Designing a Two-Sided Platform: When To Increase Search Costs?

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Abstract

We propose a model for analyzing an intermediary's incentives to *increase* the search costs incurred by consumers looking for sellers (stores). First, we show that the quality of the search service offered to consumers is more likely to be degraded (i.e. the probability that consumers find their favorite store in the first round of search is less than 1) when the intermediary derives higher revenues from consumers shopping at the lesser-known store *relative to* revenues from consumers shopping at the more popular store. Second, the intermediary may have an incentive to degrade the quality of search even further when its design decision influences the prices charged by stores. By altering the composition of demand faced by stores, the intermediary can force the latter to price lower and thereby increase total consumer traffic.

Keywords: Market Intermediation, Search Costs, Two-Sided Markets.

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1. Introduction

Conventional wisdom holds that at the most fundamental level, market intermediaries exist in order to reduce search and transaction costs among the parties they serve and that they are more valuable the larger the cost savings they generate. This would seem to be true of both traditional, brick-and-mortar intermediaries (retailers, shopping malls, brokers, magazines, market exchanges) and "new economy" ones (Amazon, eBay, iTunes, Yahoo!, etc.), all of which connect buyers and sellers of goods or services.

However, many intermediaries, while providing the relevant information, seem at some stage of the process to do the opposite of reducing search costs - and by purposeful design rather than by accident. Shopping malls are designed to *maximize* the total distance travelled by consumers (and therefore the time spent walking around the mall) while searching for the particular store(s) they have come to visit. Retail stores themselves stack the products they carry so that the most sought-after items are hard to find and thereby induce consumers to walk along alleys carrying other products. Popular magazines (e.g. Vogue, People) are full of advertising, to the extent that it is impossible to find the (little) content they carry. Finally, it is not clear whether the information and search services provided by some online portals to users are indeed designed to help the latter in their search for the particular type of content they are interested in *ex-ante*, or rather to induce users to "explore" additional types of content (e.g. sponsored links for search engines like Google, and recommendation mechanisms on Amazon, iTunes, NetFlix).

In this paper, we challenge the view that intermediaries should aim at minimizing search costs, and we propose a model which sheds light on the economic motivations that in some contexts may lead intermediaries to make it *harder* for the parties they serve - consumers and third-party sellers - to find each other. First, due to a failure of the

Coase theorem, consumers may not internalize all the externalities that their activities generate. In particular, consumers do not account for the gains from trade bestowed on their trading partners (sellers) when deciding to perform a search of such partners through an intermediary. This may lead to insufficient search, a "market failure" that the intermediary may correct by introducing some noise in the search process.

A second motive for degrading the quality of the search service offered to consumers emerges when this enables the intermediary to affect the prices at which commercial transactions between sellers and consumers (buyers) take place (and direct control of these prices is not possible). By shaping the search process through adequate design of the intermediation service, the intermediary can alter the composition of the demand faced by each seller. Designing the search process in such a way that sellers face a more elastic demand may force the latter to lower their prices, thereby promoting more transactions and increasing the overall surplus offered to consumers, even though search quality may be degraded even further.

This article was in part motivated by the shopping mall example mentioned above (the applicability of the framework we develop is however much wider than malls). A good illustration is provided by Roppongi Hills, Tokyo's most prominent real-estate complex: a 12-hectar mini-city encompassing retail space (filled with shops ranging from Louis Vuitton, Banana Republic and Zara, to niche, designer brands); an eclectic mix of restaurants and coffee shops; a large movie-theater; an outdoor arena; a television studio; a luxury hotel, and two residential buildings; as well as an imposing 54-story office tower. The complex is described by many observers as a labyrinth and easy to get lost in. Interestingly, this was apparently a deliberate feature on the part of the designers:

"To convey a feeling of exploration akin to that found in real, organic cities, the architects opted for a maze-like structure in which visitors and residents could wander around for hours, and “discover” new shops and restaurants along the way. The structure was thought to benefit some of the lesser-known shops and restaurants, but some corporate tenants were less pleased with the lack of clarity that, they complained, confused their prospective employees."[1]

In our model, a monopoly intermediary (or platform) acts as a bottleneck for consumers to access two "stores" (sellers). The platform derives exogenously given revenues whenever consumers shop at each of the two stores, but can choose the quality of the search service it offers consumers, i.e. the probability p that they will find their favorite store in the first round of search. Consistent with the quote above, our analysis predicts that the platform (in this case the developer of the complex) may benefit from diverting consumer traffic from well-known "stores" to lesser-known ones. Specifically, the platform is more likely to degrade search (i.e. to set $p < 1$) when the revenues it derives from shopping at the lesser-known store are sufficiently high *relative to* the revenues derived from shopping at the more popular store. By contrast, if consumers were able to find their favorite store immediately, they would not incur additional search costs to shop at the other store. However, if they "stumble" upon stores they did not initially plan to visit, they might shop there and then still go to their favorite store. This can generate positive surplus transactions, which would not take place if the intermediary provided a perfect search mechanism.

We show that the incentive to degrade search quality survives even when the intermediary can charge consumers fees for access to its service or menus of contracts specifying search quality and a corresponding access fee. We also show that introducing a small amount of complementarity between stores from the perspective of consumers provides them with more incentives to visit both stores and therefore makes the intermediary less

[1] Elberse, Hagiu and Egawa (2007).

likely to degrade search quality. Conversely, substitutability between stores makes it more likely that search quality will be less than perfect.

When the prices charged by the two stores are not exogenously fixed but rather set after having observed the platform's design choice (p), we show that the platform has an additional incentive to degrade search quality. Indeed, by doing so, it increases the proportion of less interested consumers that visit each store. This puts downward pressure on the prices charged by the stores and results in increased consumer traffic on the platform.

Our paper contributes both to the established economics literature on market intermediation (Biglaiser (1993), Gehrig (1993), Rubinstein and Wolinsky (1987), Spulber (1996), Rust and Hall (2001)) and to the more recent and quickly growing one on two-sided markets (Caillaud and Jullien (2003), Evans (2003), Rochet and Tirole (2003), Armstrong (2006), Hagiu (2006)). The former was mostly focused on traditional intermediaries, who buy and resell goods, while the latter was inspired by the rising importance of "new economy" intermediaries, who connect buyers and sellers and provide matching, price discovery, certification, advertising and other informational services, without (usually) assuming full control over the transactions.[2] However, these two strands of research do share one element in common: intermediaries are presumed to create value by reducing search and transaction costs and the "technologies" which enable them to do so are generally taken as given (e.g. Rubinstein and Wolinsky (1987), Spulber (1996), Caillaud and Jullien (2003)).

To the best of our knowledge, ours is the first paper to open the "black box" of the search service design by intermediaries and to show that their incentives with respect to search effectiveness are ambiguous and fundamentally determined by the structure of the revenues they derive from the parties they serve. By contrast, most of the economics

[2] Hagiu (2007) contains a unifying framework for analyzing these two forms of intermediation as two extremes along a continuum.

literature on two-sided markets to date has focused on the choice of pricing structures by two-sided platforms as a function of various industry factors (relative strengths of the indirect network effects on each side, relative demand elasticities) and has largely ignored two-sided platform design issues.

The remainder of the paper is organized as follows. In the next section we lay out a simple model and derive some basic principles regarding the incentives that a monopoly intermediary may have to degrade the quality of its search service. Section 3 contains several extensions of the basic model and shows that its main conclusions are robust. Section 4 extends the analysis to the case in which store prices and consumers' utilities from shopping at each store are no longer exogenously given but depend on the platform's design decision. Section 5 concludes.

2. Basic model: exogenous surplus from transactions

We are interested in capturing the key factors which shape a market intermediary's choice of how to design the search service it offers to the parties it serves. In the stylized setting we propose, an intermediary (which we will also call "platform") controls consumer access to two "stores", 1 and 2, in the sense that in order to visit any of the two stores, consumers must go through the intermediary.

We assume that all consumers derive utility u^H from visiting store 1 and utility u^L from visiting store 2, where $0 < u^L < u^H$. u^i should be interpreted as encompassing the utility of just looking around the store and the probability of actually buying something and as being net of the price paid in case the shopper actually buys something[3]. There is

[3] In section 4, we endogenize the stores' pricing decisions.

a unit mass of consumers, differentiated by their individual search cost c that they incur whenever they search for and visit a store. We assume c is distributed on $[0,1]$ according to a twice continuously differentiable cumulative distribution function F.

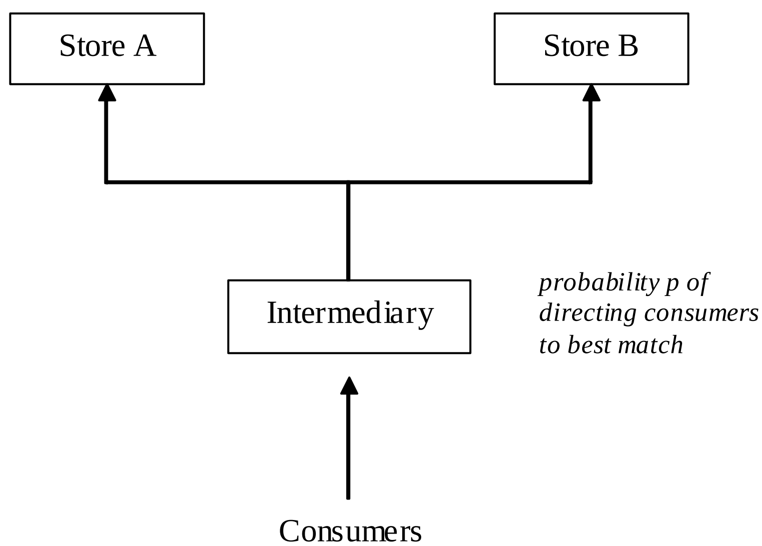
The platform is assumed to derive net revenues r_i whenever a buyer visits store $i \in \{1,2\}$ and for now, we take r_i, $i = 1,2$, as exogenously given. These revenues can be thought of as the compensation that the intermediary is able to extract in exchange for directing consumer traffic to the stores. If the intermediary owns the stores, then r_i is simply equal to the profits made by store i per customer visit. If by contrast the intermediary is a pure two-sided platform which does not own the stores, then r_i can be thought of as the fee that store i has to pay to the platform provider.[4]

The key strategic variable that the intermediary chooses is the probability $p \in (0,1)$ with which it directs consumers to their most preferred store (store 1) when they first "arrive" on the platform. If a consumer does not find store 1 in this "first round" of search, we assume she will find it with probability 1 in the second round, but only after incurring her search cost c again. Similarly, if a consumer finds store 1 in the first round, then she can find store 2 for sure in the second round if she is willing to incur her search cost again. Given that $u^H > u^L > 0$, when consumers are looking for store 1 but find store 2 instead, they will shop at store 2 and then continue their search for store 1.

This stylized model (represented in figure **??**) is an abstraction of many real world intermediation situations: shopping malls (consumers and various retail stores); Internet portals such as Google and Yahoo! (consumers, advertisers and content providers); magazines (consumers, advertisers and content); Internet and brick-and-mortar retailers such

[4]This fee can be either a percentage of store revenues or a "per-click" (i.e. per customer visit) fee. For instance, shopping mall developers charge their retailer tenants a percentage of their sales, while magazines charge advertisers a fee based on expected readership and Internet portals charge advertisers a per-click fee. In the basic version of our model, this distinction is not important; we explore its implications in section 4.

as Amazon, Rakuten, Netflix, Wal-Mart, Costco, iTunes (consumers and various types of products). The probability p can be thought of as being determined by the design of the platform. For a brick-and-mortar shopping mall, it is determined by its physical layout (how easy is it for shoppers to orient themselves?); for a magazine, it is the clarity of its organization (how easy is it to find a certain article? is the table of contents clear? is there any table of contents at all?); for an Internet search portal it is the relevance of the search results provided (are they based purely on relevance or do they contain a lot of - more or less - related advertising?).



2.1. Derivation of the platform's objective function

Clearly, consumers for whom $c \leq u^L$ will shop at both stores no matter what they find in the first round of search.

Let us now analyze consumers for whom $u^L < c \leq u^H$. If they find store 1 in the first round, they stop. If they find store 2, then they shop there and then do a second round of search to find store 1. Therefore, from an ex-ante perspective, they will bother to come to the platform to look for a store in the first round if and only if:

$$pu^H + (1-p)\left(u^L + u^H - c\right) - c \geq 0$$

which is equivalent to:

$$c \leq \frac{u^H + (1-p)\, u^L}{2-p}$$

The platform's net revenues are then:

$$(r_1 + r_2)\, F\left(u^L\right) + [r_1 + (1-p)\, r_2]\left[F\left(\frac{u^H + (1-p)\, u^L}{2-p}\right) - F\left(u^L\right)\right] \tag{2.1}$$

It is easily seen that p has two effects on platform revenues as expressed in (2.1): a lower p increases the revenues from "accidental" shopping at store 2 while searching for store 1, but on the other hand, it also results in less shoppers coming to the platform because they know the search service is not very efficient.

Assuming the maximization of (2.1) over p has an interior solution, we can write the first order condition that determines the optimal p^* if it is strictly between 0 and 1**:**

$$-r_2\left(F\left(\frac{u^H + (1-p^*)\, u^L}{2-p^*}\right) - F\left(u^L\right)\right) + [r_1 + (1-p^*)\, r_2]\, \frac{u^H - u^L}{(2-p^*)^2} f\left(\frac{u^H + (1-p^*)\, u^L}{2-p^*}\right) = 0$$

In the appendix we show that the profit function is quasi-concave in p when either one of the following sets of conditions holds:

1. u^H sufficiently close to u^L and $\left(u^H - u^L\right) \frac{1}{2} \frac{f'\left(u^L\right)}{f\left(u^L\right)} < -\frac{r_1 - r_2}{r_2}$

2. F is concave and $r_1 \leq r_2$.

3. $\frac{F(Y)-F\left(u^L\right)}{(Y-u^L)\sqrt{f(Y)}}$ is increasing in Y.

Throughout the rest of the paper, we will make the following assumption, which is sufficient for ensuring quasi-concavity for all values of r_1 and r_2:

Assumption 1 *F is concave and $\frac{F(Y)-F\left(u^L\right)}{(Y-u^L)\sqrt{f(Y)}}$ is increasing in Y.*

When the second-order conditions for a well-behaved maximization problem are satisfied, we can immediately derive the condition under which the optimal p^* is less than 1, i.e. the platform degrades the quality of search, which reduces to:

$$\frac{r_1}{r_2} < \frac{F\left(u^H\right) - F\left(u^L\right)}{\left(u^H - u^L\right) f\left(u^H\right)} \tag{2.2}$$

The following proposition follows directly:

Proposition 1 *a) The platform is more likely to degrade the quality of search when $\frac{r_1}{r_2}$ decreases.*

b) The platform is more likely to degrade the quality of search when u^H increases if and only if $\frac{F(Y)-F\left(u^L\right)}{(Y-u^L)f(Y)}$ is increasing in Y

c) If F is concave then the platform is more likely to degrade the quality of search when u^L decreases.

Proof: Immediate. Notice that $\frac{F\left(u^H\right)-F(X)}{(u^H-X)f(u^H)}$ decreases in X if F is concave.

■

Thus, the revenues the platform obtains from shopping that takes place at store 1 have to be sufficiently low relative to the revenues it obtains from shopping taking place at store

2 in order to warrant having some shoppers lost on their way to store 1. Note that when $u^H \to u^L$ condition (2.2) simply becomes $\frac{r_1}{r_2} < 1$.

Assumption 1 implies that $\frac{F(Y)-F\left(u^L\right)}{(Y-u^L)f(Y)}$ is increasing in Y, therefore we have the somewhat surprising result that increasing the value at the most valuable store (u^H) makes the platform more likely to degrade search quality. When $\frac{F(Y)-F\left(u^L\right)}{(Y-u^L)f(Y)}$ is decreasing in u^L (which reduces to F concave), increasing the value at the least valuable store (u^L) makes the platform less likely to degrade search quality. This is understood by noting that when the distance between u^H and u^L increases *all other things being equal* (in particular, keeping $\frac{r_1}{r_2}$ constant), the platform may start to find it profitable to divert some consumer traffic to store 2 among the consumers who would otherwise never shop there...

To interpret this result we can notice that profits net of the fixed revenue $(r_1 + r_2)\, F\,(u_L)$ consists in a margin $r_1 + (1-p)\, r_2$ applied to the variable demand coming from consumers with search cost above u^L. Then increasing u^H for a given level of p raises both the level of variable demand and its slope with respect to p. It is easy to see that the elasticity of this variable demand is proportional to $\frac{\left(Y-u^L\right)f(Y)}{F(Y)-F(u^L)}$. Then increasing u^H or decreasing u^L reduces the elasticity of demand with respect to p, hence with respect to the margin $r_1 + (1-p)\, r_2$. This raises the incentive to increase the margin and thus to reduce the quality of search.

In the appendix we show that condition (2.2) remains unchanged when there are $N > 2$ stores and all stores except for the most popular one generate the same utility to consumers. Of course, with more than two stores, there could be more complex strategies as the quality of search could depend in a contractual way on the number of searches performed, but we abstract from such issues here.

2.2. Optimal search quality

In order to investigate the effect of the various parameters on the optimal quality of search chosen by the platform, let us define:

$$Y = \frac{u^H + (1-p)\,u^L}{2-p} \in \left[\frac{u^H + u^L}{2}, u^H\right]$$

Then $F(Y)$ is total consumer "traffic" on the platform. (2.1) can then be rewritten as:

$$(r_1 + r_2)\,F\left(u^L\right) + \left[r_1 - r_2 + r_2\left(\frac{u^H - u^L}{Y - u^L}\right)\right]\left(F(Y) - F\left(u^L\right)\right)$$

Noting that Y is strictly increasing in p, we can change variables and optimize over Y for convenience. We obtain:

Proposition 2 *If the optimal quality of search p^* is interior ($0 < p^* < 1$) then:*

- *p^* only depends on r_1 and r_2 through $\frac{r_1}{r_2}$ and is increasing in $\frac{r_1}{r_2}$*
- *p^* is decreasing in u^H if and only if $\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}$ is increasing in Y.*

Proof See appendix.

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The first important result is that the optimal quality of search deteriorates when $\frac{r_1}{r_2}$ is reduced, as intuition might suggest. This prediction also fits well with some stylized real-world examples: we expect search quality to be the worst in contexts in which $\frac{r_1}{r_2}$ is very low. This is the case with popular magazines: the margins made through sales of *content* to consumers are very low (arguably 0), whereas most of the profits actually come from advertising. It is not surprising then that the organization of such magazines is very frustrating for readers (as anyone having tried to find an article in a fashion magazine knows). The same is true (to a certain extent) for shopping malls, where the pricing structure is such that profits for the developer come almost exclusively from stores[5].

The second prediction -regarding u^H- is somewhat surprising: provided that $\frac{F(Y)-F(u^L)}{(Y-u^L)f(Y)}$ (which is guaranteed whenever Assumption 1 is satisfied), increasing the value at the most valuable store (u^H) results in *lower* search quality (and therefore less total consumer traffic). The result follows from the above remark that increasing u^H reduces the elasticity of the variable part of demand to p and thus to the profit margin.

2.3. Welfare

It is important to note that reduced search quality may be welfare-enhancing when consumers do not internalize the entire surplus created by their search decisions. Clearly, consumer surplus (and traffic) increases with the quality of search. From the joint perspective of the platform and the consumers, the monopoly level of search quality p^* is too small: thus there is excessive degradation of search quality. Still, the monopoly level $p^* < 1$ can be socially superior to no degradation at all ($p = 1$).

Moreover, when the platform intermediates transactions between consumers and third parties (such as stores), the socially optimal quality of search should account for the surplus of these third parties. Thus one should add to r_1 and r_2 the profit that stores derive from sales. Notice that accounting for the profits of stores amounts to replacing r_1 and r_2 by the joint platform-store profit in the platform's objective function. From the above proposition, this has an ambiguous effect on the resulting optimal quality of search: the quality of search

[5] The interesting exception is warehouse clubs (e.g. Costco, Sam's Club), which have a more balanced pricing structure. Indeed, they make very low margins on sales of products and derive the bulk of their profits from subscription fees charged to consumers.

chosen by the platform may be too large or too small relative to the socially optimal level.

2.4. Platform competition

While we have not yet fully developed a model of search quality choice by competing platforms, a few insights are immediately derived from the analysis above and general principles of competition between two-sided platforms (in this case the two sides are consumers and stores).

The impact of competition at the platform level on search quality crucially depends on the intensity of competition *for consumers* relative to the intensity of competition *for stores*. Indeed, given that two-sided platforms have to balance the interests of the two sides they serve, competition will tend to make the balance tilt in favor of the side that needs to be "courted" more assiduously by the two platforms, i.e. maximizing its surplus.

Thus, if for instance stores multihome and platforms are undifferentiated from consumers' perspective, all the action will be on the consumer side. Platforms will maximize consumer surplus and it is easily seen that this leads to $p^* = 1$ in our model since for any c, consumer surplus is weakly increasing in p.[6] In this case, competition leads to higher effectiveness of search.

If on the contrary consumers can easily visit the two platforms but the stores need to be attracted exclusively, and stores are perceived symmetrically by consumers before search, it is easily seen that the resulting p^* is the same as the one determined above and is lower than 1 under the conditions we have already determined.[7] In this case, competition leads to lower search effectiveness.

[6] With Hotelling differentiation and unit transport cost t, we expect $p^*(t) < 1$; $\frac{dp^*}{dt} < 0$.

[7] This assumes that the platforms compete only in the probability p, and that stores coordinate according to the Pareto criterion (no coordination failure). Things are probably different with asymmetric stores: the more popular store may prefer a higher effectiveness of search.

Consequently, competition may lead to socially insufficient or socially excessive search quality, depending on its nature.

3. Extensions of the basic model

3.1. Revenues from total shopper traffic

Suppose that in addition to revenues r_i from the transactions conducted by consumers at stores, the platform provider also receives revenues t for each shopper who visits the platform. $t > 0$ should be interpreted as a revenue coming from indirect sources, such as advertisers paying for the privilege of reaching the consumer audience offered the platform.[8] $t < 0$ can be interpreted as a cost incurred by the platform for serving each shopper[9]. The expression of platform revenues (2.1) becomes:

$$\Pi^P = (r_1 + r_2) F\left(u^L\right) + [r_1 + (1-p) r_2] \left[F\left(\frac{u^H + (1-p) u^L}{2-p}\right) - F\left(u^L\right)\right] + tF\left(\frac{u^H + (1-p) u^L}{2-p}\right)$$

We obtain:

$$\frac{\partial \Pi^P}{\partial p}(p=1) < 0 \Longleftrightarrow \frac{r_1 + t}{r_2} < \frac{F\left(u^H\right) - F\left(u^L\right)}{f\left(u^H\right)\left(u^H - u^L\right)}$$

Thus, the platform is *less* likely to degrade search when t is higher, i.e. when it extracts more revenues from consumer traffic, which is quite intuitive. Also, it is easily verified that the slope of the profit function with respect to p is increasing in t; implying that the optimal quality of search is increasing in t.

[8] This is customary practice with shopping malls. For instance, Mori Building rents out various parts of the "public" space (physical and virtual - giant television screens) within the Roppongi Hills complex to companies wishing to showcase their products.

[9] Again, in the case of shopping malls, this cost may cover: printing maps, maintaining the cleanliness of the complex, etc.

This simple result may lead one to wonder whether allowing the platform to charge access fees to consumers could not result in search quality degradation being superfluous. In the next subsection we prove that this is not the case.

3.2. Platform charges access fees to shoppers

Suppose now that the platform can charge shoppers access fees $A \geq 0$.[10]

In this case, shoppers with $c \leq u^L$ shop at both shops and derive net utility $u^H + u^L - 2c - A$. Therefore they visit the platform if and only if:

$$c \leq \frac{u^H + u^L - A}{2}$$

Shoppers with $c \geq u^L$ stop as soon as they find their favorite store, hence their net utility from visiting is $u^H + (1-p)\, u^L - (2-p)\, c - A$, and therefore visit if and only if:

$$c \leq \frac{u^H + (1-p)\, u^L - A}{2-p}$$

It is then easily verified that:

$$\Pi^P = \begin{cases} pr_2 F\left(u^L\right) + \left(r_1 + (1-p)\, r_2 + A\right) F\left(\frac{u^H + (1-p) u^L - A}{2-p}\right) & \text{if} \quad A \leq u^H - u^L \\ \\ \left(r_1 + r_2 + A\right) F\left(\frac{u^H + u^L - A}{2}\right) & \text{if} \quad A > u^H - u^L \end{cases}$$

For large access fees, the quality of search becomes irrelevant because all consumers who visit the platform search twice.

[10] We could envision negative fees but then all consumers would join the platform and only those with a positive expected suprplus from search would engage in active search. The outcome would be the same as with $A = 0$ but with additional lump-sum payments to consumers.

Let A^* be the profit maximizing fee conditional on fixing $p = 1$; and suppose that $A^* < u^H - u^L$. Then the optimal level A^* is given by:[11]

$$\frac{F\left(u^H - A^*\right)}{f\left(u^H - A^*\right)} = r_1 + A^*$$

We can now repeat the analysis in sections 2.1 and 2.2 for a fixed value of the fee A^*. The expression of platform profits is:

$$(r_1 + r_2 + A^*) F\left(u^L\right) + (r_1 + (1-p) r_2 + A^*) \left(F\left(\frac{u^H + (1-p) u^L - A^*}{2-p} \right) - F\left(u^L\right) \right)$$

The condition for search quality degradation to be optimal is the same as before, but replacing u^H by $u^H - A^*$ and r_1 by $r_1 + A^*$. We obtain:

Proposition 3 *If the platform can charge consumers access fees A, then the platform will set $p^* < 1$ if:*

$$A^* < u^H - u^L$$

and:

$$\frac{r_1 + A^*}{r_2} < \frac{F\left(u^H - A^*\right) - F\left(u^L\right)}{\left(u^H - u^L - A^*\right) f\left(u^H - A^*\right)}$$

where $A^* = \arg\max_A \ (r_1 + A) F\left(u^H - A\right)$ *is defined by* $\frac{F\left(u^H - A^*\right)}{f\left(u^H - A^*\right)} = r_1 + A^*$.

[11] The slope of the profit function in A is:

$$\begin{array}{rcl} F\left(u^H - A\right) - (r_1 + A) f\left(u^H - A\right) \text{ if } A & < & u^H - u^L \\ F\left(\frac{u^H + u^L - A}{2}\right) - \frac{1}{2}(r_1 + r_2 + A) f\left(\frac{u^H + u^L - A}{2}\right) \text{ if } A & > & u^H - u^L \end{array}$$

There may be a non-concavity at $A = u^H - u^L$ if the slope at $A = \left(u^H - u^L\right)^-$ is lower than the slope at $A = \left(u^H - u^L\right)^+$ which is equivalent to $r_1 + A > \frac{1}{2}(r_1 + r_2 + A)$.

The profit is quasi-concave on both ranges if $\frac{F}{f}$ is increasing. Then a sufficient (but not necessary) condition for $A^* \leq u^H - u^L$ is $\frac{F\left(u^L\right)}{f\left(u^L\right)} \leq \frac{1}{2}\left(r_1 + r_2 + u^H - u^L\right)$.

Proof: Follows from proposition 1.

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When $\frac{F(u)-F\left(u^L\right)}{(u-u^L)f(u)}$ is increasing on the range $\left[u^L, u^H\right]$, allowing for access fees thus reduces the likelihood that the platform degrades quality. But provided that the fee remains small, this possibility still exists.

3.3. Screening

When the plaform can charge an access fee and commit to individualized search quality, it could use menus to screen between different types of individuals. Suppose that the platform can propose any quality between $p_l < 1$ and 1. Then the platform offers a tariff $A(p)$ (non-decreasing in p) and agents self-select by choosing p. We show in the appendix that given the linearity of the profit and the utility in p, the optimal contract consists in offering only the lowest and the highest quality (as opposed to a continuum).

Thus we study here a contract that proposes to choose between p at price A_l, and $p = 1$ at price $A_h > A_l$. Then consumers with $c < u^H - A_h$ are willing to pay for the high quality service, and consumers prefer the low quality if

$$c < c_l = u^L + \frac{A_h - A_l}{1-p}.$$

Let c_h be the highest search cost among participants. Screening is optimal if the solution of the optimal contract is such that $c_h = u^H - A_h > c_l > u^L$. Indeed a solution at $c_l = u^L$ would correspond to the highest quality of search only being offered, while a solution with $u^H - A_h = c_l$ would correspond to the lowest quality only being offered.

The expression of platform profits (using $A_l = A_h - (1-p)\left(c_l - u^L\right)$ and $A_h = u^H - c_h$)

is then:

$$\Pi^P = pr_2 F\left(u^L\right) + (1-p)\left(r_2 + u^L - c_l\right) F\left(c_l\right) + \left(r_1 + u^H - c_h\right) F\left(c_h\right).$$

Optimizing over c_l and c_h, we obtain:

$$c_l^* = \arg\max_{c_l \in [u^L, u^H]} \left(r_2 + u^L - c_l\right) F\left(c_l\right)$$

$$c_h^* = \arg\max_{c_h \in [u^L, u^H]} \left(r_1 + u^H - c_h\right) F\left(c_h\right)$$

which are such that $c_h^* \geq c_l^*$, with strict inequality if one of the two is strictly between u^L and u^H.

Proposition 4 *Assume that $\frac{f(u)}{F(u)}$ is non-increasing on $\left[u^L, u^H\right]$. When screening is possible, the platform screens if and only if $\frac{F\left(u^L\right)}{f\left(u^L\right)} < r_2 < \frac{F\left(u^H\right)}{f\left(u^H\right)}$.*

Proof: The condition is equivalent to $u^L < c_l^* < u^H$ which ensures that some consumers choose the highest quality of search, while others choose the low quality.

■

When r_2 is small then only the high quality is provided, while when r_2 is large, only the high quality is provided.

Corollary *Assume that $\frac{f(u)}{F(u)}$ is non-increasing. When screening is possible, the platform proposes a service with degraded quality of search if and only if $\frac{F\left(u^L\right)}{f\left(u^L\right)} < r_2$.*

Proof: The condition is $c_l^* > u^L$. Then either there is screening when $c_l^* < u^H$, or all consumers are proposed a low quality of search when $c_l^* = u^H$. In the case $c_l^* = u^L$, only low cost consumers intending to visit both stores would choose the low quality, therefore screening would just means a gift to these consumers and is suboptimal ($A_l = A_h$).

■

The condition is independent of r_1 and u^H provided that they are larger or equal than r_2 and u^L respectively (with one strict inequality). The reason is that the screening is used to extract surplus from infra-marginal consumers not to extend the size of the clientele. The only consideration is then whether it is profitable to offer as an extra option a service with degraded quality at a price attractive to consumers with a search cost above but close to u^L.

These consumers generate extra revenues r_2 with probability $1-p$ but need to be compensated by a reduction in fee larger than $(1-p)\left(c-u^L\right)$. This option is equivalent in terms of payoffs to a mechanism in a first search of high quality requiring a payment A_h, is followed with probability $1-p$ by the possibility for the consumer of receiving a subsidy $c_l - u^L$ for conducting a second search. This mechanism is optimal if subsidizing the participation of consumers to the search of the second-best store is optimal for the platform. Hence the condition depends only on r_2 and u^L.

This intuition confirms also that whenever there is screening, then the platform sets p at the minimal possible level.

3.4. Substitutability/complementarity between stores

Up to now we have assumed that consumers viewed the stores as independent, i.e. there was no complementarity/substitutability among them. We now explore what happens to the likelihood of degrading search quality when that assumption is relaxed.

Substitutability (complementarity) is modeled by assuming that *conditional* on having bought product i, the utility from purchasing product $j \neq i$ is reduced (respectively increased) from u^j to $u^j - \gamma$ (respectively $u^j + \gamma$), where $\gamma > 0$.

3.4.1. Substitutability

In this case, consumers with $c \leq u^L - \gamma < u^H - \gamma$ shop at both stores no matter what.

Consumers with $u^L - \gamma \leq c \leq u^H - \gamma$ only shop at store 2 if they are diverted there while looking for store 1. Their net utility is $pu^H + (1-p)\left(u^L + u^H - \gamma\right) - 2c$ and is positive if and only if:

$$c \leq \frac{u^H + (1-p)\left(u^L - \gamma\right)}{2-p}$$

Finally, consumers with $c \geq u^H - \gamma$ shop at most at one store and then stop. Therefore, they visit the platform if and only if:

$$c \leq pu^H + (1-p)\,u^L$$

Note that:

$$\frac{u^H + (1-p)\left(u^L - \gamma\right)}{2-p} \geq u^H - \gamma \Longleftrightarrow \gamma \geq \left(u^H - u^L\right)(1-p)$$

and:

$$pu^H + (1-p)\,u^L \geq u^H - \gamma \Longleftrightarrow \gamma \geq \left(u^H - u^L\right)(1-p)$$

Thus, we obtain the expression of platform profits:

$$\Pi^P = \begin{cases} \begin{array}{l} (r_1 + r_2) F\left(u^L - \gamma\right) \\ + (r_1 + (1-p) r_2) \left[F\left(\frac{u^H + (1-p)\left(u^L - \gamma\right)}{2-p} \right) - F\left(u^L - \gamma\right) \right] \end{array} & \text{if} \quad \gamma \leq \left(u^H - u^L\right)(1-p) \\ \\ \begin{array}{l} (r_1 + r_2) F\left(u^L - \gamma\right) \\ + (r_1 + (1-p) r_2) \left[F\left(u^H - \gamma\right) - F\left(u^L - \gamma\right) \right] \\ + (p r_1 + (1-p) r_2) \left[F\left(p u^H + (1-p) u^L\right) - F\left(u^H - \gamma\right) \right] \end{array} & \text{if} \quad \gamma \geq \left(u^H - u^L\right)(1-p) \end{cases}$$

We are interested in the conditions under which the platform will choose to degrade the quality of search, i.e. choose $p^* < 1$. Given $\gamma > 0$, for p close enough to 1 we will eventually have $\gamma \geq \left(u^H - u^L\right)(1-p)$, therefore if the derivative of the second expression above evaluated at $p = 1$ is negative, we can conclude that the optimal p is smaller than 1. This condition is equivalent to:

$$\frac{r_1}{r_2} \left(1 + \frac{F\left(u^H\right) - F\left(u^H - \gamma\right)}{\left(u^H - u^L\right) f\left(u^H\right)} \right) \leq \frac{F\left(u^H\right) - F\left(u^L - \gamma\right)}{\left(u^H - u^L\right) f\left(u^H\right)}$$

or:

$$H\left(r_1, r_2, \gamma\right) < 0$$

Clearly, for $\gamma = 0$ we obtain the same condition as before (2.2). Here we are interested in knowing whether introducing some small amount of substitutability makes degradation of quality more or less likely. In order to determine that, note that:

$$\frac{\partial H}{\partial \gamma}\left(r_1, r_2, \gamma\right) < 0 \Longleftrightarrow \frac{r_1}{r_2} < \frac{f\left(u^L - \gamma\right)}{f\left(u^H - \gamma\right)}$$

If F is concave, we have:

$$\lim_{\gamma \to 0} \frac{f\left(u^L - \gamma\right)}{f\left(u^H - \gamma\right)} = \frac{f\left(u^L\right)}{f\left(u^H\right)} > \frac{F\left(u^H\right) - F\left(u^L\right)}{\left(u^H - u^L\right) f\left(u^H\right)}$$

and therefore we obtain:

Proposition 5 *When assumption 1 holds, introducing an arbitrarily small amount of substitutability between the two stores ($\gamma \to 0$) makes it* more *likely that the optimal search quality p will be less than 1.*

■

3.4.2. Complementarity

Similarly, assume now the stores are complementary, i.e. conditional on having bought product i, the utility from purchasing product $j \neq i$ is increased from u_j to $u_j + \gamma$, where $\gamma > 0$.

It is then easily shown that:

$$\Pi^P = \begin{cases} \begin{array}{l} \left(r_1 + r_2\right) F\left(u^L + \gamma\right) \\ + \left(r_1 + (1-p) r_2\right) \left[F\left(\frac{u^H + (1-p)\left(u^L + \gamma\right)}{2-p}\right) - F\left(u^L + \gamma\right)\right] \end{array} & \text{if} \quad \gamma \leq u^H - u^L \\ \\ \left(r_1 + r_2\right) F\left(u^L + \gamma\right) & \text{if} \quad \gamma \geq u^H - u^L \end{cases}$$

We assume γ is small enough so that we are in the first case above. Then the platform will degrade search quality if and only if:

$$r_1 \left(u^H - u^L - \gamma\right) f\left(u^H\right) - r_2 \left[F\left(u^H\right) - F\left(u^L + \gamma\right)\right] < 0$$

or:

$$\frac{r_1}{r_2} \leq \frac{F\left(u^H\right) - F\left(u^L + \gamma\right)}{\left(u^H - u^L - \gamma\right) f\left(u^H\right)}$$

For $\gamma = 0$ we obtain (2.2). If F is concave then $\frac{F\left(u^H\right) - F\left(u^L + \gamma\right)}{\left(u^H - u^L - \gamma\right) f\left(u^H\right)}$ is decreasing, therefore, for small enough γ, complementarity between the stores makes quality degradation *less* likely.

Proposition 6 *When assumption 1 holds, introducing an arbitrarily small amount of complementarity between the two stores makes it* less *likely that the optimal search quality* p *will be less than 1.*

■

The intuition behind the results contained in Propositions 5 and 6 is quite simple: complementarity makes it less necessary to divert people in order to convince them to shop at store 2 (the attractiveness of store 2 conditional on having shopped at store 1 is increased), while substitutability makes it more necessary.

4. Strategic use of search design in order to influence store prices

Up to now we have focused on exogenously given utilities. Suppose now that stores observe the platform's choice of design (i.e. the effectiveness of search, p) *before* setting their prices and that the platform cannot control nor contract upon those prices. We will show that in this case the platform may have an additional incentive to degrade search quality in order to make the consumer demand faced by each store more elastic and therefore force them to hold down their prices.

In other words, the platform may choose an imperfect search design ($p < 1$) in order to force stores to take into account the possibility of increased traffic from "accidental shoppers" - with lower valuations -, which puts pressure on stores to lower prices, resulting in increased traffic on the platform. In other words, the platform can use design strategically in order to alter the composition of consumer demand faced by each store, which influences their pricing decision and thereby the total consumer traffic.

To analyze the strategic interaction between platform design and pricing by platform participants, we now modify our basic model in the following way. We assume consumers can be of two types, equally distributed in the population. Type $t = 1$ consumers prefer store 1 to store 2 in the sense that the distribution of their valuation v for the product sold by store 1 is G^H with continuous density g^H and that of their valuation for store 2 is G^L with continuous density g^L, where we assume the two distribution have a common support.

Assumption 2 *$G^H(.)$ has a lower hazard rate than $G^L(.)$, $\frac{g^H(\pi)}{1-G^H(\pi)} < \frac{g^L(\pi)}{1-G^L(\pi)}$, and both hazard rates are monotone.*

This assumption ensures that profit functions are well behaved and that demand from type 1 is more elastic at store 1 than at store 2. Notice that it implies that G^H stochastically dominates G^L:

$$G^H(v) < G^L(v) \text{ for all } v \text{ on the support.}$$

By contrast, type 2 consumers prefer store 2 to store 1: the respective distributions of their valuations for store 1 and store 2 are G^L and G^H. We assume that the distribution of types within the population, G^L and G^H are independent of the distribution of search costs c.

Thus, the realized demand for store i when it charges price π is:

$$\left(1 - G^H(\pi)\right) T_i + \left(1 - G^L(\pi)\right) T_j$$

where T_i is the total traffic of consumers of type i, $i, j \in \{1, 2\}$, $i \neq j$.

In this context, a consumer of type i derives utility:

$$u^H(\pi) \equiv s^H(\pi) = \int_{v \geq \pi} (v - \pi) \, dG^H(v)$$

from his favorite store when the latter charges a price π and utility:

$$u^L(\pi) \equiv s^L(\pi) = \int_{v \geq \pi} (v - \pi) \, dG^L(v)$$

from his second favorite store when the latter charges π.

Using integration by parts, we have:

$$u^H(\pi) = \int_{v \geq \pi} \left(1 - G^H(v)\right) dv \geq \int_{v \geq \pi} \left(1 - G^L(v)\right) dv = u^L(\pi)$$

For convenience, we define:

$$R^H(\pi) \equiv \pi \left(1 - G^H(\pi)\right)$$

$$R^L(\pi) \equiv \pi \left(1 - G^L(\pi)\right)$$

the revenues that a store derives from consumers for whom it is the favorite (respectively second favorite) store. Note that:

$$R^H(\pi) > R^L(\pi)$$

Under assumption 2, $R^H(.)$ *and* $R^L(.)$ *are strictly concave and continuously differentiable functions and:*

$$\pi^H \equiv \arg\max_{\pi} R^H(\pi) > \arg\max_{\pi} R^L(\pi) \equiv \pi^L$$

As before, p is the probability that a consumer finds his favorite store at the first attempt and is chosen by the platform to maximize profits.

We also distinguish now between two types of fees that the platform can extract from stores: per sales charges ρ or per visit (click) charges r. Shopping malls charge retail stores located inside a fixed percentage of sales. By contrast, web portals such as Google charge advertisers on their sites per click fees. Similarly, magazines charge advertisers fees proportional to readership.

4.1. Store prices are exogenously given

In order to understand the difference between per sales and per click/visit fees, let us start with the case in which store prices are fixed and equal to π. Then, for consumers of both types:

- consumers with $c \leq u^L(\pi)$ visit both stores no matter what
- consumers with $u^L(\pi) \leq c \leq \frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}$ always visit their favorite store and only visit their second favorite store when they get lost on the way to their favorite

store.

- consumers with $c > \frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}$ do not visit the platform.

If the platform charges per visit (click) fees r (to both stores), then store profits are:

$$\left(R^H(\pi) - r\right)\frac{1}{2}F\left(\frac{u^H(\pi)+(1-p)\,u^L(\pi)}{2-p}\right)$$
$$+\left(R^L(\pi) - r\right)\frac{1}{2}\left[pF\left(u^L(\pi)\right)+(1-p)\,F\left(\frac{u^H(\pi)+(1-p)\,u^L(\pi)}{2-p}\right)\right]$$

and platform profits are:

$$\Pi^P = r\left[pF\left(u^L(\pi)\right)+(2-p)\,F\left(\frac{u^H(\pi)+(1-p)\,u^L(\pi)}{2-p}\right)\right]$$

Therefore, the platform will choose $p<1$ if and only if[12]:

$$1 \leq \frac{F\left(u^H(\pi)\right)-F\left(u^L(\pi)\right)}{\left(u^H(\pi)-u^L(\pi)\right)f\left(u^H(\pi)\right)} \tag{4.1}$$

With per sales charges ρ, store profits are:

$$(1-\rho)\frac{1}{2}\left\{\begin{array}{l} R^H(\pi)\,F\left(\frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}\right) \\ +R^L(\pi)\left[pF\left(u^L(\pi)\right)+(1-p)\,F\left(\frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}\right)\right] \end{array}\right\}$$

and platform profits:

$$\Pi^P = \rho\left\{\begin{array}{l} R^H(\pi)\,F\left(\frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}\right) \\ +R^L(\pi)\left[pF\left(u^L(\pi)\right)+(1-p)\,F\left(\frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}\right)\right] \end{array}\right\}$$

[12] Note that r does not affect the optimal choice of p: if the platform has all the bargaining power, it will set r so that stores make 0 profits. Thus, the result that optimal design involves degraded search holds even when the platform optimizes over r and p.

In this case, the optimal search quality p is less than 1 if and only if[13]:

$$\frac{R^H(\pi)}{R^L(\pi)} \leq \frac{F\left(u^H(\pi)\right) - F\left(u^L(\pi)\right)}{\left(u^H(\pi) - u^L(\pi)\right) f\left(u^H(\pi)\right)} \tag{4.2}$$

Comparing (4.1) with (4.2) and recalling that $R^H(\pi) > R^L(\pi)$, we have:

Proposition 7 *With fixed store prices, all other things being equal, a platform charging per-click fees is more likely to degrade search quality for consumers than a platform charging per sales fees.*

■

This result has a simple interpretation: per-sales charges make the platform's interests more aligned with those of the stores, therefore it does not need to degrade search as much.

4.2. Design p affects store prices

Let us now turn to the case in which platform design p influences store prices, i.e. when stores set their prices in response to the platform's choice of design. This adds an additional channel through which p can impact platform profits. To see this, let us write:

$$\frac{d\Pi^P}{dp} = \frac{\partial \Pi^P}{\partial p} + \frac{\partial \Pi^P}{\partial \pi}\frac{d\pi}{dp} \tag{4.3}$$

where π is the (symmetric) price charged by the stores. The first effect will be the same as before: p determines consumer traffic on the platform and at the individual stores, thereby directly impacting platform profits. The second effect is new: it captures the impact that platform design has on store prices. Indeed, p affects not only total consumer traffic on the

[13] Same observation regarding ρ as the one above regarding r.

platform and at each individual store, but also the composition of that traffic for each store - high and low valuation consumers -, which the stores will take into account in setting their prices. In this section we will be interested in determining the sign of this effect, i.e. in whether the fact that the platform's design decision can influence store prices makes it more or less likely for the platform to degrade search quality. As we will see, the nature of the fees that the platform extracts from stores - per visit/click or per sales - plays an important role in determining that sign.

In terms of timing, we assume that consumers do not observe store prices before visiting the platform and the stores, however they have rational expectations regarding store prices. In other words, in equilibrium, expected values of store prices are equal to the actual prices charged by stores[14]. This is equivalent to assuming that stores set their prices taking total consumer traffic on the platform as given.

Denote by π^e the price that consumers expect each store to charge (stores are symmetric, therefore $\pi_1 = \pi_2$ in equilibrium). Then, recalling that the traffic at each store is composed of consumers who favor that store over the other and consumers who prefer the other store, we can write the expression of store profits (assume 0 marginal costs) as a function of the actual price charged π and the expected symmetric price π^e:

- if the platform charges per click fees:

$$\begin{aligned}
&\left[R^H(\pi) - r\right] \frac{1}{2} F\left(\frac{u^H(\pi^e) + (1-p)\, u^L(\pi^e)}{2-p}\right) \\
&+ \left[R^L(\pi) - r\right] \frac{1}{2}\left[pF\left(u^L(\pi^e)\right) + (1-p)\, F\left(\frac{u^H(\pi^e) + (1-p)\, u^L(\pi^e)}{2-p}\right)\right]
\end{aligned}$$

[14] The alternative is to assume that consumers observe store prices *before* making their search decisions. While the analysis of this case turns out to be slightly more complicated, the results remain unchanged.

- if the platform charges per sales fees:

$$(1-\rho)\left\{\begin{array}{c} R^H(\pi)\frac{1}{2}F\left(\frac{u^H(\pi^e)+(1-p)u^L(\pi^e)}{2-p}\right) \\ +R^L(\pi)\frac{1}{2}\left[pF\left(u^L(\pi^e)\right)+(1-p)F\left(\frac{u^H(\pi^e)+(1-p)u^L(\pi^e)}{2-p}\right)\right] \end{array}\right\}$$

In both cases, the equilibrium symmetric price charged by the stores π^* satisfies:

$$\pi^* = \arg\max_{\pi}\left\{\begin{array}{c} R^H(\pi)F\left(\frac{u^H(\pi^*)+(1-p)u^L(\pi^*)}{2-p}\right) \\ +R^L(\pi)\left[pF\left(u^L(\pi^*)\right)+(1-p)F\left(\frac{u^H(\pi^*)+(1-p)u^L(\pi^*)}{2-p}\right)\right] \end{array}\right\}$$

Or:

$$\pi^* = \arg\max_{\pi}\left\{R^H(\pi)+R^L(\pi)\left[\frac{pF\left(u^L(\pi^*)\right)}{F\left(\frac{u^H(\pi^*)+(1-p)u^L(\pi^*)}{2-p}\right)}+(1-p)\right]\right\} \tag{4.4}$$

Expression (4.4) defines a function $\pi^*(p)$ which the following lemma shows is increasing.

Lemma 1 *Assume that (4.4) defines a unique function $p \to \pi^*(p)$, then this function is increasing in p.*

Proof In the appendix.

■

Note that this expression of $\pi^*(p)$ contains the essence of our idea: the platform's choice of a lower p gives a higher weight to the low valuation consumers in the composition of demand faced by each store, which drives the equilibrium price down.[15]

Let us now turn to the expression of platform profits:

---

[15] This conclusion would be unchanged if we allowed for a more general formulation, in which stores set a single price for their sales on the platform, as well as for sales that occur outside of the platform (through store fronts on other platforms for instance). In that case, it is reasonable to expect the "responsiveness" of store prices to platform design $\frac{d\pi^*}{dp}$ will be reduced, but still positive.

- with per click charges r:

$$\Pi^P_{click} = r\left[pF\left(u^L\left(\pi^*\left(p\right)\right)\right) + \left(2-p\right)F\left(\frac{u^H\left(\pi^*\left(p\right)\right) + \left(1-p\right)u^L\left(\pi^*\left(p\right)\right)}{2-p}\right)\right]$$

- with per sales charges ρ:

$$\Pi^P_{sales} = \rho\left\{\begin{array}{c} R^H\left(\pi^*\left(p\right)\right)F\left(\frac{u^H\left(\pi^*\left(p\right)\right)+\left(1-p\right)u^L\left(\pi^*\left(p\right)\right)}{2-p}\right) \\ +R^L\left(\pi^*\left(p\right)\right)\left[pF\left(u^L\left(\pi^*\left(p\right)\right)\right) + \left(1-p\right)F\left(\frac{u^H\left(\pi^*\left(p\right)\right)+\left(1-p\right)u^L\left(\pi^*\left(p\right)\right)}{2-p}\right)\right]\end{array}\right\}$$

We have:

$$\frac{\partial\Pi^P_{click}}{\partial\pi}\left(p=1\right) = r\left[f\left(u^L\left(\pi^*\left(1\right)\right)\right)\frac{du^L}{d\pi}\left(\pi^*\left(1\right)\right) + f\left(u^H\left(\pi^*\left(1\right)\right)\right)\frac{du^H}{d\pi}\left(\pi^*\left(1\right)\right)\right] < 0$$

since $\frac{du^L}{d\pi} < 0$ and $\frac{du^H}{d\pi} < 0$.

With per sales charges:

$$\frac{\partial\Pi^P_{sales}}{\partial\pi}\left(p=1\right) = \rho\left[\begin{array}{c} \frac{dR^H}{d\pi}\left(\pi^*\left(1\right)\right)F\left(u^H\left(\pi^*\left(1\right)\right)\right) + \frac{dR^L}{d\pi}\left(\pi^*\left(1\right)\right)F\left(u^L\left(\pi^*\left(1\right)\right)\right) \\ +R^H\frac{du^H}{d\pi}\left(\pi^*\left(1\right)\right)f\left(u^H\left(\pi^*\left(1\right)\right)\right) + R^L\frac{du^L}{d\pi}\left(\pi^*\left(1\right)\right)f\left(u^L\left(\pi^*\left(1\right)\right)\right)\end{array}\right]$$

But (4.4) implies:

$$\frac{dR^H}{d\pi}\left(\pi^*\left(1\right)\right)F\left(u^H\left(\pi^*\left(1\right)\right)\right) + \frac{dR^L}{d\pi}\left(\pi^*\left(1\right)\right)F\left(u^L\left(\pi^*\left(1\right)\right)\right) = 0$$

therefore:

$$\frac{\partial\Pi^P_{sales}}{\partial\pi}\left(p=1\right) = \rho\left[R^H\frac{du^H}{d\pi}\left(\pi^*\left(1\right)\right)f\left(u^H\left(\pi^*\left(1\right)\right)\right) + R^L\frac{du^L}{d\pi}\left(\pi^*\left(1\right)\right)f\left(u^L\left(\pi^*\left(1\right)\right)\right)\right] < 0$$

Given that $\frac{d\pi^*}{dp} > 0$ and recalling expression (4.3), we can conclude:

Proposition 8 *When the platform's choice of search quality p is observed by the stores before setting their prices, the platform is more likely to degrade search quality (i.e. to set $p < 1$) relative to the case in which store prices could not be influenced by p. This holds irrespective of whether the platform charges stores per-click or per sales fees.*

■

The key reason the platform has an additional incentive to degrade the quality of search is because each store fails to internalize the effect of its price on total traffic on the platform. Thus, the platform always finds it optimal to strategically lower p in order to lower store prices.

5. Conclusion

We have proposed a framework for analyzing the incentives that market intermediaries might have to *reduce* the effectiveness of the search service offered to the parties they serve (consumers and stores that the intermediary controls access to). We have identified two fundamental mechanisms. First, when an intermediary derives higher revenues from consumers shopping at lesser-known stores *relative to* revenues from consumers shopping at more popular stores, it is more likely to degrade the quality of the search service offered to consumers (i.e. the probability that consumers find their favorite store in the first round of search is less than 1). This result survives even when we allow the intermediary to charge consumers fees for accessing its service. Second, the intermediary may have an incentive to degrade the quality of search even further when its design decision influences the prices charged by stores. Lowering search quality alters the composition of demand faced by stores and makes it more elastic, therefore the intermediary can induce lower prices and thereby increase total consumer traffic.

While these results are quite intuitive, they challenge the conventional wisdom that intermediaries - be they traditional merchants or two-sided platforms - create value by reducing search and transaction costs. This helps make sense of strategies employed by some intermediaries, which seem to purposefully make it hard for their consumers to find what they want: shopping malls, retail stores, popular magazines and even Internet portals.

There are a few promising extensions to explore. Analyzing the effect of competition among intermediaries on the effectiveness of the search service offered is the most immediate: we have provided some basic intuition for that in section 2.3., but a formal analysis is needed. Secondly, one could look at a dynamic setting in which the quality of search (p) is not known to consumers *ex-ante*, but some of them are repeat visitors. In this case, the platform has to take into account the fact that consumers form expectations of p based on their past experience and use adequate decision rules to decide whether or not to visit again.

6. References

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7. APPENDIX

7.1. Derivation of conditions ensuring the platform objective function is concave in p

Let Y be defined as:

$$Y = \frac{u^H - u^L}{2-p} + u^L \in \left[\frac{u^H + u^L}{2}, u^H\right].$$

Note that Y is strictly increasing and continuous in p. We will henceforth optimize over Y rather than over p. The expression of platform revenues (2.1) writes as:

$$(r_1 + r_2) F\left(u^L\right) \left[r_1 - r_2 + r_2 \left(\frac{u^H - u^L}{Y - u^L}\right)\right] \left[F(Y) - F\left(u^L\right)\right]$$

and its derivative with respect to Y is:

$$-r_2 \frac{u^H - u^L}{\left(Y - u^L\right)^2} \left[F(Y) - F\left(u^L\right)\right] + \left[r_1 - r_2 + r_2 \frac{u^H - u^L}{Y - u^L}\right] f(Y)$$

$$= \left\{r_2 \left[1 - \frac{F(Y) - F\left(u^L\right)}{\left(Y - u^L\right) f(Y)}\right] + (r_1 - r_2) \frac{Y - u^L}{u^H - u^L}\right\} \frac{f(Y)}{Y - u^L} \left(u^H - u^L\right) \qquad (7.1)$$

Note that if $r_1 > r_2$ and F is convex (implying $\frac{F(Y) - F\left(u^L\right)}{\left(Y - u^L\right) f(Y)} < 1$), then the derivative above is positive for all p, therefore the optimal p is $p^* = 1$.

A first sufficient condition for quasi-concavity is that the term in curly brackets is decreasing. This writes as:

$$-r_2\left[\frac{\partial}{\partial Y}\left(\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right)\right]+\frac{r_1-r_2}{u^H-u^L}<0 \tag{7.2}$$

We have:

$$\frac{\partial}{\partial Y}\left(\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right)=\frac{1}{Y-u^L}\left(1-\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right)-\left(\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\frac{f'(Y)}{f(Y)}\right)$$

and for Y close to u^L (i.e. u^H close to u^L):

$$\frac{1}{Y-u^L}\left(1-\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right)\sim\frac{1}{Y-u^L}\left(1-\frac{f\left(u^L\right)\left(Y-u^L\right)+\frac{1}{2}f'\left(u^L\right)\left(Y-u^L\right)^2}{\left(Y-u^L\right)f\left(u^L\right)+f'\left(u^L\right)\left(Y-u^L\right)^2}\right)\sim\frac{1}{2}\frac{f'\left(u^L\right)}{f\left(u^L\right)}$$

so that:

$$\frac{\partial}{\partial Y}\left(\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right)\sim-\frac{1}{2}\frac{f'\left(u^L\right)}{f\left(u^L\right)}$$

Then the platform's profit function is quasi-concave if u^H sufficiently close to u^L and $\left(u^H-u^L\right)\frac{1}{2}\frac{f'\left(u^L\right)}{f\left(u^L\right)}<-\frac{r_1-r_2}{r_2}$.

We can derive less demanding conditions for quasi-concavity by requiring that the term between curly brackets in expression (7.1) is decreasing at the point where it vanishes:

$$\begin{aligned}&-r_2\left[\frac{\partial}{\partial Y}\left(\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right)\right]+\frac{r_1-r_2}{u^H-u^L}\\ =\quad&-r_2\left[\frac{1}{Y-u^L}\left(1-\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right)-\left(\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\frac{f'(Y)}{f(Y)}\right)\right]+\frac{r_1-r_2}{u^H-u^L}\end{aligned}$$

Evaluating the above expression at $r_2\left[1-\frac{F(Y)-F\left(u^L\right)}{\left(Y-u^L\right)f(Y)}\right]+\frac{r_1-r_2}{u^H-u^L}\left(Y-u^L\right)=0$, we obtain that the objective is quasi-concave if either one of the following two conditions holds (they are equivalent):

1)

$$\left(u^H - u^L\right) \frac{1}{2} \frac{F(Y) - F\left(u^L\right)}{\left(Y - u^L\right) f(Y)} \frac{f'(Y)}{f(Y)} < -\frac{(r_1 - r_2)}{r_2}$$

which holds true if F is concave and $r_1 \leq r_2$. Conversely, if $r_1 > r_2$ then F *must be* concave.

2)

$$2\left(1 - \frac{F(Y) - F\left(u^L\right)}{\left(Y - u^L\right) f(Y)}\right) - \left(\frac{F(Y) - F\left(u^L\right)}{f(Y)} \frac{f'(Y)}{f(Y)}\right) > 0$$

We can rewrite this condition as:

$$\frac{f(Y)}{F(Y) - F\left(u^L\right)} - \frac{1}{Y - u^L} - \frac{1}{2} \frac{f'(Y)}{f(Y)} > 0$$

which reduces to:

$$\frac{\partial}{\partial Y}\left(\frac{F(Y) - F\left(u^L\right)}{\left(Y - u^L\right)\sqrt{f(Y)}}\right) > 0$$

When F is concave this implies that $\frac{\partial}{\partial Y}\left(\frac{F(Y) - F\left(u^L\right)}{\left(Y - u^L\right) f(Y)}\right) > 0$.

■

7.2. Derivation of imperfect search condition with $N \geq 2$ stores.

Assume there are N stores and each consumer gets u^H from shopping at her most favorite store and u^L from shopping at any of the other $(N-1)$ stores.

All consumers with $c \leq u^L$ will shop at all stores and their resulting utility from visiting the platform will be:

$$u^H + (N-1) u^L - Nc$$

Consumers with $c > u^L$ will stop as soon as they find their favorite store. The utility from visiting is then:

$$u^H - c + \left[(1-p) + (1-p)^2 + ... + (1-p)^{N-1}\right]\left(u^L - c\right)$$

Therefore, such consumers choose to shop on the platform if and only if:

$$c \leq \frac{u^H + \left(\frac{1-(1-p)^N}{p} - 1\right)u^L}{\frac{1-(1-p)^N}{p}}$$

We obtain:

$$\Pi^P = (r_1 + r_2)\, F\left(u^L\right) + \left[r_1 + \left(\frac{1-(1-p)^N}{p} - 1\right) r_2\right]\left[F\left(\frac{u^H + \left(\frac{1-(1-p)^N}{p} - 1\right)u^L}{\frac{1-(1-p)^N}{p}}\right) - F\left(u^L\right)\right]$$

Taking the derivative of Π^P at $p = 1$, we obtain:

$$\frac{\partial \Pi^P}{\partial p}(p = 1) < 0 \Longleftrightarrow \frac{r_1}{r_2} < \frac{F\left(u^H\right) - F\left(u^L\right)}{\left(u^H - u^L\right) f\left(u^H\right)}$$

which is exactly the same as (2.2).

■

7.3. Proof of Proposition 2

The derivative of platform profits with respect to p is:

$$\frac{\partial \Pi}{\partial p} = -r_2\left(F\left(\frac{u^H + (1-p)\, u^L}{2-p}\right) - F\left(u^L\right)\right) + \left[r_1 + (1-p)\, r_2\right]\frac{u^H - u^L}{(2-p)^2} f\left(\frac{u^H + (1-p)\, u^L}{2-p}\right)$$

Dividing by r_2, it is clear that $\frac{\partial \Pi}{\partial p}$ is increasing in $\frac{r_1}{r_2}$. This implies that p^* (the solution to $\frac{\partial \Pi}{\partial p} = 0$) is increasing in $\frac{r_1}{r_2}$.

$$\frac{\partial^2 \Pi}{\partial p \partial u^H} = -\frac{r_2 f(Y)}{2-p} + \frac{[r_1 + (1-p) r_2]}{(2-p)^2} \left(f(Y) + \frac{u^H - u^L}{2-p} f'(Y) \right)$$

Evaluating this expression at $\frac{\partial \Pi}{\partial p} = 0$ we obtain:

$$\frac{\partial^2 \Pi}{\partial p \partial u^H}(p = p^*) = -\frac{r_2 f(Y)}{2-p^*} + \frac{r_2 \left(F(Y) - F\left(u^L\right)\right)}{f(Y)} \left(\frac{f(Y)}{u^H - u^L} + \frac{f'(Y)}{2-p^*} \right)$$

Regrouping and recalling that $Y - u^L = \frac{u^H - u^L}{2-p}$, we have:

$$\frac{\partial^2 \Pi}{\partial p \partial u^H}(p = p^*) < 0 \iff \frac{f(Y)}{F(Y) - F(u^L)} - \frac{1}{Y - u^L} - \frac{f'(Y)}{f(Y)} > 0$$

or:

$$\frac{\partial^2 \Pi}{\partial p \partial u^H}(p = p^*) < 0 \iff \frac{\partial}{\partial Y} \left(\frac{F(Y) - F\left(u^L\right)}{\left(Y - u^L\right) f(Y)} \right) > 0$$

■

7.4. Proof of optimality of non-linear tariff with only the highest and lowest search qualities offered

The tariff $A(p)$ can be assumed to be non-decreasing without loss of generality. Denote by $(p(c), A(c))$ the quality and the tariff paid by consumer c, where $A(c) \equiv A(p(c))$.

A consumer with $c < u^L$ chooses the lowest quality as she is indifferent, provided $A(p_L) < u^H - u^L$. The utility of a consumer with search cost between u^L and u^H is then

$$U(c) = \max_p \left\{ u^H + (1-p) u^L - A(p) - (2-p) c \right\}.$$

Notice that setting $A(c) \geq u^H - u^L$ is useless for screening purpose as only consumers with $c < u^L$ would accept such a fee and these consumers search twice anyway (indeed, $U(c) \geq 0$ implies that $A(c) < u^H - u^L$).

Incentive compatibility then writes for c between u^L and $\hat{c}$, where $\hat{c}$ is the largest individual search cost among participating consumers[16]:

$$\begin{aligned}
U'(c) &= -(2 - p(c)) \\
U\left(u^L\right) &= u^H - u^L - A(p_L) \\
U(\hat{c}) &= 0 \\
& \quad p(c) \text{ is non-decreasing}
\end{aligned}$$

The last constraint is that $A(c) \geq 0$ as any consumer could claim the charge $A(c)$ and not search. Given that $A(c)$ is non decreasing this reduces to $A\left(u^L\right) \geq 0$ or

$$U\left(u^L\right) \leq u^H - u^L$$

Notice this ensures also that any consumer prefers his contract $(p(c), A(c))$ to a contract with no search.

The profit derived by the platform from consumer c is then:

$$\begin{aligned}
r_1 + r_2 + A\left(u^L\right) &= r_1 + r_2 + \left(u^H - u^L\right) - U\left(u^L\right) \;\; if \;\; c \leq u^L \\
r_1 + (1 - p(c)) r_2 + A(c) &= r_1 + (1 - p(c)) r_2 + u^H + (1 - p(c)) u^L - (2 - p(c)) c - U(c)
\end{aligned}$$

[16] The first order condition for optimal choice of p by a consumer with search cost c is:

$$A'(p) = c - u^L$$

The second order condition requires $A''(p) < 0$, hence $p(c)$ is non-decreasing.

We assume that $\frac{F(c)}{f(c)}$ is increasing which ensures that the solution will verify the second-order conditions for incentive compatibility.

The expression of platform profits is then:

$$\begin{aligned}
\Pi^P &= \left(r_1 + r_2 + \left(u^H - u^L\right)\right) F\left(u^L\right) - \left(\int_{u^L}^{\hat{c}} \left(2 - p\left(c\right)\right) dc\right) F\left(u^L\right) \\
&\quad + \int_{u^L}^{\hat{c}} \left(r_1 + \left(1 - p\left(c\right)\right) r_2 + u^H + \left(1 - p\left(c\right)\right) u^L - \left(2 - p\left(c\right)\right) c\right) dF\left(c\right) \\
&\quad - \int_{u^L}^{\hat{c}} \left(\int_{c}^{\hat{c}} \left(2 - p\left(u\right)\right) du\right) dF\left(c\right)
\end{aligned}$$

which can be written as

$$\begin{aligned}
\Pi^P &= \left(r_1 + r_2 + \left(u^H - u^L\right)\right) F\left(u^L\right) \\
&\quad + \int_{u^L}^{\hat{c}} \left\{ r_1 + u^H - \left(c + \frac{F\left(c\right)}{f\left(c\right)}\right) + \left(1 - p\left(c\right)\right) \left[r_2 + u^L - \left(c + \frac{F\left(c\right)}{f\left(c\right)}\right)\right] \right\} dF\left(c\right).
\end{aligned}$$

that we maximize under the following constraint:

$$\int_{u^L}^{\hat{c}} \left(2 - p\left(c\right)\right) dc \leq u^H - u^L$$

We then obtain:

$$\begin{aligned}
p\left(c\right) &= p_0 \ if \ r_2 + u^L > c + \frac{F\left(c\right)}{f\left(c\right)} + \lambda \\
p\left(c\right) &= 1 \ if \ r_2 + u^L < c + \frac{F\left(c\right)}{f\left(c\right)} + \lambda
\end{aligned}$$

where λ is the multiplier of the non-negativity constraint.

■

7.5. Proof of Lemma 1

Let:

$$\beta(p,\pi)=\frac{pF\left(u^L(\pi)\right)}{F\left(\frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}\right)}+(1-p)$$

We have:

$$\frac{\partial\beta}{\partial p}=-1+\frac{F\left(u^L(\pi)\right)}{F\left(\frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}\right)}+p\frac{\partial}{\partial p}\left(\frac{F\left(u^L(\pi)\right)}{F\left(\frac{u^H(\pi)+(1-p)u^L(\pi)}{2-p}\right)}\right)<0$$

for all π.

Let then:

$$\phi(\beta)=\arg\max_{\pi}R^H(\pi)+R^L(\pi)\beta$$

Assumption 2 implies that $\phi(\beta)\in\left[\pi^L,\pi^H\right]$. On this range $R^L(.)$ is decreasing whilst $R^H(.)$ is increasing. In particular $\frac{\partial^2}{\partial\beta\partial\pi}\left(R^H(\pi)+R^L(\pi)\beta\right)=\frac{\partial}{\partial\pi}\left(R^L(\pi)\right)<0$. This implies that $\phi(\beta)$ is decreasing.

Thus, (4.4) can then be rewritten as:

$$\pi^*=\phi\left(\beta\left(p,\pi^*\right)\right)$$

Using the implicit function theorem, we obtain:

$$\frac{d\pi^*}{dp}=\frac{\frac{d\phi}{d\beta}\frac{\partial\beta}{\partial p}}{1-\frac{d\phi}{d\beta}\frac{\partial\beta}{\partial\pi}}$$

But the uniqueness condition for the process of tatonnement between consumer expectations and actual prices charged by the store, along with the fact that $\phi\left(\beta\left(p,\pi_L\right)\right)>\pi_L$

imply:

$$1 > \left| \frac{d\phi}{d\beta} \frac{\partial \beta}{\partial \pi} \right|$$

Thus, we can conclude that:

$$\frac{d\pi^*}{dp} > 0$$

■