Product Complexity and Search*

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Abstract

In many situations, consumers buy complex products without being fully aware of what they are actually buying: goods are simply too difficult to understand for them. I study the incentives of firms to obfuscate their products and the effects of such product complexity on profits and welfare in a duopoly search model. I show that when firms can simultaneously choose prices and complexity of their products, competition is not effective under fairly general assumptions: there cannot be equilibria in which firms do not charge monopoly prices. Consumers suffer from complexity because it prevents them from finding out about which deal is best for them. Moreover, it keeps them from searching which in turn softens competition. Competitive pressure does not lead to better information for consumers calling for policy intervention.

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1 Introduction

There are numerous examples in real life where consumers buy goods or sign contracts without being fully aware of what they get for the money they spend or which price they ultimately end up paying. While this clearly applies to goods that cannot be evaluated before purchase (experience goods) this also often happens with products for which this could generally be done (search goods). Mobile phone contracts, bank accounts, credit offers, and insurance contracts are just a few examples. What all of them have in common is that in principle it would be possible to acquire all relevant information before purchasing. All contract terms are available to consumers. The way in which information is presented, however, makes it difficult for consumers to understand and compare offers. There is surprisingly little search for better deals in the market. Empirical evidence shows that people often do not compare alternatives and do not know about the conditions of the contracts they signed. OFT (2008), for instance, provides evidence that 70% of consumers do not shop around for credit card offers and 75% of consumers do not know the annual percentage rate (APR) of their credit cards. Moreover, even those people that do search around for better offers often fail to select the best deal available (see e.g. Wilson and Price (2007) for a study of switching behavior in the electricity market).

The question arises why firms want to make it difficult for consumers to find out about what exactly they have to offer in the first place and what role competition plays in this context. The next step is then whether and how firm's behavior differs from social interests to evaluate the need for policy intervention. This paper sheds some light on these questions.

The point it emphasizes is that in the presence of search costs, firms have no incentives to provide consumers with more information than they anticipate to obtain once they have incurred search costs. The argument goes as follows. Suppose a consumer needs to buy a good. Goods are horizontally differentiated and thus may match her tastes or not. There are several shops, each offering one alternative of the good and the consumer selects a first store to visit. Suppose moreover that the shops can obfuscate their products such that the consumer cannot tell to which degree it is suitable for her or not. If products were transparent, a consumer would evaluate the first product and then, depending on how she likes the product, decide to buy or visit another firm. If all products are so complex that the consumer does not understand any them, her sole objective for searching around would be to find a lower price (given that she is at least able to understand prices). However, if prices are the same (or if she does not understand prices at all), which is the case in a symmetric equilibrium, a consumer has no incentive to do so and always buys at the first firm she visits. By unilaterally making its own product transparent, a firm only allows consumers to find out about bad matches. In case the product fits her, she buys it, if it does not fit, she goes on to search other firms. However, she would have bought the product if she did not understand it while knowing that she wouldn't understand the other products in the market.

From a welfare point of view, perfect information about product characteristics is optimal as it allows consumers to find out about their best match in the market. Consumers suffer from complex contracts because it prevents them from finding out about which deal is best for them. Moreover, it keeps them from searching which in turn softens competition. Competitive pressure does not lead to better information for consumers calling for policy intervention.

The rest of the article is organized as follows. The next section briefly reviews the related literature. Section 3 introduces the basic model. Section 4 then analyzes the price and complexity choice game. Section 5 discusses the results and comments on the modeling assumptions. The final section offers some concluding remarks.

2 Related literature

In terms of modeling, this paper is most closely related to work in the areas of search, advertising and product design.

There has been a large literature on the effects of search costs on firm's pricing behavior. The main focus of it has been to explain price dispersion of homogenous goods. Stahl (1989) for instance shows that firms equilibrium price distributions change smoothly from competitive marginal cost pricing to monopoly pricing as the distribution of search costs shifts towards higher search costs.[1] However, only recently Ellison and Wolitzky (2009) have proposed a model where obfuscation in the sense of unilaterally increasing search cost is individually rational for firms. Assuming convex search costs for consumers, they show that firms deliberately choose to increase search cost to maximize their profits. All this literature has to assume that there are some consumers without any search cost to overcome the Diamond paradox: even if search costs are arbitrarily small for all consumers, having each firm charging monopoly prices is an equilibrium.

[1] In all the literature on search with homogenous goods, equilibria are in mixed strategies only. Hence there are only equilibrium price distributions and not single equilibrium prices.

An alternative specification to avoid this and achieve pure strategy equilibria at the same time is to allow for product heterogeneity. Anderson and Renault (1999), extending Wolinsky (1986), 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).

Recently, the role of advertising as a mean to inform about product characteristics and prices has gained attention in the literature. Johnson and Myatt (2006) study product design choices of a monopolist in the sense of altering the taste variance for its product. They show that a firm always chooses extreme designs, appealing to as many consumers as possible or produce the most controversial design possible. Moreover, firms supply consumers with either full information about their product or no information at all before they start searching. Related to the present paper is the work by Bar-Isaac et al. (2009). They study firms' product design choices in a competitive environment with sequential search.[2] 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. A similar point is made by Anderson and Renault (2009) in the context of advertisement: quality disadvantaged firms would like to differentiate themselves from their competitor by informing consumers about product attributes through comparative advertising. While for similar qualities the advantaged firm also prefers to provide consumers with their product attributes, for large quality differentials, the high quality firm prefers consumers to have as little information as possible.

Moreover, there have been a couple of papers about product complexity in different modeling contexts. Carlin (2009), for instance, studies firms' complexity choices and pricing strategies in a model of all-or-nothing search with homogenous products. Complexity increases the cost of finding out about the best deal in the market in his model. He shows that there exists a mixed-strategy equilibrium in this game where firms randomize over complexity and prices. In this equilibrium, high complexity goes along with high prices, i.e. when a firm charges a high price (above some cutoff), it obfuscates its product as much as possible whereas for low prices, it makes its product as transparent as possible.

Gabaix and Laibson (2003) model product complexity as spurious product differentiation in a model without search. Despite the latter difference, it yields qualitatively

[2] Larson (2008) uses a similar set-up to study endogenous product differentiation.

similar predictions to Bar-Isaac et al. (2009): low quality firms prefer their product to be excessively complex (equivalent to have a high taste variance) while high quality firms want their products to be overly simplistic (low taste variance).

In Bar-Isaac et al. (2010) a monopolist can choose the easiness with which consumers can acquire information about its product. Search costs are modeled as cost of acquiring information about the product and consumers can buy without being informed about the product's characteristics. This contrasts the notion of search costs being transportation costs (and hence necessary to incur in order to purchase) that is used in the literature on product design and search. They show that it might be optimal to choose an intermediate strategy, i.e. impose intermediate costs on consumers to find out about product characteristics in order facilitate price discrimination or to commit to producing a high quality product.

This paper takes a different view and assumes that product differentiation is exogenously given and then studies firms' decisions to make information about their products accessible through search or not. Contrary to the previous literature, search does not necessarily yield information about products. The core question is how firms want to use their ability to conceal information.

3 The model

The basic setup shares elements with Wolinsky (1986), Anderson and Renault (1999) and in particular, Anderson and Renault (2000). The new component is that firms have the possibility to obfuscate consumers as detailed later on.

There are two profit-maximizing, risk-neutral firms, denoted by $j = 1,2$, each selling one variant of a horizontally differentiated good. The price they charge consumers is given by p_j. For simplicity, firms do not face fixed costs and marginal costs for production are normalized to zero.

There is a continuum of consumers with mass normalized to one. Consumers, denoted by i, have inelastic unit demand and buy at most one product. They are assumed to be risk-neutral as well. When buying from firm j, a consumer i obtains utility (ignoring search costs detailed later on):

$$u_{ij}(p_j) = v - p_j + \epsilon_{ij} \tag{1}$$

where the fixed utility from buying either good is denoted by v and ϵ_{ij} captures the idiosyncratic taste value of consumer i for product j. Taste values ϵ are distributed according to the distribution function $F(\epsilon)$ with density $f(\epsilon)$ over the interval $[\underline{\epsilon}, \overline{\epsilon}]$. The ϵ's are independently and identically distributed across consumers and firms. The density $f(\epsilon)$ is assumed to be log-concave and twice continuously differentiable. The expectation of ϵ_{ij} is denoted by $\mathbb{E}(\epsilon)$.

In order to sample a firm, consumers incur a non-monetary search cost c. Search costs can thus be seen as transportation costs of consumers to reach a firm. For simplicity, the first visit is assumed to be costless and thus does not play any role as in most of the literature.[3] Returning to a firm later on is assumed to be costless. Consumer's search is directed and sequential, i.e. depending on their beliefs, consumers choose one firm to visit first and after that decide to search the other firm or not.

Upon sampling firm j, consumers see the price p_j. Contrary to the existing literature in this field, depending on the complexity $\theta_j \in \{0,1\}$ of the product, consumers either understand the product or not. If $\theta_j = 0$, firm j's product has a low level of complexity: consumers are able to evaluate the product upon sampling, they learn their idiosyncratic match value when visiting the firm. On the contrary, if $\theta_j = 1$, consumers are not able to do so and keep the correct belief that $\epsilon_{ij} = \mathbb{E}(\epsilon)$.[4] Complexity choices are assumed to be costless.

This setup can be reinterpreted in the following way. Consider a situation where consumers are confronted with a set of usage prices, e.g. a mobile phone contract. Product differentiation can be thought of as different firms charging different prices for different services and the contract being a bundle of all these services (calls, messages, roaming etc.). What matters is that consumers derive different levels of utility from the same good. Whether the fixed utility of having the good is the same for all consumers but they pay different prices because of different usage, they differ in their utility of having the good only, or they differ in both dimensions is irrelevant. If the offer a consumer faces is complex ($\theta_j = 1$), she is not able to perfectly evaluate the effective price she ends up

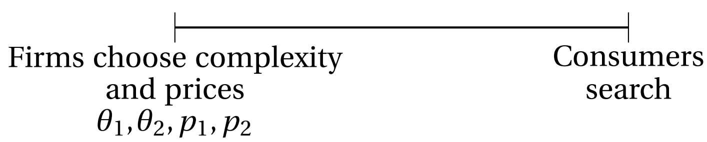
[3]Note that the assumption of a free first visit plays a role for whether the Diamond paradox results in consumer purchasing at monopoly prices or market breakdown as noted by Stiglitz (1979) but does not change any results of the present paper. It allows me to focus on consumers decisions to shop around and abstract from the possibility of hold-up on the first visit. Moreover, there are other ways to circumvent market breakdown in situations where the Diamond paradox holds by either introducing a mass of sophisticated consumers who cannot be obfuscated or by treating the fixed utility as income as in Anderson and Renault (2000).

[4]In several papers (e.g. Armstrong et al. (2009) or Schultz (2005)) some consumers are assumed not to observe prices rather than not observing characteristics. Hence they have inelastic demand for one product.

paying when signing a contract with a firm since she cannot predict her consumption behavior. The assumption that she holds correct beliefs about it means that despite not understanding a product, she is right “on average” and cannot be fooled systematically. Modeling uncertainty on product characteristics rather than price allows to keep prices as the strategic variables of firms.

Alternatively, the model can be interpreted as one of product design where firms face the binary choice of offering a homogenous mass market product or a differentiated product targeting a niche of the market.

To fix ideas, consider the following timing of the game:



In the first stage, firms choose product complexities and prices simultaneously. After that, depending on their beliefs about prices and complexity levels, consumers pick one firm for their first search. They either buy there, continue to search the other firm or leave the market. In case they visit the other firm, they either buy there, return to the first firm to buy there or don’t buy at all.

The simultaneity of firms’ decisions on prices and complexity captures the idea that deviations could occur on both dimensions: firms can change their product complexity and adjust their price at the same time. In the literature on product design, which is mainly concerned with physical goods, it is reasonable to assume that design and price choices are sequential: once a product is built, it’s easy to change the price but not its characteristics. The present paper, however, rather aims at explaining the complexity of contracts. The simultaneous decision about complexity and price can be interpreted as giving sales advice in this context. Absent advice, a consumer is not able to understand the product since, e.g. the relevant information is buried in the fine print of a contract and the consumer has no chance to find it by herself. The firm has the choice to inform the consumer upon her visit about the product or not. Clearly this decision can be made as easy as changing the price. Moreover, if we think about interactions taking place online, it is straightforward that all information on a webpage, price and product description, can be changed at the same time.

The solution concept that will be used throughout the paper is that of a Perfect Bayesian Equilibrium with passive beliefs. Hence, an equilibrium is characterized by :

- firms maximizing their own profits given the expected price of the rival and consumer search behavior
- consumer behavior is utility maximizing given prices and product characteristics observed and anticipated
- anticipated prices and complexities are consistent with equilibrium strategies and independent of those already observed

4 Price/Complexity choices

Depending on the beliefs of consumers about the chosen complexity of each firm, different demand structures arise. The beliefs about whether to find a complex product at a firm or not affect the search behavior of consumers. In order to check for the existence of equilibria for each possible complexity configuration (both firms transparent, only one firm transparent, both complex), I start by assuming that firms set complexity levels equal to consumers' beliefs. I then derive candidate equilibria for each case by maximizing firms' profits for given consumer beliefs about prices. Afterwards, I check for the profitability of possible deviations on both dimensions, complexity and price. I will focus on non-trivial equilibria in my analysis. Having both firms charging prices above any consumer's valuation for its good and consumers not visiting any firm are such trivial equilibria that always exists.

Before turning to the analysis, let us briefly examine the complexity choice of a monopolist, i.e. under which conditions a monopolist would like to provide consumers with information about the product it sells.

4.1 Benchmark: Monopoly

If a monopolist offers a complex product to consumers (equivalent to a homogenous product), it can charge a price $p_c^m = v + \mathbb{E}(\epsilon)$ and sell to all consumers, resulting in profits

$$\pi_c^m = v + \mathbb{E}(\epsilon) \tag{2}$$

On the contrary, if a monopolist provides consumers with all information about the product and charges a price p_t^m, its demand is given by $(1 - F(p_t^m - v))$ and its profits by

$$\pi_t^m = p_t^m D_t^m = p_t^m (1 - F(p_t^m - v)) \tag{3}$$

where p_t^m optimally solves $p_t^m = \frac{1-F(p_t^m - v)}{f(p_t^m - v)}$ which is well defined due to the assumption of log-concavity of the density $f(\epsilon)$. The following lemma will be useful for the subsequent analysis.

Lemma 1 *Depending on the fixed valuation v and the distribution $F(\epsilon)$, a monopolist strictly prefers to offer a complex product and hide information iff π_c^m given by (2) strictly exceeds π_t^m given by equation (3).*

Moreover, by imposing the following condition, I can be more precise when this is the case.

Lemma 2 *If the distribution $F(\epsilon)$ is skewed to the right*[5] *or symmetric and $v > \frac{\bar{\epsilon}}{2} - \frac{3\mathbb{E}(\epsilon)}{2}$ (or $v > -\frac{\bar{\epsilon}}{4} - \frac{3\epsilon}{4}$), then the condition of Lemma 1 is satisfied.*

Proof. To start, note that it is more profitable to provide information for the monopolist the more high valuation consumers there are. Given the assumption of log-concavity and right-skewness or symmetry, the distribution that puts most weight on the upper tail is the uniform distribution. Hence, any condition that satisfies Lemma 1 for the uniform distribution is sufficient to guarantee it for any other symmetric or right-skewed log-concave distribution.

Targeting a niche can only be profitable if $p_t^m > p_c^m = v + \mathbb{E}(\epsilon)$. Using log-concavity and the uniform distribution:

$$\pi_t^m = p_t^m (1 - F(p_t^m - v)) = \frac{(1 - F(p_t^m - v))^2}{f(p_t^m - v)} \leq \frac{(1 - F(p_t^c - v))^2}{f(p_t^c - v)} = \frac{1}{4f(\mathbb{E}(\epsilon))}$$

[5] I will stick to this wording throughout the paper. The property of skewness I exploit in this paper is that a right-skewed distribution has a mean exceeding the median whereas for a left-skewed distribution the opposite holds. Strictly speaking, this holds if the measure of skewness taken is Pearson's second skewness coefficient which ranks the mean and the median in this way. The standard definition of skewness as the third standardized moment yields the same ranking of the mean and the median of a distribution for almost all distributions that are log-concave and continuous (except for e.g. the Weibull distribution over a small set of parameters, see von Hippel (2005)). As shown in MacGillivray (1981) the ranking of mean and median according to the skewness is valid for the entire Pearson family of distributions which encompasses all examples mentioned in the text.

Hence it is strictly profitable to offer a complex product if

$$\frac{1}{4f(\mathbb{E}(\epsilon))} < v + \mathbb{E}(\epsilon) = v + \frac{\overline{\epsilon} + \underline{\epsilon}}{2}$$
$$v > -\frac{\overline{\epsilon}}{4} - \frac{3\underline{\epsilon}}{4} \Leftrightarrow v > \frac{\overline{\epsilon}}{2} - \frac{3\mathbb{E}(\epsilon)}{2}$$

■

Note that most of the commonly used log-concave distributions are either symmetric or right-skewed, e.g. the uniform, (log-)normal, exponential, and the logistic distribution. Moreover, assuming potentially full coverage of the market, i.e. every consumer derives positive utility from the good ignoring price, is sufficient for Lemma 1 to hold in this case. Hence, under the prevailing assumptions in the literature, the prediction would be that a monopolist chooses a mass-market strategy by offering a complex product.

4.2 Full transparency

Let us start with the case where consumers believe that they understand both products. This corresponds to the standard case that has been treated in the literature (e.g. Wolinsky (1986) and Anderson and Renault (2000)).

In the following I am looking for a symmetric equilibrium where both firms offer transparent products and charge the same price.[6] I will concentrate on the case where the market is fully covered, i.e. assume that the fixed utility from buying either good is sufficiently high such that all consumers buy in equilibrium. At least some consumer find it worthwhile to search for equal prices, search costs are not prohibitively high.

Consumers search firms sequentially with costless recall. This leads them to optimally use a simple stopping rule as follows. Since I am focusing on a symmetric equilibrium, consumers randomly choose one firm to visit first. They then buy from that firm if their match value is sufficiently high. If not, they go on to search the second firm. If they find a better match there, they buy at the second firm, otherwise they return to the first firm and buy there.

Consider a consumer who starts at firm 1. Intuitively, a consumer wants to search the second firm if the expected gain from doing so exceeds the search costs. Throughout the paper I assume that a consumer does not carry out another search unless it is strictly better to do so. This tie breaking rule simplifies the exposition but does not affect the

[6] I will explain why equilibria where both firms offer transparent products but charge different prices cannot exist afterwards.

results qualitatively. The gains from search accrue from finding a higher match value and/or a lower price. Formally, the expected gain from search is given by (see Wolinsky (1986) and Anderson and Renault (2000)):

$$\int_{\epsilon_1 - p_1 + \tilde{p}_2}^{\overline{\epsilon}} (\epsilon - \epsilon_1 + p_1 - \tilde{p}_2) f(\epsilon) d\epsilon \tag{4}$$

the expected increase in utility given that the consumer indeed prefers the second product over the first one. In order to derive the demand for a firm, let us start with the search behavior of consumers. After seeing the first product, a consumer wants to search the other firm if the gains from doing so exceed the search cost. Define $\hat{\epsilon}_1(p_1, \tilde{p}_2)$ as the match value a consumer visiting firm 1 first has to hold to be indifferent between buying from firm 1 and searching the other firm. For notational simplicity I will drop the arguments and simply write $\hat{\epsilon}_1$ in the following. This means that all consumers seeing $\epsilon_1 < \hat{\epsilon}_1$ at their first visit will go on to search the other firm, while those with $\epsilon_1 \geq \hat{\epsilon}_1$ buy upon their first visit. $\hat{\epsilon}_1$ is given by:

$$\int_{\hat{\epsilon}_1}^{\overline{\epsilon}} (\epsilon - \hat{\epsilon}_1) f(\epsilon) d\epsilon = c \tag{5}$$

Since the left-hand side is continuous and decreasing in $\hat{\epsilon}_1$ and between ∞ (at $\hat{\epsilon}_1 = -\infty$) and 0 (at $\hat{\epsilon}_1 = \overline{\epsilon}$), $\hat{\epsilon}_1$ is uniquely defined.

Demand for firm 1 is given as follows. Since the first search of consumers is random, one half of all consumers visit it first. Out of those consumers, those who learn about a match value of at least $\hat{\epsilon}_1$ do not want to search the other firm and buy directly from firm 1. Thus firm 1 sells to $\frac{1}{2}[1 - F(\hat{\epsilon}_1)]$, its first visitors that buy directly upon their first visit.

Firm 1's other first visitors go on to search firm 2. They then return and buy from firm 1 if they find a worse match at firm 2. The probability of a consumer finding a worse match at firm 2 given that they were willing to search it is given by $\int_{\underline{\epsilon}}^{\hat{\epsilon}_1} F(\epsilon - p_1 + p_2) f(\epsilon) d\epsilon$. The demand for firm 1 is thus one half of this expression since this applies only to consumers visiting firm 1 first. Note that the expected price of firm 2 influences the decision to visit it but for the purchasing decision, only the actual price charged matters.

Finally, firm 1 sells to all consumers that initially visit its rival but then decide to visit firm 1 and find a better match there. This demand equals the conditional probability of finding a better match at firm 1 given that the match at firm 2 was sufficiently low to induce further search. It is given by $\frac{1}{2} \int_{\underline{\epsilon}}^{\hat{\epsilon}_2} \left[1 - F(\epsilon - p_2 + p_1)\right] f(\epsilon) d\epsilon$. Putting these parts together yields the total demand for firm 1:[7]

$$D_1 = \frac{1}{2}[1 - F(\hat{\epsilon}_1)] + \frac{1}{2}\int_{\underline{\epsilon}}^{\hat{\epsilon}_1} F(\epsilon - p_1 + p_2) f(\epsilon) d\epsilon + \frac{1}{2}\int_{\underline{\epsilon}}^{\hat{\epsilon}_2} \left[1 - F(\epsilon - p_2 + p_1)\right] f(\epsilon) d\epsilon \tag{6}$$

Taking the FOCs and using symmetry yields

$$p^* = \frac{1}{[1 - F(\hat{\epsilon})] f(\hat{\epsilon}) + 2\int_{\underline{\epsilon}}^{\hat{\epsilon}} f(\epsilon)^2 d\epsilon} \tag{7}$$

as the unique candidate equilibrium (see also proposition 3 in Anderson and Renault (2000)). Since prices are equal for both firms and demand is symmetric, firms share the market equally and profits are thus $\pi_1^* = \pi_2^* = \pi^* = \frac{1}{2\{[1-F(\hat{\epsilon})] f(\hat{\epsilon}) + 2\int_{\underline{\epsilon}}^{\hat{\epsilon}} f(\epsilon)^2 d\epsilon\}}$.

To check whether this candidate constitutes indeed an equilibrium, consider a deviation by one firm towards complexity while keeping the same price p^*. Without loss of generality the deviating firm will be firm 1 in the following. This affects consumers in the following way. All first visitors of firm 1 do not understand the product they see upon their first visit and hence keep the belief that their match value is equal to the expectation. Moreover, all consumers attach the same match value to product 1. Hence, all consumers make the same decision to search the rival firm or not: either they all go or they all stay. Their decision to visit firm 2 boils down to whether $\hat{\epsilon}$, the match value for which they would be indifferent between buying and searching the other firm, is larger or smaller than their current match $\mathbb{E}(\epsilon)$. If $\mathbb{E}(\epsilon) \geq \hat{\epsilon}$, then all consumers do not want to search the other firm and directly buy from the deviating firm, otherwise all consumers go to see the rival.

The consumers visiting firm 2 first do not see this deviation and base their decision to visit firm 1 upon the expectation of understanding firm 1's product and finding p^* there. Hence, the fraction of consumers that decides to visit firm 1 after seeing firm 2 is unchanged.

The conditions under which such a deviation is profitable are given in the following proposition.

Proposition 1 *There exists no full transparency equilibrium if search costs are sufficiently high such that $\hat{\epsilon} \leq \mathbb{E}(\epsilon)$. Moreover, there exists no such equilibrium for any level of search costs if the distribution $F(\epsilon)$ is skewed to the right or symmetric.*

[7] Despite the different way of deriving and formulating demand, it is equivalent to the demand function derived in Anderson and Renault (2000) (equation (8)).

Proof. For the first part of the proposition, consider a deviation by one firm towards complexity while keeping p^*. Since $\hat{\epsilon} \leq \mathbb{E}(\epsilon)$, all consumers starting at the now complex firm do not find it worthwhile to visit the rival firm and buy directly upon their first visit. Moreover, it must be that all the deviating firm's second visitors have learned a valuation below the expected value at the other firm. Hence it sells to all of them as well. The demand captured with such a deviation strictly exceeds $1/2$, each firm's demand in the candidate equilibrium. Thus becoming complex is strictly profitable if $\hat{\epsilon} \leq \mathbb{E}(\epsilon)$, independent of the skewness of the distribution of taste values.

What is left to show is that if $F(\epsilon)$ skewed to the right or symmetric, this candidate equilibrium does not exist even for lower values of search costs. Let us turn to the case where search costs are so low that $\hat{\epsilon} > \mathbb{E}(\epsilon)$. This means that a consumer seeing a complex product upon her first visit and expecting the other firm to be transparent and charging the same price finds it worthwhile to search. Once again, consider a deviation from the candidate equilibrium towards complexity without a change in price. As noted before, this induces all first visitors of the deviating firm to search the rival. Those consumers, however, who learn about a bad valuation at the other firm return. To be precise, $F(\mathbb{E}(\epsilon))$ of those consumers return. The second visitors of the deviating firm have learned about a relatively low valuation upon their first visit. However, since $\hat{\epsilon} > \mathbb{E}(\epsilon)$, those consumers with valuations above the expected value return to the firm they initially visited. This means that by such a deviation, a firm sells to $F(\mathbb{E}(\epsilon))$ of *all* consumers. Given the assumptions of log-concavity and continuity of the density $f(\epsilon)$, right-skewness implies that $F(\mathbb{E}) > 1/2$, the mean value is above the median of the distribution.[8] Hence such a deviation strictly increases demand. For symmetric distributions, $F(\mathbb{E}(\epsilon)) = 1/2$ and thus such a deviation towards complexity without changing price does not alter profits. Now consider a change in price accompanying the deviation to complexity. Taking the total differential of profits with respect to price evaluated at the candidate equilibrium price yields:

$$\left.\frac{d\pi}{dp^d}\right|_{p^d=p^*} = D^* + p^* \frac{\partial D^d}{\partial p^d} = \frac{1}{2} - \frac{f(\mathbb{E}(\epsilon))}{[1-F(\hat{\epsilon})]f(\hat{\epsilon}) + 2\int_{\underline{\epsilon}}^{\hat{\epsilon}} f(\epsilon)^2 d\epsilon} \leq 0 \tag{8}$$

This expression is negative by the following argument. As shown in Anderson and Renault (2000) (Corollary 1), p^* is increasing in search costs, hence attains its minimum at c=0 which is given by $\frac{1}{2\int_{\underline{\epsilon}}^{\bar{\epsilon}} f(\epsilon)^2 d\epsilon}$ as $\hat{\epsilon} = \bar{\epsilon}$, all consumers search both firms. Since $f(\epsilon)$ is symmetric and log-concave, it has its maximum at $\mathbb{E}(\epsilon)$. Thus $\int_{\underline{\epsilon}}^{\bar{\epsilon}} f(\epsilon)^2 d\epsilon \leq$

[8] See also the footnote in the benchmark section.

$f(\mathbb{E}(\epsilon))\int_{\underline{\epsilon}}^{\overline{\epsilon}} f(\epsilon)d\epsilon = f(\mathbb{E}(\epsilon))$. (see also Anderson and Renault (2009), Proposition 2). The denominator of the second part of (8) is thus smaller or equal than $2f(\mathbb{E}(\epsilon))$ and hence the whole expression is negative. Thus for $c > 0$, deviating to complexity and simultaneously slightly lowering price is strictly profitable. ■

The corollary of this proposition is that only if the distribution of taste values is left-skewed and search costs are sufficiently low, a full transparency equilibrium can exist. The conditions for non-existence are, however, sufficient but not necessary. Note that if search costs are such that $\hat{\epsilon}$ is just marginally larger than $\mathbb{E}(\epsilon)$, there exists no such equilibrium since a firm could deviate to deviate to a price to make its first visitors just indifferent between staying and searching. Such a deviation discontinuously increases demand and thus could be profitable. The situations in which a full transparency equilibrium can exist are hence very limited.

The intuition why a full transparency equilibrium cannot exist in most cases when firms can simultaneously choose their prices and transparency is the following. For high search costs, a firm can deviate to complexity and keep all its first visitors without having to lower its price. Since it also sells to all its second visitors for the same price, such a deviation is profitable independent of the distribution of taste values. Moreover, just by obfuscating its product and charging the candidate equilibrium price, a firm is able to to increase its demand if $F(\epsilon)$ is skewed to the right. If the distribution is symmetric, a deviation to complexity rotates the demand curve for the deviating firm (demand becomes more elastic) where the rotation point is given by the candidate equilibrium price. Hence a deviation becomes strictly profitable if the change in complexity is accompanied by a slight decrease in price. If the distribution of taste values is skewed to the left, just moving to complexity results in lower demand, there is a disadvantage of being the firm whose match values are unknown to consumers. However, by changing the price as well as complexity, such a deviation could also be profitable. Hence only in such situations a full transparency equilibrium can exist.

By using the same argument, we can also rule out equilibria with partial coverage and asymmetric prices. In the former case, any candidate that implies a market coverage between 1/2 and full coverage cannot exist under the same conditions as in Proposition 1. By moving towards complexity, the deviating firm captures all consumers that otherwise would not buy at all. Hence, it is strictly profitable to do so. For the latter case, consider a situation where both firms offer transparent products but one firm charges a low price p_l and the other firm a price p_h. This means that all consumers visit firm l first. If search costs are sufficiently high ($\hat{\epsilon}_l \leq \mathbb{E}(\epsilon)$) the supposedly lower price firm can move to complexity and raise its price just to make consumers indifferent between searching and staying, thus increasing demand, price and hence profits. If search costs are low, the lower price firm can profitably deviate to complexity since such a move either increases demand elasticity (symmetric distributions) or increases demand (right skewed distributions).

4.3 One-sided transparency

Let us now examine possible equilibria when consumers believe that they understand only one product. For these asymmetric equilibria, let us first turn to the question how consumers choose their search order. Assume there is one firm t offering a transparent product and one firm c offering a complex product, charging p_t and p_c respectively. Upon visiting a complex firm a consumer does not learn anything about the product characteristics and only sees a price which, in equilibrium, she expected to find before. Hence it never makes sense for a consumer to visit a complex firm first, knowing that she wants to visit the other firm as well. A consumer choosing to visit a complex firm hence must buy there with probability 1 in equilibrium. The utility a consumer obtains from buying from a complex firm is

$$U_c = v - p_c + \mathbb{E}(\epsilon) \tag{9}$$

and, as given before, when buying from a transparent firm

$$U_t = v - p_t + \epsilon_t \tag{10}$$

When visiting a transparent firm first, a consumer has the (outside) option of buying the complex product if she learns about a bad valuation at the complex firm. Thus the expected utility she gets from searching, starting at the transparent firm is given by

$$U_s = [1 - F(\hat{\epsilon})] \int_{\hat{\epsilon}}^{\overline{\epsilon}} U_t f(\epsilon) d\epsilon + F(\hat{\epsilon}) \max\{U_c - c; 0\} \tag{11}$$

where

$$\hat{\epsilon} = \max\{p_t - \tilde{p}_c + \mathbb{E}(\epsilon) - c; 0\} \tag{12}$$

Thus possible consumer equilibrium strategies (where beliefs are consistent with firms' strategies) are

- visit firm t first if $U_s > U_c$ and $U_s > 0$; buy there if $\epsilon \geq \hat{\epsilon}$; buy from firm t if $\epsilon < \hat{\epsilon}$ and $U_c - c \geq 0$; leave the market otherwise

- visit each firm with equal probability if $U_s = U_c \geq 0$; if t is visited first, buy there if $\epsilon \geq \hat{\epsilon}$; buy from firm t if $\epsilon < \hat{\epsilon}$ and $U_c - c \geq 0$; leave the market otherwise; if c is visited first, buy there

- buy from firm c if $U_c > U_s$ and $U_c > 0$

In principal, there could be equilibria for each strategy. However, examining these cases the following result holds.

Proposition 2 *There can only be asymmetric equilibria in which only one firm is active and charges a monopoly price.*

Proof. Let us start with the first case where all consumers initially visit the transparent firm. By construction, the complex firm only gets visitors who visit it second. But all those consumers must have learned a valuation that is sufficiently low such that they are willing to incur search costs to buy the complex product. Once at the complex firm, however, they are willing to pay a price up to $v + \mathbb{E}(\epsilon)$. The search cost is sunk and the complex firm can hold-up its visitors. Anticipating that they will be held-up if visiting firm c, no consumer will ever want to do so. This in turn gives firm t monopoly power over all consumers: they either buy from firm t or not at all. It thus depends on whether a monopolist would want to reveal product information or hide it. If a monopolist prefers a niche strategy, an equilibrium in which one firm offers a transparent product and charges monopoly prices and the other firm offers a complex product and charges a price above $v + \mathbb{E}(\epsilon) - c$. If a monopolist prefers a mass market strategy, this equilibrium does not exist as the transparent firm prefers a deviation to complexity and a price $v + \mathbb{E}(\epsilon)$.

Now consider the case where consumers visit each firm with equal probability. For this to be the case, $U_s = U_c \geq 0$. To see why such an equilibrium cannot exist, consider the following argument. If the expected utility from going to either firm is strictly positive, a consumer arriving at firm c holds an offer that she strictly prefers to not buying at all. Since she was indifferent between going to either firm at the beginning, she is still willing to buy if the price is increased by $\min\{U_c; c\}$: an increase by U_c would make her indifferent between buying and leaving the market, an increase by c indifferent between buying and searching the other firm.[9] The only candidate that is thus left is $U_s = U_c = 0$. But for $U_s = 0$, it must be that $p_t = v + \bar{\epsilon}$, even the highest realization of ϵ brings zero surplus for consumers at the transparent firm. However, charging such a price, firm t does not sell at all which clearly cannot be optimal given that some consumers visit it. Thus there cannot be an asymmetric equilibrium in which consumers randomize over which firm to visit first.

Last, let us turn to the case where all consumers initially visit firm c and buy there. As in the previous cases, due to the existence of search cost, the only candidate equilibrium price p_t is $v + \mathbb{E}(\epsilon)$ giving zero surplus to consumers. At any price below and the same search behavior, firm c could raise its price by $\min\{U_c; c\}$ without losing any sales. Hence in such an equilibrium it must be that $U_t < 0$, i.e. p_t must be above $p_t = v + \bar{\epsilon}$. Whether this is indeed an equilibrium depends again on the monopolist's complexity choice. ■

The corollary of this is that if we restrict attention to cases where both firms charge non-prohibitive prices, i.e. prices are so high that no consumer would ever want to visit that firm, no asymmetric equilibrium exists. Only equilibria where (at least) one firm is inactive exist. Depending on whether the results from Lemma 1 (do not) hold, an equilibrium where one firm is complex (transparent) and charges monopoly prices and the other firm is transparent (complex) and charges a price high enough that no consumer ever wants to visit exists.

4.4 Full complexity

Finally, let us consider the case where both products are complex and thus perceived as homogenous by consumers. Since consumers understand neither product, their sole objective for searching would be to find a lower price. For any prices lower than the monopoly price $p^m = v + \mathbb{E}(\epsilon)$ there is a profitable deviation for the cheaper firm. Assume that one firm charges a lower price than its rival. Consumers, correctly anticipating that they find a better deal there, all initially decide to visit the cheaper firm. Once at the cheaper firm, they are still willing to buy there as long as the current price does not exceed the rival's one by less than the search cost, provided that the utility offered by the firm is positive. Hence for any price below p^m, the cheaper firm can increase its price without losing customers. The rival firm cannot do better than matching this price and hence the only candidate equilibrium where both firms offer complex products entails

[9] This argument also holds if the first visit is costly, thus also ruling out the existence of such an equilibrium if the first visit is not free.

monopoly prices $p^m = v + \mathbb{E}(\epsilon)$ by both firms, the Diamond paradox.

Now consider a deviation from such a candidate equilibrium towards transparency. By becoming transparent, a firm only gives its consumers the possibility to find out about a bad match in which case it would go to see the rival firm. The consumers starting at the other firm do not see this deviation. Hence, such a deviation can only be profitable if a monopolist would prefer its customers to understand its product and the condition in Lemma 1 does not hold. We thus have the following result.

Proposition 3 *A symmetric full complexity equilibrium entailing monopoly prices $p^m = v + \mathbb{E}(\epsilon)$ exists iff the condition of Lemma 1 is satisfied.*

Proof. Follows from the discussion above. ■

Moreover, using Lemma 2, we can state that:

Proposition 4 *If the distribution $F(\epsilon)$ is symmetric or right-skewed and $v \geq \frac{\bar{\epsilon}}{2} - \frac{3\mathbb{E}(\epsilon)}{2}$ (or $v \geq -\frac{\bar{\epsilon}}{4} - \frac{3\epsilon}{4}$), there exists a unique equilibrium of the price/complexity game where both firms are active: each firm offers a complex product and charges monopoly prices.*

Proof. By Proposition 1 and 2, no other equilibrium in which both firms are active can exist. Since by Lemma 1 and Proposition 3, a full complexity equilibrium exists, it is unique. ■

The profitability of offering complex products is decreasing in the taste variance and increasing in the fixed valuation v. Most of the literature assumes that the fixed valuations is sufficiently high such that all consumers buy in equilibrium. Under this assumption and using any of the most commonly used log-concave distributions of taste values like e.g. the uniform or the exponential, the sufficient conditions of Proposition 4 are satisfied. In turn, this implies that only equilibria in which firms charge at least monopoly prices can exist at all in this setting.

5 Discussion

This result shows that competition does not lead to improved information about products for consumers which would be socially desirable. In this section I want to discuss the relationship of my results with those of the existing literature and comment on the assumptions used.

The results of the duopoly model used in this paper do not all generalize to competition among any number of firms as modeling competition as a duopoly stresses the importance of returning customers. However, the conditions for existence of a full complexity equilibrium where any number of firms offer complex products and charge monopoly prices are the same. Only the uniqueness results do not carry over. The second part of proposition 1 relies on many consumers returning to their initially visited firm after visiting the rival. With more than two firms in the market, consumers would not return until having searched all other firms. Hence offering a complex product with a price that induces consumers to visit further becomes less attractive the more firms there are. As the number of firms becomes large, the possibility of return vanishes. This is precisely what Larson (2008), Bar-Isaac et al. (2009), and others who model the supply side as a continuum of firms, use to derive their results: either a consumer buys upon the first visit at a firm or does not buy at all since she never runs out of options to visit new firms. In such a setting, the probability of a complex firm of selling to consumers becomes binary, either it sells to all consumers or to none at all. Those authors get rid of this by assuming that there is always some residual differentiation of firms' products to smooth demand.

I abstract from the possibility of advertising, i.e. I do not allow firms to convey information to consumers before they start to search. This seems to be restrictive. However, for the motivating examples for this paper mentioned in the introduction, it need not be. It is hard to imagine that it is feasible to provide consumers with all the necessary information about all different cost components of, for instance, a bank account by means of simple advertisement. Contracts entailing a large amount of fine print are hard to fully understand and clearly cannot be fully understood and evaluated without incurring some form of search costs. Moreover, there would be a commitment problem if firms could communicate to consumers that they are more transparent than their rival. As we have seen before, once a consumer is visiting a firm, the firm would like to hide all information that would be given in excess of what she would get at the rival. Telling consumers that it is more transparent than the other firm thus is not credible. Investigating the possibility of altering the search behavior of consumers via advertising will be the next step in my analysis.

The assumption of inelastic demand seems to be particularly suitable for these instances. Insurance contracts or bank accounts are must-haves, either because they are required by law or are necessary in everyday's life. This in turn implies that the fixed utility attached to these should be high, making obfuscation in my model more likely.

Consumers are modeled as homogenous in their ability to understand products in this version of the paper. Naturally, one would think that complexity could be set such that some consumers understand the product while others do not. Consider a variant of the model where consumers have differing cognitive ability and firms the possibility to obfuscate their products such that all consumers with ability below the level of complexity of the product do not understand it while the others understand it. Essentially, the problem of making a product complex in such a setting boils down to the one investigated in this paper if we just think of the decision analyzed in this paper being for every individual consumer rather than for all consumers: does a firm want this type of consumers to learn her match value or not? This alters the results quantitatively without changing them qualitatively.

6 Conclusion

In this paper, I study the incentives of firms to obfuscate their products and the effects of such product complexity on profits and welfare, trying to explain why so many products consumer face in real life are almost impossible to understand. I show that when firms can simultaneously choose prices and complexity of their products, competition is not effective under fairly general assumptions. Importantly, the level of search costs plays (almost) no role in this model. Consumers do not search in equilibrium because they do not understand products independent of the level of search costs. This explains why even more efficient search technologies do not push firms to abandon obfuscatory practices.

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