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Vertical product differentiation, prominence, and costly search*

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Abstract

In many markets, firms offering low-quality goods are more prominent than firms offering high-quality goods. Then, consumers are perfectly informed about the good of the prominent low-quality firm but incur search costs to bring the high-quality good of a competitor to mind. We analyze under which circumstances the less-prominent firm has an incentive to invest in high quality. We investigate two scenarios: (i) homogeneous and (ii) heterogeneous search costs. If search costs are homogeneous, the less-prominent firm produces high-quality goods for sufficiently low search costs, and an increase in search costs reduces the range of values for which the less-prominent firm invests in high quality. In contrast, if search costs are heterogeneous, the less-prominent firm produces high-quality goods for sufficiently high search cost heterogeneity, and an increase in average search costs expands the range of values for which the less-prominent firm invests in high quality.

JEL classification code: D43, D83, L13.

Keywords: consideration sets, duopoly, prominence, search costs, vertical product differentiation.

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1 Introduction

In many markets, firms offering low-quality goods are more prominent than firms offering high-quality goods. For example, a lot of consumers automatically consider IKEA when buying a new couch, H&M when buying a new t-shirt, Decathlon when buying new sports gear, or Spotify when streaming music. In contrast, the high-quality variant of those goods does not come to mind automatically; instead, consumers need to exert costly effort to bring those high-quality variants to mind. Consequently, a less-prominent firm, which has the capacity to produce high-quality goods but anticipates that producing high-quality is costly and that consumers will not exert effort to consider alternatives to the prominent low-quality firm, may find it optimal not to invest in high quality.

In this article, we analyze the implications on market outcomes when consumers automatically consider a prominent low-quality firm, but need to exert costly effort to bring a less-prominent high-quality firm to mind. We consider a duopoly where consumers automatically consider the prominent low-quality firm, Firm 1. In contrast, although consumers are aware that there is more than one firm in the market, consumers need to exert costly effort to bring the less-prominent Firm 2 to mind, i.e., these consumer incur *search costs* for Firm 2. Firm 2 can save consumers the costs to bring Firm 2 to mind by producing goods that are similar to the good of Firm 1. Research from psychology and neuroscience shows that similar objects are stored together (see, e.g., Kahana 2020, Roediger & Abel 2022). Then, if a consumer considers buying a good from a particular market, the consumer automatically considers the good of the prominent firm, because that firm is salient and produces goods that are representative of the market. By thinking of the good of the prominent firm, the consumer triggers thoughts of similar goods. Therefore, if Firm 2 produces goods that are similar to the good of Firm 1, Firm 2 can ensure that consumers also automatically consider its product and do not need to exert costly effort. We analyze whether the less-prominent firm in a duopoly has an incentive to make her good similar to the prominent firm's good to facilitate consideration by consumers or whether the firm prefers to differentiate which allows both firms to charge higher prices.

We distinguish two cases: First, we model a situation where all consumers have homogeneous search costs. We assume that the prominent firm provides a good that serves its purpose but does not offer additional quality. The less-prominent firm faces a trade-off: If the firm invests in additional quality, the vertical product differentiation in the market allows both firms to charge higher prices. However, few consumers exert effort to bring the high-quality firm to mind. In contrast, if the firm does not invest in quality, the firms are similar such that both firms are recalled without exerting costly effort. However, this similarity between the goods intensifies price competition. We show that product differentiation depends on the costs of producing high quality. The less-prominent firm produces higher quality than the prominent firm if the costs for producing high quality are sufficiently low. Increasing consumers' search costs reduces the range of values for which we observe this product differentiation. If the search costs increase, fewer consumers exert effort to recall the less-prominent firm. To dampen this effect, the less-prominent firm additionally decreases its price. In consequence, with increasing search costs, producing high quality becomes less attractive as demand and price decrease.

Second, we model a situation where the search costs are heterogeneous and depend on consumers' marginal willingness to pay for quality. We capture situations where consumers with a high marginal willingness to pay are also more likely to be confronted with high-quality brands in their day-to-day lives and are thus more likely to recall those brands when buying a good from that market. For example, comparatively richer people often have a higher marginal willingness to pay for quality, but are also more often confronted with high-quality brands in the magazines they read or because they visit cities, where these brands have stores. If consumers have heterogeneous search costs, an increase in average search costs or an increase in search cost heterogeneity increases the range of values for which we observe product differentiation. Heterogeneous search costs (in contrast to homogeneous search costs) allow both firms to increase prices, because consumers are less likely to switch between firms if prices increase. Thus even for higher production costs, Firm 2 produces high-quality goods. Comparing the results of homogeneous and heterogeneous search costs reveals major differences: With homogeneous search costs, an increase in search costs decreases the range of values for which firms differentiate. In contrast, with heterogeneous search costs, an increase in average search costs increases the range of values for which firms differentiate. Thus our analysis highlights the importance of accounting for heterogeneity in search costs.

In an extension, we analyze the implications when Firm 2 first has to decide whether to enter the market. This extension does not change our results about the quality decision of Firm 2: In the homogeneous-cost case, the range of values for which Firm 2 enters and produces high quality decreases in the search costs. In the heterogeneous-cost case, the range of values for which Firm 2 enters and produces high quality increases in the average search cost. However, Firm 2 never enters with low quality. Therefore, the results on consumer surplus change. In the homogeneous- and the heterogeneous-cost case without entry, consumer surplus is highest if Firm 2 produces low quality, because consumers benefit from the low prices in that situation. In the homogeneous- and the heterogeneous-cost case with entry, consumer surplus is highest if Firm 2 produces high quality and enters. As Firm 2 never enters with low quality, in such situations, Firm 1 operates as a monopolist and extracts the complete surplus from consumers. Therefore, consumer surplus is higher if Firm 2 enters and produces high quality.

The remainder of this article is structured as follows. In Section 2, we discuss our contributions to the literature. In Section 3, we introduce our model. In Sections 4, we analyze the benchmark case where all consumers have identical search costs. In Section 5, we analyze the version of our model where consumers differ in their search costs. In Section 6, we discuss the differences between the homogeneous- and the heterogeneous cost case. In addition, we discuss a variant of our model where Firm 2 first has to decide whether to enter the market. Section 7 concludes.

2 Related Literature

We study consumers who automatically consider the prominent firm in the market, but do not necessarily consider the less-prominent firm. Thus we contribute, first and foremost, to the literature on consideration sets (Eliaz & Spiegler 2011*a*,*b*, Haan & Moraga-González 2011, de Clippel et al. 2014, Manzini & Mariotti 2018, Hefti 2018, Astorne-Figari et al. 2019, Hefti & Liu 2020).[1] The consideration set literature assumes that consumers do not always consider all goods in the market, but instead consider only a subset of the goods, the so-called consideration set, in their consumption decision. Firms can affect consumers' consideration sets, for example, via the salience of their goods (Manzini & Mariotti 2018), the prices of their goods (de Clippel et al. 2014), or via advertising (Eliaz & Spiegler 2011*a*, Astorne-Figari et al. 2019).[2]

In line with this literature, we assume that the supply side of the market can affect the formation of the consideration sets directly: By producing goods with qualities that are similar to the goods of the prominent firm, the less-prominent firm also enters the consideration set of all consumers automatically. Manzini & Mariotti (2018) and Eliaz & Spiegler (2011*b*) also consider similarity. Manzini & Mariotti (2018) discuss situations where more salient options, i.e., options that are dissimilar from the other options, have a higher probability of entering the consideration sets. Manzini & Mariotti (2018) analyze under which conditions the most salient option is the best.

[1] For other models on limited attention, see Gabaix (2019) for an overview.

[2] Alternatively, the consideration sets can be exogenously given (e.g., Varian 1980, Schultz 2004, Boone & Potters 2006, Cosandier et al. 2018, Armstrong & Vickers 2022). Another related strand of the literature analyzes the implications when the number of available options exceeds the number of options consumers are able to consider (van Zandt 2004, Falkinger 2007, 2008, Anderson & de Palma 2009, 2012, Hefti 2018, Hefti & Liu 2020).

Our consideration set formation is closely related to Eliaz & Spiegler (2011*b*). Eliaz & Spiegler (2011*b*) address the case that consumers automatically consider the menu of their default firm, but only consider the menu of the competitor if the menus are similar on the quality dimension. We contribute to this literature in two ways. First, neither Manzini & Mariotti (2018) nor Eliaz & Spiegler (2011*b*) analyze price-setting in competition. In contrast, our focus lies on the implications on qualities, prices, and welfare. Second, in our model, not only firms can affect consumers' consideration sets, consumers can exert effort to extend their consideration set to high-quality alternatives.

Like the consideration set literature, the costly search literature considers consumers that do not consider all goods in the market in their consumption decision. The rationale behind this assumption is that searching for goods requires effort, and not all consumers exert enough effort to include all available goods in their consumption decision. Therefore, our modeling approach is also related to the literature on costly search. Following the seminal article by Stigler (1961), a large literature in industrial economics studies the implications of consumer search costs (see Anderson & Renault 2018, for an excellent survey). This literature shows that search costs can, for example, lead to prices above marginal costs (Diamond 1971) and price dispersion (Salop & Stiglitz 1977, Reinganum 1979, Burdett & Judd 1983, Vickers 2021).[3] In particular, our article falls into the strand of literature that assumes ordered search, where the search order is exogenously given (Arbatskaya 2007, Armstrong et al. 2009, Rhodes 2011, Zhou 2011, Wang et al. 2022).[4]

Our objective is to analyze the implications of search costs on firms' investments in quality. Previous articles study conditions under which an increase in search costs can lead to higher quality in the market. Fishman & Levy (2015) show that the effect of search costs depends on the initial fraction of high-quality firms in the market: If the initial fraction of high-quality firms in the market is large, an increase in search costs increases the fraction of high-quality firms. Gamp & Krähmer (2022) analyze quality investments in a market with naive and sophisticated consumers. Gamp & Krähmer (2022) show that lower search costs lead to less investment in quality. Moraga-González & Sun (2023) show that whether an increase in search costs increases investments in quality depends on the effects of search costs on the firm's margin, the number of consumers who search a particular firm, and the probability that consumers stop searching after looking at one particular firm. Chen et al. (2022) show that an increase in search costs can increase investments in quality for experience

[3]Byrne & Martin (2021) summarize evidence for price dispersion and show that a relationship between search and income exists.

[4]See, e.g., Armstrong & Zhou (2011), Haan & Moraga-González (2011) for models where firms can influence the search order. See also Armstrong (2017).

goods.

In contrast to Fishman & Levy (2015), Gamp & Krähmer (2022), Moraga-González & Sun (2023), Chen et al. (2022), we assume that consumers differ in their marginal willingness to pay for quality, that the prominent firm is searched first, and we focus on a duopoly. We contribute to this literature, by contrasting the equilibrium investments in quality when consumers have homogeneous search costs with the equilibrium investments when consumers have heterogeneous search costs. In particular, we introduce correlation between search costs and marginal willingness to pay for quality.

Heterogeneous search costs are often included in models by distinguishing two groups of consumers with different search costs, shoppers with lower search costs and non-shoppers with higher search costs (Stahl 1989, Chan & Leland 1982), or by assuming that the search costs of each consumer are drawn from a common distribution (Stahl 1996, Moraga-González et al. 2017, 2021).[5] Chan & Leland (1982) analyze the effects on quality and show that search costs can lead to lower quality. In contrast, we assume different search costs for all consumers that depend on each consumers' individual marginal willingness to pay for quality.

3 Model

Two firms, Firm 1 and Firm 2, compete for a unit mass of consumers. We assume that both firms produce goods with identical base value v to consumers, but that goods can differ in their prices, and their quality levels. The price set by Firm i is p_i, where $i \in \{1, 2\}$. The quality of a good can be high or low, $q_i \in \{q^L, q^H\}$ with $q^H > q^L = 0$ where $i \in \{1, 2\}$. We assume that Firm 1 is the prominent low-quality firm, i.e., $q_1 = q^L = 0$. Firm 2 can decide whether to produce goods with high or low quality. Producing low quality is costless; producing high quality is costly: $C(q_i) = c_v q_i x_i(p_1, p_2, q_1, q_2) + c_F q_i$ with $c_v \in [0, 2]$ and $c_F \geq 0$.[6] If Firm 2 decides to produce high-quality goods, Firm 2 incurs a fixed cost $c_F q^H$ as well as variable costs $c_v q^H x_2(p_1, p_2, q_1, q_2)$ where $x_2(p_1, p_2, q_1, q_2)$ is the demand for the good of Firm 2. For example, producing goods with high quality may require costs for research and development, which are independent of the quantity sold. In addition, producing goods with high quality may require more expensive materials, which are dependent on the quantity sold. We assume that all other marginal production costs are identical for both firms and set them to zero.

[5] Such heterogeneous search costs can, for example, explain price dispersion (Varian 1980, Stahl 1989, 1996).

[6] The assumption $c_v \leq 2$ streamlines the exposition and does not affect the qualitative results.

Consumers buy exactly one unit of the good, either from Firm 1 or from Firm 2. We assume that, if consumers buy one unit of the good from Firm $i \in \{1, 2\}$, they receive utility

$$u_\theta(i) = v + \theta q_i - p_i,$$

where $\theta \in [0, 1]$ represents the marginal willingness to pay for quality and is distributed uniformly on $[0, 1]$. We assume that v is large enough such that consumers always buy. Assumption 1 ensures that we focus on interior solutions:

Assumption 1. *$v > q^H$.*

Firm 1 is the prominent firm in the market. That means, all consumers who consider buying a good from this market automatically consider Firm 1 and perfectly observe the quality and the price of Firm 1. Consumers are aware that there is more than one firm in the market. However, whether consumers also consider Firm 2 in their consumption decision depends on Firm 2's quality decision. We assume that if Firm 2 produces low-quality goods, consumers automatically also consider Firm 2 and perfectly observe the quality and the price of Firm 2. However, if Firm 2 produces high-quality goods, consumers do not automatically consider Firm 2. Consumers have to exert costly effort to bring Firm 2 to mind, i.e., consumers incur *search costs*.[7] We analyze two cases: First, we analyze the case where all consumers have identical search costs: $S(\theta) = s$ with $s \in [0, 2q^H]$. Second, we analyze the case where search costs depend on the marginal willingness to pay of consumers: $S(\theta) = \sigma(1 - \theta)$, with $\sigma \in [0, \hat{\sigma}]$. With this specification, an increase in σ (i) increases the heterogeneity in the search cost (an increase in σ increases the range of values that $S(\theta)$ takes), (ii) increases the search costs for all consumers, and (iii) increases the average search costs.

Assumption 2. *$\hat{\sigma} \equiv \frac{1}{2}(3v - q^H - c_v q^H)$.*

Assumption 2 limits the analysis to cases where prices and profits depend on σ. We capture the benchmark of fully informed consumers with $s = 0$ and $\sigma = 0$.

Firms play a two-stage game: In the first stage, Firm 2 chooses its quality $q_2 \in \{q^L, q^H\}$. In the second stage, Firm 1 observes the quality of Firm 2. Then, both firms simultaneously choose prices. Afterwards, consumers decide whether to exert effort to bring Firm 2 to mind and make a consumption decision. We assume that consumers have rational expectations. We solve the game by backward induction for the pure-strategy subgame-perfect Nash equilibria. An equilibrium is a vector

[7] Search is necessary to identify the high-quality firm in the market.

$\left(p_1^L, p_2^L, p_1^H, p_2^H, q_2^*\right)$, where p_i^K is the price of firm i in the case where $q_2 = q^K$, with $K = \{L, H\}$. We call the pair $\left(p_1^K, p_2^K\right)$ a price equilibrium.

4 Homogeneous search costs

In this section, we focus on the situation where all consumers have identical search costs: $S(\theta) = s$ with $s \in [0, 2q^H]$.

4.1 Consumers

If Firm 2 produces low-quality goods, i.e., $q_2 = q^L$, consumers consider both firms and buy from the firm with the lower price. Therefore, if $p_1 < p_2$, consumers buy from Firm 1. If $p_2 < p_1$, consumers buy from Firm 2. If $p_1 = p_2$, consumers are indifferent and randomize.

If Firm 2 produces high-quality goods, i.e., $q_2 = q^H$, and consumers consider both firms, consumers buy from Firm 1 if and only if

$$u_\theta(1) > u_\theta(2) \text{ and } u_\theta(1) \geq 0 \Leftrightarrow \; \theta < \hat{\theta} \equiv \frac{p_2 - p_1}{q^H} \text{ and } p_1 \leq v. \tag{1}$$

Similarly, consumers buy from Firm 2 if and only if

$$u_\theta(2) \geq u_\theta(1) \;\; \Leftrightarrow \;\; \theta \geq \hat{\theta} \equiv \frac{p_2 - p_1}{q^H}. \tag{2}$$

That means, $\hat{\theta}$ describes the indifferent consumer. In contrast, if Firm 2 produces high-quality goods and consumers only recall Firm 1, consumers buy from Firm 1. As all consumers with $\theta < \hat{\theta}$ buy from Firm 1 independently of whether they consider both firms or only Firm 1 and as effort is costly and consumers have rational expectations, all consumers with $\theta < \hat{\theta}$ never exert effort to bring Firm 2 to mind. All consumers with $\theta \geq \hat{\theta}$ exert effort to bring Firm 2 to mind if

$$\begin{aligned} & u_\theta(2) - S(\theta) \geq u_\theta(1) \text{ and } u_\theta(2) - S(\theta) \geq 0 \\ \Leftrightarrow \;\; & \theta \geq \hat{\theta}^s \equiv \frac{p_2 - p_1 + s}{q^H} \text{ and } \theta \geq \bar{\theta} \equiv \frac{p_2 + s - v}{q^H}. \end{aligned}$$

Thus all consumers with $\theta < \hat{\theta}^s$ do not exert effort and buy from Firm 1 if $p_1 \leq v$. All consumers with $\theta \geq \hat{\theta}^s$ exert effort and buy from Firm 2 if $\theta > \bar{\theta}$.

4.2 Firms

In the price-setting stage, we have to distinguish two subgames: One subgame where Firm 2 produces low-quality goods $q_2 = q^L$ and one subgame where Firm 2 produces high-quality goods $q_2 = q^H$.

If Firm 2 produces low-quality goods, i.e., $q_2 = q^L$, Bertrand competition ensures that both firms choose prices equal to marginal costs $p_1^L = p_2^L = 0$ and make zero profits. If Firm 2 produces high-quality goods, i.e., $q_2 = q_2^H$, the firms' profits are

$$\Pi_1(p_1, p_2, q^L, q^H) = \begin{cases} 0 & \text{if } p_1 > min\{p_2 + s, v\} \\ p_1\hat{\theta}^s & \text{if } min\{p_2 + s - q^H, v\} \leq p_1 \leq min\{p_2 + s, v\} \\ p_1 & \text{if } p_1 < min\{p_2 + s - q^H, v\} \end{cases} \tag{3}$$

$$\Pi_2(p_1, p_2, q^L, q^H) = \begin{cases} -c_F q^H & \text{if } p_2 > min\{p_1 - s + q^H, v - s + q^H\} \\ (p_2 - c_v q^H)(1 - max\{\hat{\theta}^s, \bar{\theta}\}) - c_F q^H & \text{if } min\{p_1 - s, v - s\} \leq p_2 \\ & \leq min\{p_1 - s + q^H, v - s + q^H\} \\ p_2 - c_v q^H - c_F q^H & \text{if } p_2 < min\{p_1 - s, v - s\}. \end{cases} \tag{4}$$

Firms choose their prices simultaneously to maximize their profits. The equilibrium prices are given in Lemma 1.

Lemma 1. *If consumers have identical search costs* $s \in [0, 2q^H]$*, the equilibrium prices are* $\left(p_1^L, p_2^L\right) = (0, 0)$ *and* $\left(p_1^H, p_2^H\right) = \left((q^H(1 + c_v) + s)/3, (2q^H(1 + c_v) - s)/3\right)$ *if* $c_v \leq 2 - s/q^H$ *and* $(p_1^H, p_2^H) \in \{(p_1, p_2)|q^H \leq p_1 \leq min\{q^H(c_v - 1) + s, v\}, 2q^H - s \leq p_2 \leq min\{q^H c_v, v + q^H - s\},\ p_1 = p_2 + s - q^H)\}$ *if* $c_v \geq 2 - s/q^H$*.*

The proof is in Appendix A.1.1. If both firms produce goods with low quality, the goods can only differ in prices. Then, all consumers buy from the firm with the lower price. This intense price competition ensures prices equal to marginal costs.

If firms produce goods with different quality levels, product differentiation allows firms to choose prices above marginal costs. Firm 2 is dependent on consumers first exerting effort. If the search costs s increase, Firm 2 has to reduce its price to ensure that some consumers still find it profitable to invest effort to bring Firm 2 to mind. In contrast, Firm 1 can increase its price with higher search costs: As s increases, fewer consumers will search for the high-quality good and Firm 1 has more market power over these consumers, which allows Firm 1 to increase its price. However, for $c_v > 2 - s/q^H$, Firm 2's price $p_2^H = (2q^H(1+c_v) - s)/3$ no longer exceeds the marginal costs $c_v q^H$. Consequently, the price combination $\left((q^H(1 + c_v) + s)/3, (2q^H(1 + c_v) - s)/3\right)$ would imply negative profits for Firm 2 and thus no longer constitutes an equilibrium. For all $c_v > 2 - s/q^H$, firms choose prices such that all consumers buy from Firm 1. Firm 2 makes zero revenues but still incurs fixed costs for the investment in high quality.

In the quality-setting stage, Firm 2 then decides whether to produce goods with high or low quality, taking the prices in Lemma 1 into account. If Firm 2 produces goods with low quality, intense price competition ensures that both firms make zero profits. If Firm 2 produces goods with high quality, the resulting product differentiation allows firms to set prices above marginal costs. However, Firm 2 then also incurs costs for high quality. Consequently, Firm 2 produces goods with high quality if and only if the costs for producing high quality are sufficiently low. Proposition 1 summarizes the results.

Proposition 1 (Homogeneous search costs)**.**
If consumers have identical search costs $s \in [0, 2q^H]$, Firm 2 produces goods with high quality if and only if $c_v \leq 2 - s/q^H$ and $c_F \leq \left(q^H(2-c_v) - s\right)^2/(9(q^H)^2)$.

The proof is in Appendix A.1.1. Proposition 1 shows that Firm 2 produces high quality if the costs of producing high quality are sufficiently low. In addition, the consumers' search costs affect the incentive of Firm 2 to produce goods with high quality. As search costs s increase, the range of costs c_v and c_F for which Firm 2 produces high quality decreases. Figure 1 illustrates Proposition 1 graphically for different values of s. Panel (a) of Figure 1 represents the benchmark case in which consumers have zero search costs. Comparing panel (a) to panels (b) and (c) shows that the area where Firm 2 produces goods with high quality shrinks with increasing s. If s increases, $\hat{\theta}^s$ increases. As only consumers with $\theta \geq \hat{\theta}^s$ exert effort to consider Firm 2, with increasing s, the demand for the good of Firm 2 decreases. To dampen this demand effect, Firm 2 reduces its price. Consequently, Firm 2's revenue from producing high quality decreases. Therefore, Firm 2 has less incentives to produce high quality and produces high quality for a smaller range of production costs.

In sum, if the search costs are homogeneous, an increase in search costs implies that Firm 2 loses market share to Firm 1 that increasingly operates as a monopolist towards consumers who do not recall Firm 2. This result hinges on the assumption of homogeneous search costs. Therefore, in Section 5, we consider a case where the search costs are heterogeneous across consumers.

4.3 Welfare

Figure 2 illustrates the consumer surplus, producer surplus, and welfare as a function of s. As

$$\begin{aligned} c_v \leq 2 - \frac{s}{q^H} \text{ and } c_F \leq \frac{1}{9(q^H)^2}\left(q^H(2-c_v) - s\right)^2 \\ \Leftrightarrow s \leq \bar{s} \equiv \max\{0, (2 - c_v - 3\sqrt{c_F})q^H\}, \end{aligned}$$

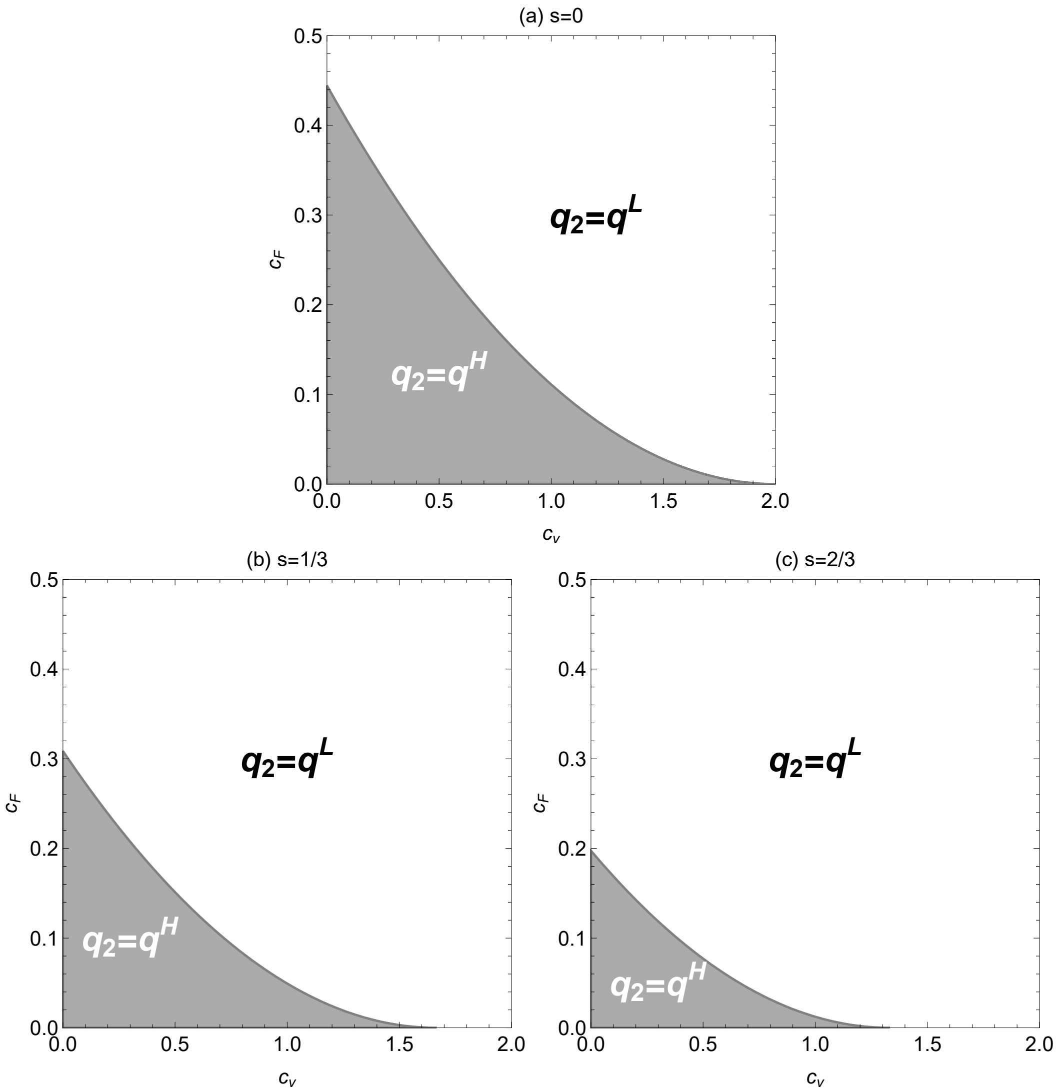

Figure 1: Quality decision of Firm 2 for $q^H = 1$ and (a): $s = 0$, (b): $s = 1/3$; (c): $s = 2/3$. In the gray area, Firm 2 produces high quality. In the white area, Firm 2 produces low quality.

for $s \leq \bar{s}$, Firm 2 produces high quality and, for $s \geq \bar{s}$, Firm 2 produces low quality. Consequently, if $2 - c_v - 3\sqrt{c_F} \leq 0 \Leftrightarrow c_F \geq (2 - c_v)^2/9$, Firm 2 produces low-quality goods for all $s \in [0, \infty)$.

For $s \leq \bar{s}$, Firm 2 produces high quality. Some consumers do not consider the good of Firm 2 and just consider the low-quality good. This gives Firm 1 market power. As the search costs s increase, fewer consumers search for the high-quality good, i.e., $\hat{\theta}^s$ increases. This allows Firm 1 to charge higher prices. Firm 2 reduces its price to dampen this effect. Nevertheless, with increasing search costs s, more consumers buy from Firm 1 instead of Firm 2. In sum, the profit of Firm 1 increases and the profit of Firm 2 decreases. Figure 3 illustrates this. For $s < q^H(1 - 2c_v)/2$, the profit of Firm 1 increases less than the profit of Firm 2 decreases, such that the

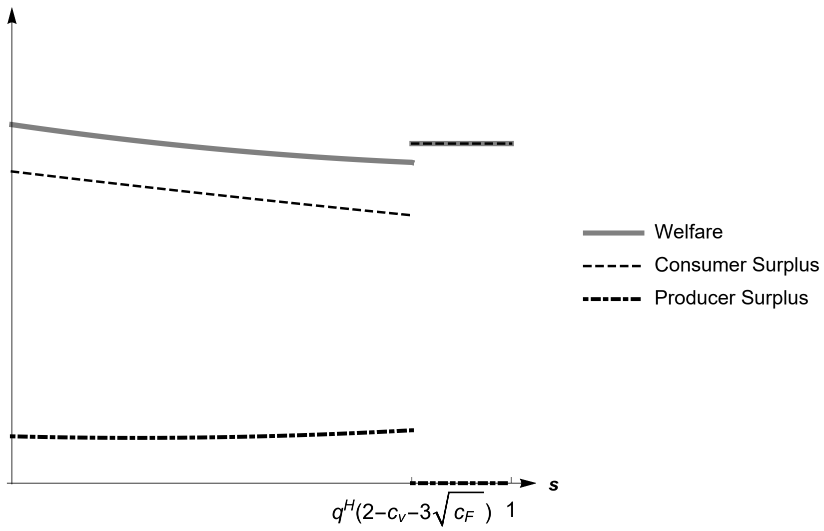

Figure 2: Consumer surplus, producer surplus, and welfare as a function of the search costs s for $v = 3$, $q^H = 1$, $c_v = 1/4$, and $c_F = 1/10$.

producer surplus is decreasing in s. Otherwise, the producer surplus is increasing in s.

Despite the fact that consumers first have to exert costly effort to bring Firm 2 to mind, situations exist where Firm 2 makes more profit that Firm 1 (left panel of Figure 3). When the search costs s are sufficiently low (relative to the costs for quality), i.e., if $s < (q^H - 2c_v q^H - 3c_F q^H)/2$, the search costs do not deter many consumers from searching for Firm 2. Firm 2 can charge a mark-up for producing high quality and the profit of Firm 2 is higher than the profit of Firm 1. With increasing search costs s, more consumers are deterred from searching and Firm 2 loses demand. To dampen this effect, Firm 2 reduces its price, whereas Firm 1 increases its price. The profit of Firm 2 decreases and the profit of Firm 1 increases until, for $s > (q^H - 2c_v q^H - 3c_F q^H)/2$, Firm 1 makes more profit than Firm 2. However if producing high-quality goods is sufficiently costly, i.e., $(q^H - 2c_v q^H - 3c_F q^H)/2 < 0$, Firm 1 always makes higher profits (see right panel of Figure 3).

In contrast, if $s \geq \bar{s}$, Firm 2 produces low quality. Consumers consider both firms, Bertrand competition ensures that both firms make zero profits, and all the surplus goes to consumers. A change in search costs s has no effect on the producer surplus. In sum, producer surplus is highest either at $s = 0$ or $s = \bar{s}$ if $\bar{s} > 0$. If $\bar{s} = 0$, producer surplus is zero everywhere.

The consumer surplus is decreasing in search costs s for $s \leq \bar{s}$: As s increases, more consumers buy from the low-quality firm, Firm 1. In addition, Firm 1 increases its price which harms consumers. In contrast, consumers who still buy from Firm 2 now pay lower prices but also have higher search costs which harms consumers. In sum, consumer surplus is decreasing. For $s \geq \bar{s}$, both firms produce goods with the same quality, i.e., consumers observe both goods without search costs. As prices are $p_1^L = p_2^L = 0$, the prices do not change with s. Thus consumer surplus is constant in s. Consumers benefit from the lower prices and the lack of search costs. Therefore, the consumer surplus is highest for all $s \in [\bar{s}, \infty)$, where Firm 2 produces low quality.

Welfare depends on the costs of firms, the quality of Firm 2, and the search costs. Prices are a reallocation of surplus from consumers to firms and thus do not affect overall welfare. For $s \leq \bar{s}$, an increase in search costs s means that less consumers search and thus less consumers incur search costs, which increases welfare. In contrast, less consumers buy the high-quality good, which reduces welfare, but Firm 2 also has less variable costs, which increases welfare. These trade-offs imply that welfare is decreasing for $s < (7q^H - 5c_v q^H)/5$ and increasing otherwise. For $s \geq \bar{s}$, both firms produce goods with low quality and consumers do not incur search costs. The welfare is constant at the base value of the good v. In sum, if $c_F < (8 - 14c_v + 5c_v^2)/18$, the welfare is higher for s=0; if $(8 - 14c_v + 5c_v^2)/18 \leq c_F \leq 4/9$, the welfare is highest for $s \in [\bar{s}, \infty)$, and if $c_F > 4/9$, the welfare is highest for $s = \bar{s}$.

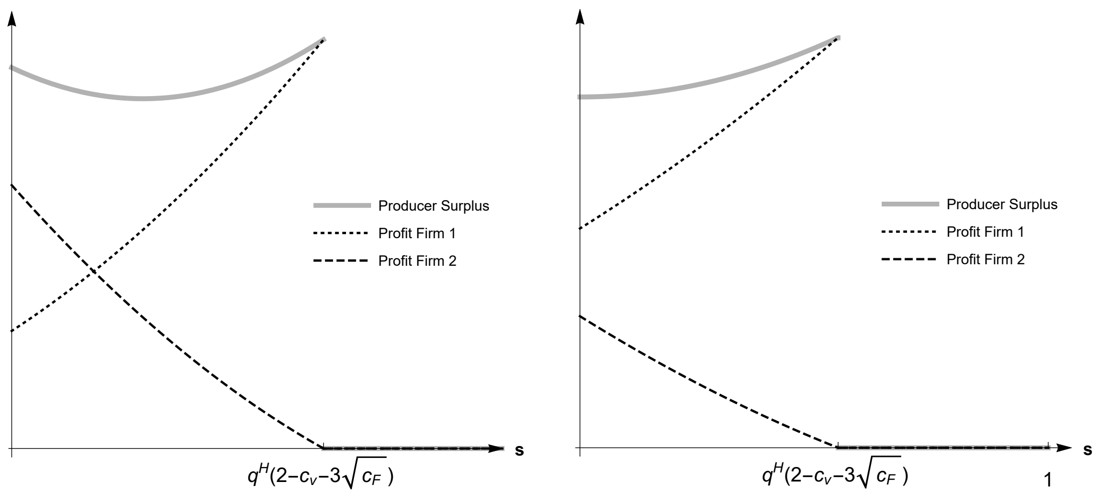

Figure 3: Profit of Firm 1, profit of Firm 2, and producer surplus as a function of $s \in [0, 2q^H]$ for $q^H = 1$ (left panel: $c_v = 1/10$ and $c_F = 1/10$; right panel: $c_v = 1/2$ and $c_F = 1/10$).

Proposition 2 summarizes the results.

Proposition 2. *If consumers have identical search costs $s \in [0, 2q^H]$, then*

(i) if $c_F \geq (2 - c_v)^2/9$, the producer surplus reaches its highest values for all $s \in [0, \infty)$, where Firm 2 produces low quality. If $c_v < 1/2$ and $1/9(1 + c_v)^2 \leq c_F \leq (2 - c_v)^2/9$, producer surplus is highest at $s = 0$, where Firm 2 produces high quality. Otherwise, producer surplus is highest at $s = \bar{s}$, where Firm 2 produces high quality.

(ii) consumer surplus is highest for all $s \in [\bar{s}, \infty)$, where Firm 2 produces low quality.

(iii) if $c_F < (8 - 14c_v + 5c_v^2)/18$, welfare is highest for $s = 0$, where Firm 2 produces high quality. If $(8 - 14c_v + 5c_v^2)/18 \leq c_F \leq 4/9$, the welfare is highest for $s \in [\bar{s}, \infty)$, where Firm 2 produces low quality. Otherwise, if $c_F > 4/9$, welfare is highest for $s = \bar{s}$, where Firm 2 produces high quality.

The proof is in Appendix A.1.2.

5 Heterogeneous search costs

In this section, we focus on the situation where consumers differ in the effort it requires them to bring Firm 2 to mind. In particular, we assume that consumers with higher marginal willingness to pay have lower search costs: $S(\theta) = \sigma(1-\theta)$ with $\sigma \in [0, \hat{\sigma})$.

5.1 Consumers

If Firm 2 produces goods with low quality, i.e., $q_2 = q^L$, consumers consider both firms and buy from the firm with the lower price. That means, if $p_1 < p_2$, consumers buy from Firm 1. If $p_2 < p_1$, consumers buy from Firm 2. And, if $p_1 = p_2$, consumers are indifferent and randomize.

If Firm 2 produces goods with high quality, i.e., $q_2 = q^H$, and consumers have exerted effort to bring Firm 2 to mind, consumers buy from Firm 1 if $\theta < \hat{\theta}$ with $\hat{\theta}$ given in (1). In contrast, if consumers have not exerted effort, they only consider Firm 1 and buy from Firm 1. That means, all consumers with $\theta < \hat{\theta}$ buy from Firm 1 independently of whether they consider both firms or only Firm 1. As effort is costly and consumers have rational expectations, all consumers with $\theta < \hat{\theta}$ never exert effort. All consumers with $\theta \geq \hat{\theta}$ exert effort if

$$u_\theta(2) - S(\theta) \geq u_\theta(1) \;\Leftrightarrow v + \theta q^H - p_2 - \sigma(1-\theta) \geq v - p_1 \;\Leftrightarrow \theta \geq \hat{\theta}^\sigma \equiv \frac{p_2 - p_1 + \sigma}{q^H + \sigma}.$$

Thus everyone with $\theta < \hat{\theta}^\sigma$ does not exert effort and buys from Firm 1. Everyone with $\theta \geq \hat{\theta}^\sigma$ exerts effort and buys from Firm 2.

5.2 Firms

In the price-setting stage, we have to distinguish two subgames: One subgame where Firm 2 produces goods with low quality $q_2 = q^L$ and one subgame where Firm

2 produces goods with high quality $q_2 = q^H$.

If Firm 2 produces goods with low quality, i.e., $q_2 = q^L$, Bertrand competition leads to prices equal to marginal costs $p_1^L = p_2^L = 0$ and zero profits.

If Firm 2 produces goods with high quality, i.e., $q_2 = q^H$, the firms' profits are[8]

$$\Pi_1(p_1, p_2, q^L, q^H) = p_1 \hat{\theta}^\sigma \tag{5}$$

$$\Pi_2(p_1, p_2, q^L, q^H) = (p_2 - c_v q^H)(1 - \hat{\theta}^\sigma) - c_F q^H. \tag{6}$$

As firms produce goods with different quality levels, firms can set prices above marginal costs. The equilibrium prices then depend on the search cost parameter σ: As σ increases, the consumers who buy from Firm 1, i.e., consumers with a low marginal willingness to pay for quality, are less likely to switch to Firm 2, which allows Firm 1 to raise its price. In turn, for the consumers who buy from Firm 2, i.e., consumers with a high marginal willingness to pay for quality, an increase in σ has a smaller effect on total search costs. Consequently, Firm 2 also increases its price.

In the quality-setting stage, Firm 2 chooses to produce goods with high quality if the profits with high-quality goods exceed the profits with low-quality goods. Proposition 3 summarizes the results.

Proposition 3 (Heterogeneous search costs)**.**
If consumers differ in their search costs, i.e., if $S(\theta) = \sigma(1-\theta)$ with $\sigma \in [0, \hat{\sigma}]$, equilibrium prices are $(p_1^L, p_2^L) = (0, 0)$ and $(p_1^H, p_2^H) = \big((q^H(1+c_v)+2\sigma)/3, (2q^H(1+c_v)+\sigma)/3\big)$. Firm 2 produces goods with high quality if and only if $c_F \leq (q^H(2-c_v)+\sigma)^2/(9q^H(q^H+\sigma))$.

The derivation of the results is included in Appendix A.2.1. Figure 4 illustrates Proposition 3 graphically for different values of σ. Proposition 3 shows that the range of production costs for which Firm 2 produces high quality increases if σ increases.

Assume Firm 2 produces high quality. Then, if σ increases, $\hat{\theta}^\sigma$ increases as long as the variable cost parameter $c_v < 1$ and decreases as long as $c_v > 1$. That means, if $c_v < 1$ and σ increases, the demand of Firm 1 increases. However, if $c_v > 1$ and σ increases, the demand of Firm 1 decreases. In addition, an increase in σ induces both firms to charge higher prices. Thus, for $c_v < 1$, if σ increases, Firm 2 charges higher prices but its demand decreases. Nevertheless, in this case, Firm 2's revenue from producing goods with high quality is increasing. For $c_v > 1$, if σ increases, both price and demand of Firm 2 are increasing. Then, in sum, Firm 2's revenue from producing goods with high quality is increasing. In other words, when the search

[8] For sufficiently different prices, $\hat{\theta}^\sigma$ or $1 - \hat{\theta}^\sigma$ could become negative such that the demand for the good of one firm is zero. In equilibrium, firms choose prices such that both firms receive some demand.

costs are negatively related to consumers' willingness to pay for quality, the higher the search cost heterogeneity, the more the consumers who buy the good of Firm 2 value quality on average.

In contrast, a change in σ has no effect on the profit of Firm 2 for producing low quality. Thus, as an increase in σ increases Firm 2's profit for producing high quality but has no effect of Firm 2's profit for producing low quality, Firm 2 has a higher incentive to produce high quality. Consequently, if σ increases, the range of costs for which Firm 2 produces high quality increases (see Figure 4).

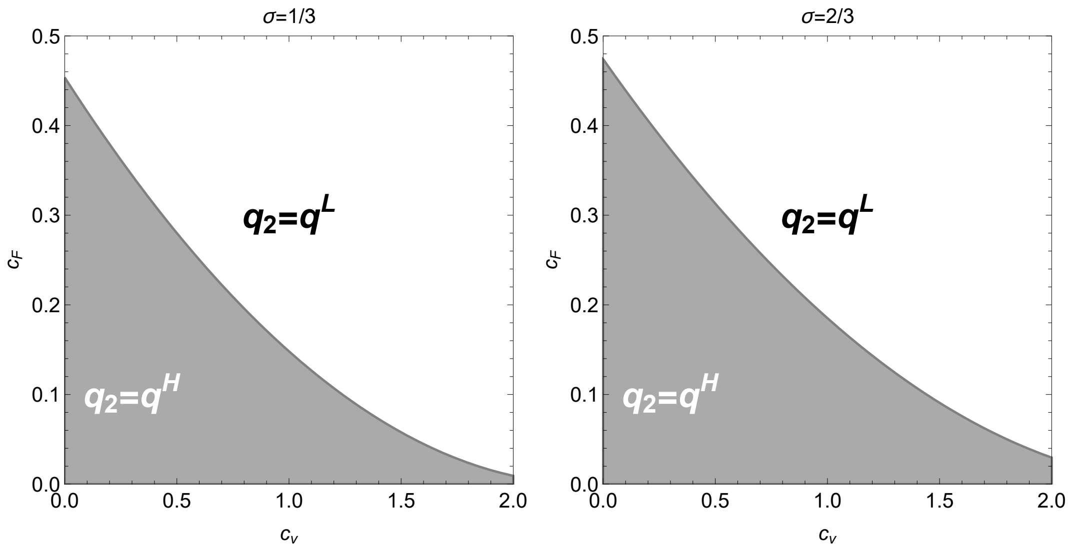

Figure 4: Quality decision of Firm 2 for $q^H = 1$ (left panel: $\sigma = 1/3$; right panel: $\sigma = 2/3$). In the gray area, Firm 2 produces high quality. In the white area, Firm 2 produces low quality.

5.3 Welfare

Figure 5 illustrates the consumer surplus, producer surplus, and welfare as a function of σ. Note that

$$
\begin{aligned}
& c_F \leq \frac{(q^H(2-c_v)+\sigma)^2}{9q^H(q^H+\sigma)} \\
\Leftrightarrow\ & \sigma \geq \bar{\sigma} \equiv \max\{0, \frac{q^H}{2}(9c_F + 2c_v - 4 + 3\sqrt{4c_v c_F + 9c_F^2 - 4c_F})\}.
\end{aligned}
$$

In addition, $\hat{\sigma} > \bar{\sigma}$ if and only if $v > \frac{q^H}{3}(c_v + 1) \equiv v'$ when $\bar{\sigma} = 0$ and if $v > q^H\left(3c_F + c_v - 1 + \sqrt{4c_v c_F + 9c_F^2 - 4c_F}\right) \equiv v''$ when $\bar{\sigma} = \frac{q^H}{2}(9c_F + 2c_v - 4 + 3\sqrt{4c_v c_f + 9c_F^2 - 4c_F})$. Therefore, whenever $v < v''$, Firm 2 always produces low quality, and when $v > v''$, Firm 2 produces goods with high quality if and only if $\bar{\sigma} \leq \sigma \leq \hat{\sigma}$.

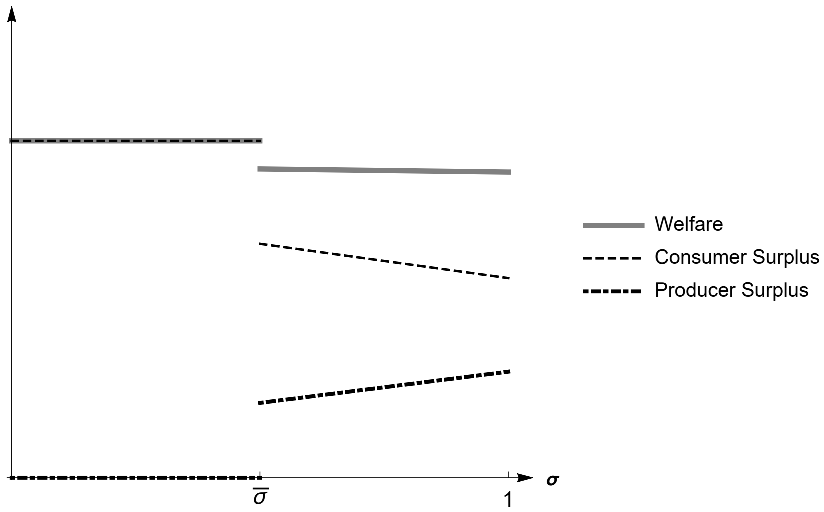

Figure 5: Consumer surplus, producer surplus, and welfare as a function of search cost heterogeneity σ for $v = 3$, $q^H = 1$, $c_v = 1$, and $c_F = 1/6$. Note that in this case $\hat{\sigma} = 3.5$.

When Firm 2 produces goods with high quality, vertical product differentiation allows firms to charge prices above marginal costs and make positive profits. With increasing σ, firms charge higher prices (which balance potential losses in demand) such that profits increase. Therefore, when Firm 2 produces goods with high quality, producer surplus is increasing with σ. In contrast, when Firm 2 produces goods with low quality, Bertrand competition leads to zero profits for both firms. In sum, firms thus benefit from search cost heterogeneity that is sufficiently high such that Firm 2 produces goods with high quality. Specifically, when $\hat{\sigma} > \bar{\sigma}$, producer surplus is higher for any $\sigma \geq \bar{\sigma}$ than for any $\sigma < \bar{\sigma}$. Figure 6 illustrates this case.

The left panel of Figure 6 illustrates a situation, where $\bar{\sigma} = 0$. Consequently, Firm 2 produces high quality for all $\sigma \in [0, \hat{\sigma}]$. For sufficiently low search cost heterogeneity, Firm 2 makes a higher profit than Firm 1. In general, Firm 2 makes a higher profit than Firm 1 if $c_F < (q^H - 2c_v q^H - \sigma)/(3q^H)$. The right panel of Figure 6 illustrates a situation, where Firm 2 produces low quality for sufficiently low search cost heterogeneity $\sigma < \bar{\sigma}$ and high quality otherwise. Then, the profit of Firm 1 is always weakly higher than the profit of Firm 2.

For $\sigma \geq \bar{\sigma}$ where Firm 2 produces goods with high quality, with increasing search cost heterogeneity σ consumers are harmed by the higher costs to exert effort as well as by the increasing prices of the firms. Thus for $\sigma \geq \bar{\sigma}$, consumer surplus is decreasing in search cost heterogeneity σ. In contrast, for $\sigma \leq \bar{\sigma}$ where Firm 2 produces goods with low quality, consumer surplus is constant at v. In sum, consumer surplus is higher for any $\sigma \leq \bar{\sigma}$ where Firm 2 produces goods with low quality compared to any $\sigma \geq \bar{\sigma}$ where Firm 2 produces goods with high quality.

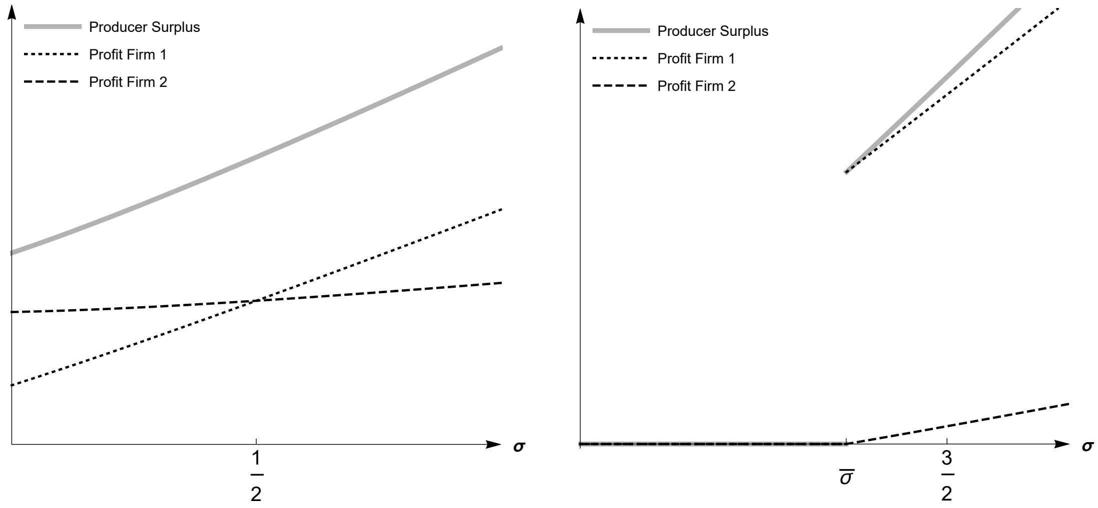

Figure 6: Profit of Firm 1, profit of Firm 2, and producer surplus as a function of search cost heterogeneity σ for $q^H = 1$ (left panel: $c_v = 1/10$, $c_F = 1/10$, and $v > 31/30$; right panel: $c_v = 1/4$, $c_F = 3/7$, and $v > 7/4$).

For welfare, prices are just a reallocation of welfare from consumers to firms. Thus for $\sigma \geq \bar{\sigma}$, the increase in costs drives the effect of σ on welfare. In general, the welfare is decreasing with increasing σ. For every $\sigma \geq \bar{\sigma}$ the welfare is lower than for any $\sigma < \bar{\sigma}$.

Proposition 4 summarizes the results.

Proposition 4. *If consumers differ in their search costs, i.e., if $S(\theta) = \sigma(1-\theta)$ with $\sigma \in [0, \hat{\sigma}]$, then*

(i) if $v < v''$, producer surplus is highest at $\sigma \in [0, \min\{\hat{\sigma}, \bar{\sigma}\}]$, where Firm 2 produces low quality. If $v > v''$, producer surplus is highest at $\sigma = \hat{\sigma}$, where Firm 2 produces high quality.

(ii) consumer surplus and welfare are highest for all $\sigma \in [0, \min\{\hat{\sigma}, \bar{\sigma}\}]$, where Firm 2 produces low quality.

The proof is in Appendix A.2.2.

6 Discussion

6.1 Comparison homogeneous- and heterogeneous-cost cases

A comparison of the homogeneous- and the heterogeneous-cost case yields a number of observations. First, in the homogeneous-cost case, an increase in search costs leads to a reduction in the range for which Firm 2 produces high-quality goods.

In contrast, in the heterogeneous-cost case, an increase in the average search costs, increases the range for which Firm 2 produces high-quality goods.

Second, in the homogeneous cost case, Firm 2's profit is weakly decreasing in the search costs s: With increasing search costs, demand for the good of Firm 2 decreases. To dampen this effect, Firm 2 reduces its price. In sum, this leads to a reduction in profits for Firm 2 with increasing search costs. In contrast, in the heterogeneous-cost case, Firm 2's profits are increasing in the average search costs. This outcome is due to the fact that consumers with a high willingness to pay for quality are less affected by an increase in σ and will search for the product even if the average search costs are high. Firm 2 charges higher prices to the shrinking niche of consumers that will search and buy the high quality good as σ increases (up to the point where $\sigma = \hat{\sigma}$, when Firm 2 ceases to produce the high quality good). Considering the search costs as exogenous could have misleading conclusions.

Third, in the homogeneous-cost case, Firm 2 produces goods with high quality for sufficiently low search costs. In contrast, in the heterogeneous-cost case, Firm 2 produces goods with high quality for sufficiently high search cost heterogeneity.

6.2 Entry costs

Our model resembles an entry game where Firm 1 is the incumbent and Firm 2 is the entrant.[9] A natural follow-up question is whether our results hold when considering a real entry game, where Firm 1 is already in the market, and Firm 2 has to decide whether to enter or not.

Independent of whether search costs are homogeneous or heterogeneous, if Firm 2 incurs an entry cost $E > 0$, Firm 2 never enters with a low quality: If both firms produce goods with low quality, Bertrand competition leads to prices equal to marginal costs but Firm 2 pays entry cost. Thus Firm 2 would make a negative profit of $\Pi_2 = -E$ when entering and producing low quality. That means, Firm 2 is better off not entering and making zero profit.

Consequently, Firm 2 only enters with a high quality. In the homogeneous cost case, Firm 2 enters if

$$\begin{aligned} &\Pi_2(q^L, q^H) - E \geq 0 \\ \Leftrightarrow\ & c_v \leq 2 - \frac{s}{q^H} \text{ and } c_F \leq \frac{1}{9(q^H)^2}\left(q^H(2-c_v) - s\right)^2 - \frac{E}{q^H}. \end{aligned}$$

Consequently, our results only change quantitatively. The range of values for which

[9] The structure of our model is linked to the literature about market entry (Shaked & Sutton 1982, 1983, Lutz 1997, Noh & Moschini 2006, Vives 2008, Oertel & Schmutzler 2022).

Firm 2 produces goods with high quality is shifted downward proportional to the entry cost. With increasing search costs s, the range of values for which Firm 2 produces high quality decreases.

In the heterogeneous cost case, Firm 2 enters if

$$\Pi_2(q^L, q^H) - E \geq 0 \;\Leftrightarrow\; c_F \leq \frac{(q^H(2-c_v)+\sigma)^2}{9q^H(q^H+\sigma)} - \frac{E}{q^H}.$$

In the heterogeneous cost case, the results also do not change qualitatively. The range of values for which Firm 2 produces goods with high quality is shifted downward proportional to the entry cost. The main result that, with increasing average search costs, the range of values for which Firm 2 produces high quality increases, still holds.

Yet, introducing an entry cost changes our results on consumer surplus. In all scenarios without any entry cost, consumers are consistently better off when Firm 2 produces a low-quality good. This effect arises from the Bertrand competition, where both firms produce the same type of good at low prices. However, the presence of entry costs eliminates this effect, as Firm 2 refrains from entering the market and engaging in Bertrand competition. In such cases, Firm 1 is a monopolist, resulting in a downward shift in consumers' welfare compared to the previous Bertrand competition scenario. Firm 1's monopolistic behavior exposes consumers to monopoly prices: $p_1 = v$. The consumer surplus is then $CS = 0$. Therefore, the consumer surplus is higher if Firm 2 enters and produces goods with high quality.

6.3 Entry and market concentration

We only consider markets with two firms. This scenario can be interpreted as a high-concentration case (i.e., the market share is distributed across a few firms). Our results depend on the concentration level of the market. To illustrate this point, consider a market with three firms: two incumbent firms and a third firm that decides whether to enter the market and produce high- or low-quality goods. First, if the two incumbents produce low-quality goods, there is low concentration in the low-quality good market and the two incumbent firms face Bertrand competition (the example could be generalized to a case of n incumbents as the profits of these firms would be the same under Bertrand competition). If the third firm does not enter the market, consumers buy low-quality goods at Bertrand prices. As a result, they do not experience a welfare loss arising from monopolistic prices. Similarly, if the third firm enters the market and produces low-quality goods, the intense price competition allows only for prices equal to marginal costs. As the firm faces entry costs, the third firm will not enter. If the third firm enters the market and produces high-quality goods, product differentiation allows the third firm to charge prices above marginal costs. In this scenario, instead of having a single firm acting as a monopolist towards consumers who are not actively seeking the high-quality good, two firms would compete for consumers with a high search costs. This effect would enhance the competitiveness of the third firm producing the high quality good. As a consequence, the third firm earns higher profits than the two incumbents: such a scenario is only possible in our model when the search costs are low. Consumers' welfare would not decrease when the third firm produces the high quality good, as they would face Bertrand prices for the low quality good, and have the option of a high.quality alternative.

Second, if one incumbent produces low-quality goods and the other incumbent produces high-quality goods, there is high concentration in both the high-quality and low-quality goods markets. In such a case, the entrant would never enter the market. In both cases, the entrant would face Bertrand competition after entry. Therefore, the entrant would receive zero profits after entry. Given the entry cost, the firm never enters such a market. In such a case, consumers cannot benefit from more intense competition, because the third firm has no incentive to enter.

7 Conclusion

In this paper, we study vertical product differentiation where consumers do not automatically take all firms into consideration. Consumers always consider the good of the prominent low-quality firm, but consumers need to exert costly effort to bring the good of the less-prominent firm to mind. The less-prominent firm can reduce consumers' search costs by making its good similar to the prominent firm's good, i.e., by matching the prominent firm's quality. We distinguish two cases: (i) a case where the search costs are homogeneous and (ii) a case where the search costs are heterogeneous and depend on consumers' marginal willingness to pay for quality.

In the homogeneous-cost case, we show that if the search costs increase, the incentive of the less-prominent firm to produce goods with high quality decreases: If the less-prominent firm produces goods with high quality, the subsequent product differentiation allows both firms to charge higher prices. However, producing goods with high quality is more costly than producing goods with low quality. As with increasing search costs less consumers consider the less-prominent firm, the less-prominent firm produces goods with high quality only if the search costs are sufficiently low. For such sufficiently low search costs, the profit of the prominent firm increases and the profit of the less-prominent firm decreases with increasing search costs. However, if the search costs are so high that both firms produce low-quality goods, the intense price competition leads to zero profits. Consumer surplus is decreasing in the search costs up to the point where both firms produce the low quality good, where consumers extract all the surplus from producers.

In the heterogeneous-cost case, the incentive of the less-prominent firm to produce goods with high quality is increasing in the search cost heterogeneity. Heterogeneous search costs allow both firms to increase prices, because consumers are less likely to switch between firms if prices increase. Consequently, the producer surplus is increasing in consumers' search cost heterogeneity. Similar to the homogeneous-cost case, the profit of the prominent firm is increasing in the average search cost. However, the profit of the less-prominent firm is also increasing in the average search cost. In contrast, the consumer surplus is decreasing in the average search cost, as even for higher values of the production cost, the less-prominent firm produces a high quality good and also increases the price.

Our analysis highlights the importance of understanding the nature of consumers' search costs.

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A Appendix

A.1 Homogeneous costs for effort

A.1.1 Derivation of equilibrium prices and profits

Proof of Lemma 1. Firms choose their prices to maximize their profits given in Equations (3) and (4). This yields the following best reply for Firm 1:

$$p_1^*(p_2) = \begin{cases} \frac{p_2+s}{2} & \text{if } p_2 < 2q^H - s \\ p_2 + s - q^H & \text{if } 2q^H - s \leq p_2 \leq v - s + q^H \\ v & \text{if } p_2 > v - s + q^H. \end{cases}$$

If $s < v - q^H - c_v q^H$, the best reply of Firm 2 is

$$p_2^*(p_1) = \begin{cases} p_1 - s + q^H & \text{if } p_1 < q^H(c_v - 1) + s \\ \frac{p_1 - s + q^H(1+c_v)}{2} & \text{if } q^H(c_v - 1) + s \leq p_1 \leq q^H(c_v + 1) + s \\ p_1 - s & \text{if } q^H(c_v + 1) + s < p_1 \leq v \\ v - s & \text{if } p_1 > v, \end{cases}$$

if $v - q^H - c_v q^H \leq s \leq v + q^H - c_v q^H$, the best reply of Firm 2 is

$$p_2^*(p_1) = \begin{cases} p_1 - s + q^H & \text{if } p_1 < q^H(c_v - 1) + s \\ \frac{p_1 - s + q^H(1+c_v)}{2} & \text{if } q^H(c_v - 1) + s \leq p_1 \leq v \\ \frac{v + q^H - s + c_v q^H}{2} & \text{if } p_1 > v. \end{cases}$$

and if $s > v + q^H - c_v q^H$, the best reply of Firm 2 is

$$p_2^*(p_1) = \begin{cases} p_1 - s + q^H & \text{if } p_1 \leq v \\ v - s + q^H & \text{if } p_1 > v. \end{cases}$$

Consequently, if and only if $c_v \leq 2 - s/q^H$, the equilibrium prices are

$$p_1^H = \frac{q^H(1 + c_v) + s}{3}$$
$$p_2^H = \frac{2q^H(1 + c_v) - s}{3}.$$

If and only if $c_v > \max\{0, 2 - s/q^H\}$, any price pair such that

$$
\begin{aligned}
(p_1^H, p_2^H) \in \{(p_1,p_2) | q^H \le p_1 \le \min\{q^H(c_v - 1) + s, v\},& \\
2q^H - s \le p_2 \le \min\{q^H c_v, v + q^H - s\},& \\
p_1 = p_2 + s - q^H)\}&
\end{aligned}
$$

constitutes a price equilibrium.

□

Proof of Proposition 1. The corresponding profits from the equilibrium prices are

$$
\begin{aligned}
\Pi_1(q^L, q^L) &= 0 \\
\Pi_1(q^L, q^H) &= \begin{cases} \frac{1}{9q^H}(q^H(1+c_v)+s)^2 & \text{if } c_v \le 2 - \frac{s}{q^H} \\ p_2 + s - q^H & \text{if } c_v > 2 - \frac{s}{q^H} \end{cases} \\
\Pi_2(q^L, q^L) &= 0 \\
\Pi_2(q^L, q^H) &= \begin{cases} \frac{1}{9q^H}(q^H(2-c_v)-s)^2 - c_F q^H & \text{if } c_v \le 2 - \frac{s}{q^H} \\ -c_F q^H & \text{if } c_v > 2 - \frac{s}{q^H}. \end{cases}
\end{aligned}
$$

In the first stage, Firm 2 chooses high quality if and only if

$$
\Pi_2(q^L, q^H) \ge \Pi_2(q^L, q^L) \;\Leftrightarrow\; c_v \le 2 - \frac{s}{q^H} \text{ and } c_F \le \frac{1}{9(q^H)^2}\left(q^H(2-c_v) - s\right)^2.
$$

□

A.1.2 Welfare

Producer surplus:
If $s \le \bar{s} \equiv \max\{0, (2 - c_v - 3\sqrt{c_F})q^H\}$, the producer surplus (PS) is

$$
\begin{aligned}
PS &= \frac{1}{9q^H}\left((q^H)^2(5 - 2c_v + 2c_v^2) + 2q^H s(2c_v - 1) + 2s^2\right) - c_F q^H \\
\frac{\partial PS}{\partial s} &= \frac{2}{9q^H}\left(-q^H + 2c_v q^H + 2s\right) > 0 \Leftrightarrow s > \frac{1}{2}q^H(1 - 2c_v).
\end{aligned}
$$

Otherwise, the producer surplus (PS) is

$$
PS = 0.
$$

If $c_F \ge (2 - c_v)^2/9$, the producer surplus is 0 for all $s \in [0, \infty)$.

If $c_F < (2-c_v)^2/9$ and $c_v \geq 1/2$, the producer surplus is increasing in $s \in [0, \bar{s}]$ and

$$PS(s = \bar{s}) > 0.$$

If $c_F < (2-c_v)^2/9$ and $c_v < 1/2$, the producer surplus is decreasing in $s \in [0, q^H(1-2c_v)/2)$ and increasing in $s \in (q^H(1-2c_v)/2, \bar{s}]$. In addition,

$$PS(s = \bar{s}) \geq PS(s = 0) \Leftrightarrow c_F \leq \frac{(1+c_v)^2}{9}$$

and

$$PS(s = \bar{s}) > 0 \text{ and } PS(s = 0) > 0.$$

Consequently, if $c_F \geq (2-c_v)^2/9$, the producer surplus reaches its highest values for all $s \in [0, \infty)$. If $c_v < 1/2$ and $1/9(1+c_v)^2 \leq c_F \leq (2-c_v)^2/9$, the producer surplus reaches its highest value at $s^* = 0$. If $c_v < 1/2$ and $c_F \in [(1+c_v)^2/9, (2-c_v)^2/9)$ or if $c_v \geq 1/2$, the producer surplus reaches its highest value at $s^* = 2q^H - c_v q^H - 3q^H \sqrt{c_F}$.

Consumer surplus:

If $s \leq \bar{s}$, the consumer surplus (CS) is

$$\begin{aligned} CS &= \int_0^{\hat{\theta}^s} (v - p_1)\, d\theta + \int_{\hat{\theta}^s}^1 \Big(v + \theta q^H - p_2 - s\Big)\, d\theta \\ &= v - \frac{1}{9q^H}\Big((q^H)^2(1 + 5c_v - \frac{1}{2}c_v^2) + q^H s(5 - c_v) - \frac{1}{2}s^2\Big) < v \end{aligned}$$

If $s > \bar{s}$, the consumer surplus (CS) is

$$CS = v.$$

Consequently, the consumer surplus reaches its highest value fo $s \in [\bar{s}, \infty)$.

Welfare:

If $s \leq \bar{s}$, the welfare is

$$\begin{aligned} W &= PS + CS \\ &= v - \frac{1}{18q^H}\Big(-8(q^H)^2 - 5(c_v q^H)^2 - 5s^2 + 14c_v(q^H)^2 + 14q^H s - 10c_v q^H s\Big) - c_F q^H \end{aligned}$$

$$\frac{\partial W}{\partial s} > 0 \Leftrightarrow s > \frac{7}{5}q^H - c_v q^H$$

If $s > \bar{s}$, the welfare is

$$W = PS + CS = v.$$

As

$$\begin{aligned}
W(s=0) = v - \frac{1}{18q^H}\left(-8(q^H)^2 - 5(c_v q^H)^2 + 14c_v(q^H)^2\right) - c_F q^H \leq v \\
\Leftrightarrow c_F \geq \frac{1}{18}(8 - 14c_v + 5c_v^2),
\end{aligned}$$

$$W(s=\bar{s}) = v + \frac{3}{2}c_F q^H - \sqrt{c_F}q^H \leq v \Leftrightarrow c_F \leq \frac{4}{9}.$$

and if $c_F > 4/9$

$$W(s=0) > W(s = (2 - c_v - 3\sqrt{c_F})q^H),$$

Therefore, if $c_F < 1/18(8 - 14c_v + 5c_v^2)$, welfare is highest for $s = 0$, where Firm 2 produces high quality. If $1/18(8 - 14c_v + 5c_v^2) \leq c_F \leq 4/9$, welfare is highest for all $s \in (\bar{s}, \infty)$, where Firm 2 produces low quality. If $c_F \geq 4/9$, welfare is highest for all $s = \bar{s}$, where Firm 2 produces high quality.

A.2 Heterogeneous costs for effort

A.2.1 Derviation of equilibrium prices and profits

Proof of Proposition 3. Firms choose their prices to maximize the profits in Equation (5) and (6). This yields the following best replies:

$$\begin{aligned}
p_1^*(p_2) &= \frac{p_2 + \sigma}{2} \\
p_2^*(p_1) &= \frac{p_1 + q^H(1 + c_v)}{2}.
\end{aligned}$$

The equilibrium prices are

$$\begin{aligned}
p_1^H &= \frac{q^H(1 + c_v) + 2\sigma}{3} \\
p_2^H &= \frac{2q^H(1 + c_v) + \sigma}{3}.
\end{aligned}$$

The corresponding profits are

$$\Pi_1(q^L,q^H) = \frac{1}{9(q^H+\sigma)}(q^H(1+c_v)+2\sigma)^2$$
$$\Pi_2(q^L,q^H) = \frac{1}{9(q^H+\sigma)}(q^H(2-c_v)+\sigma)^2 - c_F q^H.$$

In the first stage, Firm 2 chooses the high quality if and only if

$$\Pi_2(q^L,q^H) \geq \Pi_2(q^L,q^L) \;\Leftrightarrow\; c_F \leq \frac{(q^H(2-c_v)+\sigma)^2}{9q^H(q^H+\sigma)}.$$

□

A.2.2 Welfare

If $\sigma < \bar{\sigma} \equiv \max\{0, \frac{q^H}{2}(9c_F+2c_v-4+3\sqrt{4c_vc_F+9c_F^2-4c_F})\}$, the producer surplus is

$$PS = 0.$$

If $\sigma \geq \bar{\sigma}$, producer surplus (PS) is

$$PS = \frac{1}{9(q^H+\sigma)}(q^{H^2}(5-2c_v+2c_v^2)+2q^H\sigma(4+c_v)+5\sigma^2) - c_F q^H > 0,$$
$$\frac{\partial PS}{\partial \sigma} = \frac{9}{81(q^H+\sigma)^2}\left((q^H)^2(3+4c_v-2c_v^2)+10q^H\sigma+5\sigma^2\right) > 0.$$

Therefore, the producer surplus reaches its highest value at $\sigma = \hat{\sigma}$ if $\bar{\sigma} \leq \hat{\sigma} \Leftrightarrow v \geq v''$. If $\bar{\sigma} > \hat{\sigma} \Leftrightarrow v < v''$, the producer surplus is constant in σ and thus reaches the highest value for all $\sigma \in [0,\hat{\sigma}]$.

If $\sigma < \bar{\sigma}$, the consumer surplus is

$$CS = v.$$

If $\sigma \geq \bar{\sigma}$, the consumer surplus is

$$CS = \int_0^{\hat{\theta}^\sigma} (v-p_1)\,d\theta + \int_{\hat{\theta}^\sigma}^1 \left(v+\theta q^H - p_2 - \sigma(1-\theta)\right) d\theta$$
$$= v - \frac{1}{18(q^H+\sigma)}(q^{H^2}(2+10c_v-c_v^2)+q^H\sigma(14+8c_v)+11\sigma^2) < v,$$
$$\frac{\partial CS}{\partial \sigma} = -\frac{5}{6} + \frac{4(q^H+\sigma)(q^H+c_vq^H+2\sigma)-(q^H+c_vq^H+2\sigma)^2}{18(q^H+\sigma)^2} < 0.$$

Therefore, the consumer surplus reaches its highest value for all $\sigma \in [0, \min\{\hat{\sigma},\bar{\sigma}\}]$.

If $\sigma < \bar{\sigma}$, the welfare is

$$W = v.$$

If $\sigma \geq \bar{\sigma}$, the welfare is

$$\begin{aligned} W &= PS + CS \\ \frac{\partial W}{\partial \sigma} &= -\frac{1}{18(q^H + \sigma)^2} \left((q^H + \sigma)^2 + 5(q^H)^2(1 - c_v)^2 \right) < 0. \end{aligned}$$

In addition,

$$W(\sigma = \bar{\sigma}) = v - \frac{1}{2} q^H \sqrt{c_F(9c_F + 4c_v - 4)} < v$$

Therefore, the welfare reaches its highest value for all $\sigma \in [0, \min\{\hat{\sigma}, \bar{\sigma}\}]$.

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