according to their choice of search technology: the informed and uninformed. Suppose a fraction λ of consumers is informed and the remaining fraction $(1 - \lambda)$ is uninformed. The mixed strategy equilibrium of this game with exogenous λ is fully characterized by Dubovik (2008). Some properties of the equilibrium strategies:

1. The pairs (p^*, q^*) that are offered in equilibrium solve the problem

$$\max_{(p,q)}(p - w(q)) \qquad (3)$$
$$s.t. U(p,q) \geq u$$

for every u.

Consumers and firms have opposing interests with respect to the pair (p, q), so it is reasonable to assume that this problem has a solution. A slightly stronger assumption is needed to guarantee the uniqueness of the solution:

Assumption 2: Problem (3) has a unique solution ($q^*(u), p^*(u)$) for every u. There exists a continuous function $g(p)$ such that $q^*(u) = g(p^*(u))$ for given u.

Assumption 1 and Assumption 2 allow us to claim that the pairs (p^*, q^*) that would be offered in equilibrium would lie on the contract curve, as choosing $(p^*, g(p^*))$ strictly dominates all other choices. Also these assumptions imply that utility over a contract curve, $U(p, g(p))$, is strictly monotone in p.

2. Let

$$m(p) = p - w(g(p))$$

The following is true: (for proof see Dubovik,(2008), $Lemma 1$)

$$U(p_i, g(p_i)) > U(p_j, g(p_j)) \Longleftrightarrow m(p_i) < m(p_j)$$

Assuming that there exists $m^{-1}(p_i) = p_i$ then $\widetilde{U}(m_i) = U(p_i, g(p_i)) > \widetilde{U}(m_j) = U(p_j, g(p_j)$. It is reasonable to assume that $\frac{d^2U}{dm^2}(m(x)) > 0$, as the expected property of utility function is to be concave in the surplus, therefore convex in the margin.

So choosing p and q translates for the firms into choosing m.

Now the analysis of Carlin (2009) can be carried out replacing prices with margins.

Equilibrium Distribution of Prices and Quality

There is a price and quality dispersion in the equilibrium except of the case when $U(p, q) = h(q) - p$. In this case there is a unique quality offered and dispersion exists only in prices. In equilibrium only the lowest or the highest level of complexity is chosen. The firms that charge higher margins choose high complexities and the firms that choose low margins choose low complexity. In the case of costly information acquisition, at equilibrium prices are higher than the marginal costs and firms have positive profits, due to the strategic use of the complexity by the firms.

Depending on the shape of consumer preferences and the firms' cost functions, the equilibrium dispersion of margins and complexity translates into the equilibrium of price and quality pairs in the following way:

Case 1 Utility is strictly decreasing in p. In this case:

$$U(p_i, g(p_i)) > U(p_j, g(p_j)) \Leftrightarrow p_i < p_j$$

so that informed consumers will buy the cheapest product. Decreasing utility is consistent with both increasing and decreasing $g(p)$:

a) $g(p)$ is increasing in p: as in the basic model equilibrium, this results in informed consumers choosing the lowest price and lowest quality. Uninformed consumers get higher prices and higher qualities. Firms that offer higher quality and higher prices choose high complexity.

b)$g(p)$ is decreasing in p: in equilibrium informed consumers still buy the cheapest good but now the good is of the highest quality. Uninformed consumers pay higher prices for a lower quality compared to informed consumers.

Firms that offer higher prices and lower quality choose high complexity.

Case 2: Utility is strictly increasing in p.

In this case the informed consumers would buy the most expensive good. $g(p)$ is strictly increasing. Uninformed consumers buy goods of lower price and quality.

In equilibrium firms that offer low price and quality choose high complexity.

NUMERICAL EXAMPLE

Conclusions

The existing literature on obfuscation shows that firms choose to limit the product net-value comparison by consumers. However the dimension that firms might obfuscate is usually exogenously chosen: either price or product features. In this paper we provide analysis of firms' incentives to limit comparison by consumers of net value of horizontally or vertically differentiated products. The firms choose which dimension if any they obfuscate. We adopt the framework developed by Carlin (2009) to study firms' strategic choices of price and product complexity We find that price and product complexities are substitutes rather than complements. Firms either choose to limit price comparison or product comparison. The equilibrium results in a mixed pricing strategy by firms and the choice of price and product complexity is a deterministic function of a price. Firms that charge low prices choose transparent prices however they try to limit comparison of their product features with those of competing firms. In other words, when choosing low prices, firms tend to encourage price shopping and limit the extend to which their products are viewed as a niche products by consumers, in order to maximize the share of consumers that make their purchasing decisions based on price comparison. Whereas firms that charge higher prices tend to encourage consumer shopping based on product features comparison, by making their price structures complex and their products transparent. Having transparent product guarantees some captive consumers for the firm on the one hand, and limiting price comparison relaxes price competition on the other hand. When the number of firms increases in the market, the choice of complex prices and transparent products becomes more frequent, as the probability of winning the price competition decreases for each firm when the total number of firms increases. Therefore, this leads to consumers making suboptimal choices based on price information. We also run a numerical simulation to study the effect on prices with an increased number of firms. We find that expected prices increase with the number of firms.

We further apply the framework to vertically differentiated markets. We find that firms that choose higher margins choose to limit net-value comparison by consumers. Depending on the shape of cost function and on consumer preferences, at equilibrium firms that choose high quality choose high or low complexity.

We also consider the effect of a policy targeted on regulating price and product complexity. We consider two relevant policies: a cap on upper limit of price or product complexity or a floor on lower bound of price and product complexity. Our analysis shows that imposing a cap on price complexity or introducing a floor on product complexity results in lower market prices. However the frequency of choosing complex prices and a transparent product increases but the aggregate market price and product complexity decreases as a result of such an intervention. In the case of the imposition of a cap on product complexity and a floor on price complexity, the effect on aggregate market complexity levels is the same, however market prices increase as a result. When product complexity is regulated consumers shift from price comparison to product comparison, which in turn relaxes price competition for firms and therefore results in higher market prices. Even though both policies lead to more transparent markets, regulating price complexity appears to be more efficient for lowering market prices than regulating product complexities. Together with the result that increasing the number of firms leads to more complex and higher prices, the efficiency advantage of price complexity regulation becomes more pronounced.

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