Competition and welfare consequences of information platforms

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Preliminary version: please do not circulate it.

Abstract

Exogenous shocks in the informational level of a subset of consumers may affect the market structure, equilibrium and welfare. Information platforms (e.g. *Yelp*, *Airbnb*) provide information about experience goods, such as restaurants and lodging. Their existence may cause an heterogeneity in the level of information available to potential consumers, depending on their access to the platform. This study fosters our understanding of how information platforms impacted competition, profits and welfare. Using a *spokes* model of horizontal competition, I show that platforms may enhance welfare by increasing the value of realised transactions (better matching) and by increasing the size of the market. However, they may also enable producers to extract a larger share of surplus and variety may decrease. Therefore, consumers are always *ex ante* better off with the platform, however some of them will be worse off *ex post*, for their preferred variety has disappeared.

JEL Classification: D02, D21, D43, D61, D83, L11, L13, L15

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1 Introduction

Information platforms (also known as *information aggregators*) publish both objective facts and opinions on a product for the benefit of potential new customers. Restaurant and tourist guides (e.g. *Michelin guide* and *Lonely Planet*) were arguably the forerunners of current information aggregators, providing objective facts (e.g. the address) as well as one subjective review. However, reprint costs impeded constant updates; besides, having only one review was a limitation. *On-line* information platforms appeared in the 2000s and have enjoyed a rapid expansion ever since.[1] Information platforms improved upon guides by allowing consumers to post their reviews, thus ensuring an always up-to-date monitoring of the product, more variety in reviews and a lower risk of bribery.[2] Furthermore, on-line aggregators are often enhanced with features that bring down search costs to (almost) zero.[3]

This analysis provides a theoretical framework that allows identifying the mechanism through which information aggregators affect the free market equilibrium. More generally, it studies the impact of an exogenous informational shock that affects a subset of consumers, in any horizontally differentiated market. The welfare analysis produces clear policy recommendations, particularly in terms of regulation. In particular, I identify the conditions under which the existence of such a platform is welfare enhancing, and whether MFN clauses are desirable in such a setting. The model of spatial horizontal competition that I use, based on the spokes model (Chen and Riordan, 2007), displays some interesting features discussed in subsection 1.1.

Review platforms share one common feature: they operate in markets with asymmetric information regarding experience goods. The absence of information alters both consumers' expected utility and total welfare by inducing *mismatch costs*. By mismatch costs I refer to the welfare loss resulting from: i) poor matches of consumers with products (i.e. alternative transactions or no transaction would produce a larger surplus); ii) failure to generate surplus-enhancing transactions. Mismatch costs may occur with either vertically or horizontally differentiated goods. I restrain my attention to the latter case.[4]

Aggregators also differ from each other along several dimensions.[5] A one-fit-all model

[1]To cite a few, *Airbnb*, *Booking*, *Hotwire* operate in the lodging sector; *ClubKviar, OpenTable, TheFork* and *Urbanspoon* in the restaurant industry. *Foursquare*, *Tripadvisor* and *Yelp* are active in several sectors.

[2]For example, *TheFork* features an average of 70+ reviews per restaurant.

[3]This includes, for example, filters to refine queries, or to ensure that only available products are displayed, and personalised suggestions based on the customer's consumption history.

[4]Mismatch costs with vertically differentiated goods are analysed in Akerlof's (1970) *market for lemons*, where high quality goods are inefficiently not traded. Common solutions include insurances and warranties. Those solutions are not effective with horizontally differentiated goods, as the perception of quality is subjective.

[5]Platforms vary in their membership policy, source of information and complementary services. For example, anybody can leave a review on *Tripadvisor* or *Yelp*, while only certified consumers can post on *ClubKviar*, as a measure to reduce the risk of fraudulent reviews. *ClubKviar* offers to its members a 30% discount

does not seem feasible, hence I propose a stylised model loosely inspired by *ClubKviar* (restaurant) and *HomeAway* (lodging).[6] The assumption that firms only compete horizontally captures the recent tendency of platforms to specialise on narrow market segments, similarly to what happens with restaurant guides (e.g. the *Michelin* guide): the reputation of the aggregator becomes the guarantee of the vertical positioning.[7] Horizontal differentiation can be interpreted as the combination of several components, amongst which the style (types of regional cuisine, for restaurants; architectural styles for lodging) and the atmosphere (e.g. modern and trendy, romantic, old style).

Agents' information is crucial: I assume that consumers have no *ex-ante* information, hence they cannot tell goods apart. Absent the platform, they decide whether or not to consume based on expectations. If they decide to consume, they choose the seller randomly. By contrast, the platform credibly reveals relevant pieces of information.[8] Both the total lack of *ex-ante* information and the full information setting provided by the platform are extreme, but harmless, assumptions. The driving force of the model comes from the differential information available through the platform, and not from its level.

One may argue that producers could provide all the relevant information to consumers, e.g. through their web page, without making use of the platform. However, sellers may fail to be credible when they release subjective product characteristics. Furthermore, a single producer would not provide the important service of gathering together the information about all the competitors, which is crucial to abate the searching cost.[9] Conversely, successful information platforms can effectively inform customers and help in the matching process. Their independence and their reputation vouch for them, and regrouping all the information is necessary to make search costs negligible.

The aggregators' impact on welfare passes through both the demand and supply side.

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and customised suggestions based on past consumption and on consumption of users with a similar profile. (Einav et al., 2016) propose a discussion of some aspects that characterise P2P markets in general and what makes each of them differ from the others; it also includes a large overview of the related literature.

[6]The model that I propose tries to be as general as possible, and therefore it should not be considered as a description of either *ClubKviar* or *HomeAway*, but rather as a general tool to be used in understanding the main driving forces in such markets. Stewart Masters, CEO of *ClubKviar*, shared with me – off the record – insights about the functioning of *ClubKviar*. *ClubKviar* belongs to *GrupoMercantis*, which also owns an aggregator operating in the leisure sector (*Kviarcity*), and two group-buying services (*Triavip* for triathlon products, and *Destinity* for travels and tourism). *HomeAway* is a vacation rental marketplace and currently a subsidiary of *Expedia*. *HomeAway* owns several brands, including *VRBO*, *VacationRentals*, *Luxury*, *Toprural*, all operating in the vacation rental marketplace, but covering different market segments.

[7]*ClubKviar*, for example, specialises in high quality restaurants, but its brand *KviarCasual* covers the segment slightly below. The same happens with *Luxury, HomeAway* and *Toprural* for lodging. Subsection 1.2 includes an overview of the literature that suggests such tendency to have vertical convergence.

[8]A restaurant platform, for instance, provides detailed information about location, type of cuisine, menu, price, atmosphere, and several other characteristics.

[9]Firms' reputation and word-of-mouth may alleviate this issue, especially if repeated purchases are likely. In markets with mostly one-time visitors, such as holiday lodging, exclusive restaurants, or museums these mechanisms are less likely to be effective.

By reducing mismatch costs, aggregators affect both the quantity of transaction and each transaction's generated surplus. Meanwhile, they affect the degree of competition. Most importantly, those platforms create an asymmetry in the structure of the market, because only a subset of consumers acquires the information in equilibrium.

I compare the equilibrium before and after the entry of an information platform. When the aggregator is available, sellers endogenously decide whether to be indexed on it or not. Likewise, buyers' decision to use the platform is also endogenous. The model, *ex-ante*, is as symmetric as possible: firms only differ in the horizontal characteristics of their product, and agents only differ in their preferences regarding the horizontal characteristics of products. However, in equilibrium some firms will be listed on-line and some consumers will acquire information on-line, introducing some *ex-post* asymmetries. I focus on the impact of the first platform entering a market, while I leave for future analysis the study of the role of competition in the platforms market.

Each firm sells a different variety or brand of a same good, hence there are as many firms as varieties. Consumers are unable to *ex-ante* distinguish varieties. This means that if they don't acquire information, they can only decide whether to consume or not but, conditional on consuming, they randomly select a variety. The lack of information is at the origin of the mismatch cost, which is realised the moment of consumption. For example, an uninformed consumer willing to have a romantic weekend in an elegant environment, may mistakenly book a room at a crowded, noisy, casual hotel. The cost for a consumer of purchasing a variety that is different from their preferred one is proportional to the distance between the ideal variety of the consumer (represented by the location of the consumer in the model space) and the purchased variety (represented by the location of the firm). Firms' entry decision is endogenous, as well as the consumption decision of agents. A firm willing to enter the market has to pay a lump sum fee, that represents the license to operate. Locations are instead exogenous (both for firms and for consumers).

I consider, as the initial setting, the case in which firms are actively competing, but yet the market is not fully covered. In this setting, all consumers are uninformed. The equilibrium in the initial setting represents the case of an economy in which information platforms are not available. I show that in this setting the lack of information induces those consumers with the most extreme tastes not to consume. The intuition is that agents with a strong preference for a specific variety would bear a high cost of consuming any other variety, and hence their expected benefit of randomly consuming one brand is low. Instead, consumers with only a weak preference for a variety are willing to give it a try and to consume a random product, because their mismatch cost is never going to be too high.

When an information aggregator enters a market, firms may register there, upon the payment of the registration fee. I assume this fee to be of fixed amount, to be paid once every period.[10] I denote firms that are listed on-line as e-sellers, as opposed to c-sellers, where e stands for "electronic" while c stands for "conventional". For the sake of exposition, I will define as **initial equilibrium** the one without a platform. Once the aggregator starts to operate, I distinguish between the **short run** equilibrium, in which firms decide whether to be listed on-line or not, taking the others' decisions as fixed; the **medium run**, in which the number of firms listed on-line adjusts and ensures equal profits for both listed and not listed firms; finally, in the **long run**, free entry ensures that the zero-profit condition holds.

Agents may also register on the platform, in which case they observe the variety of all products that are listed on-line (i.e. the location of the registered firms). Registration is free for consumers, however they incur in some non-monetary registration or usage costs, which reflect the time spent to register and to learn to use the platform.[11] To keep the model symmetric, I assume that such usage cost is the same for all agents. I denote platform users as *surfers*, as opposed to *walkers*, who never do so and choose the brand randomly out of a list (e.g. yellow pages).

I assume that agents' valuations are large enough to ensure that some transactions are *ex-ante* profitable even when agents are uninformed about the firms' characteristics (location). The decision to use the platform is endogenous both for firms and for consumers. The fee is the same for any firm, and the usage cost is the same for every consumer. Despite the extremely symmetric environment, the model is able to capture the fact that only some consumers are willing to use the platform to get informed, and similarly that only some firms decide to reveal their characteristics through the platform.[12]

1.1 The spokes model

I use the *spokes* model of horizontal differentiation, which is an extension of the Hotelling model, and also a special case of Hart (1985). The general properties of the spokes model are studied and discussed in Chen and Riordan (2007). The spokes model has been used extensively in the most recent literature, in a broad set of different environments (Aoki et al., 2014; Caminal and Claici, 2007; Caminal and Granero, 2012; Germano and Meier, 2013; Mantovani and Ruiz-Aliseda, 2016; Reggiani, 2014; Somaini and Einav, 2013).

[10] Platforms may use very different payment schemes, for the sake of tractability I assume lump sum payments. Amongst the aggregators charging a per-year fee, there are *ClubKviar*, *TripAdvisor* (for the "listing service", see Teixeira and Kornfeld, 2013), *HomeAway* and *VRBO*. *TheFork*, instead, charges a per-reservation fee, while other platforms (e.g. *Airbnb, Wimdu*) charge a percentage of the consumer price.

[11] The magnitude of the registration and usage cost may depend on how user-friendly is the platform, on the agents' technological skills, or the opportunity cost of agents' time spent to search on the platform.

[12] Matsumoto and Spence (2016) can be considered as suggestive evidence of the fact that not all potential customers use online platforms. Indeed, in their sample of college students, more than 10% declared to buy all their books in regular stores and have never searched or purchased on online stores or platforms.

Contrary to the Hotelling or Salop model, it accommodates market expansions even when firms are already actively competing. Indeed, the spokes model does not require the market to be fully covered in order to feature some competition amongst firms. Hence, it is possible to model in a meaningful way the case in which firms have some market power, without being a monopolist, and still allow for the entry of a platform to have an expansionary effect on the market.

A further, very convenient, feature of the spokes model is that its star-shape structure allows to deal with cases of firms simultaneously competing on different markets. When information platforms operate, some firms compete simultaneously off-line and on-line, against different subsets of competitors. Circular competition models à la Salop cannot be easily adapted to such a framework, for firms location adjusts constantly to react to a change in the number of competitors. Indeed, the Salop model would conceptually fail to adapt to this case, as the automatic relocation along the circle depending on the number of competitors, would mean that the firm's very same product has different characteristics depending on how it is purchased, which is a contradiction in terms.[13] In the spokes model, however, entry and exit of firms do not imply (unrealistic) relocations of competitors.

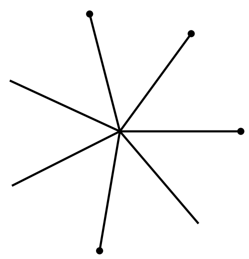

Figure 1: Spokes model with 7 spokes ($\bar{N} = 7$) and 4 firms ($N = 4$)

The spokes model takes the shape of a star and it could be seen as the union of several Hotelling lines of equal length. Figure 1 illustrates an example with 7 spokes and 4 firms. The intersection of all the spokes is denoted centre. Each spoke has an origin, which is the point on the segment opposite to the centre. The origin of the spoke represents one variety or brand of the good. Firms' location is exogenous and it is always at the origin of one spoke; Reggiani (2014) extends the spokes model to allow for an endogenous location of firms. On each and every spoke there can be at most one firm. When a spoke is empty, it means that such variety is not produced. Consumers are uniformly distributed over all the spokes. The distance between a consumer and a firm represents the distance in taste, that is, how different is the ideal product with respect to the variety produced by the firm. Therefore, the *mismatch*

[13] Within this context, it would mean that a given place, for example, would be perceived as elegant by off-line consumers, and kitsch to those who booked on-line.

cost is a function of such distance and represents the consumer's disutility from consuming a variety other than the preferred one.

The standard spokes model has a technical limitation when there are no firms located on some spokes, if mismatch costs are low enough for firms to be willing to serve customers located on spokes other than their own. All the agents distributed on empty spokes form a mass of consumers willing to switch from one seller to another at any marginal change in prices. This generates a discontinuity in the demand functions that inhibits the existence of a pure strategy equilibrium. Chen and Riordan (2007) discuss this problem and compare possible ways to deal with it. The seemingly weakest condition to avoid this issue is to assume that consumers attach a positive valuation to consumption only to a finite number of products. Following Chen and Riordan (2007), I assume that each consumer positively values two products.[14]

1.2 Related literature

Besides the aforementioned references, this model is interconnected with several strands of the literature. As previously discussed, I focus on horizontal competition. I claimed that vertical differentiation within a single platform seems unlikely to be long-lasting and that, in equilibrium, we should expect vertical convergence within aggregators. The theoretical (Klein et al., 2016; Vial and Zurita, Forthcoming), empirical (Cabral and Hortaçsu, 2010; Jin and Leslie, 2003) and experimental (Hosasain et al., 2011) literature indeed suggest that - in the long run - poorly ranked firms either disappear or converge to their competitors' quality. To be completely forthright, vertical differentiation is likely to arise when different aggregators compete, in an attempt to differentiate from each other. However, such analysis is beyond the scope of this work. Therefore, one first link to the literature is with other models of spacial competition, and in particular those on horizontal competition. Amongst those, Janssen and Teteryatnikova (Forthcoming) studies the incentives of competitors to disclose information about their horizontally differentiated products, whereas Sun (2011) considers the case of a monopolist with a product that has both vertical and horizontal attributes. Somaini and Einav (2013) and Edelman and Wright (2015) propose a model that is isomorphic to the spokes model in order to study competition when customers suffer partial lock-in. Bar-Isaac et al. (2014) studies optimal product design, in an extension of the Salop model in which firms can locate also within the circle.

Broadly speaking, this paper belongs to the literature on internet economics. Such literature includes studies on internet commerce: Alba et al. (1997) and Bakos (1997) are amongst

[14] An alternative solution to deal with the existence of an equilibrium problem would be to assume that agents have different valuations for each product.

the first to discuss electronic sales. Jin and Kato (2007) discusses possible advantages and disadvantages of on-line selling. Anderberg and Andersson (2003); Arabshahi (2010); Dholakia (2010); Byers et al. (2011); Jing and Xie (2011) and Chen and Zhang (2015), consider group buying and the *Groupon* experience. Edelman et al. (2011) examines the use of group-buying as a device to introduce price discrimination and as an advertising device. See Liang et al. (2014) and the references therein for an overview of the most recent literature on group-buying. Biyalogorsky et al. (2001) focuses on referral-reward programs, Shaffer and Zhang (2002) on one-to-one promotion, and Xie and Shugan (2001) on advance selling.

Information platforms share some features with search engines, however they are distinct in some crucial aspects. Both aggregators and search engines can list firms and provide some basic and objective characteristics. In the practice, however, search engines do not allow users to leave reviews, which is the main channel of transmission of third-party information. Secondly, although both are financed by firms (aggregators set a fee, while search engines rely on firms' advertisement), the aggregator is meant to be neutral, and its reputation is based on that. In other words, aggregators treat all the listed firms equally. When an information platform ranks firms, it does it based on the measures decided by the user (price, location, availability, other users' ranking, etc.), whereas search engines charge firms in exchange for visibility, hence search outcomes are a weighted compromise between users interest for the best possible match and firms interest to be listed on top. Eliaz and Spiegler (2011) studies the search engines' trade-off and shows that they have an incentive to degrade the quality of results compared to the minimising search cost outcome. Bar-Isaac et al. (2012) studies how search engines affect the firms' incentives to design products for niches (markets with few enthusiastic consumers), as opposed to be mass-oriented, trying to attract many consumers, although with low willingness to pay.

Data on information platforms have been used in several and heterogeneous empirical studies, either for their interest *per se* or because they offer an extremely rich database that can be used for different purposes. An example of the latter is Davis et al. (2016) which uses information from Yelp to study how spatial and social frictions affect consumption. Ghose et al. (2012) shows that consumers base their purchase on reviews. However, DellaVigna and Pollet (2007, 2009) show that consumers tend to disregard several pieces of information, Pope (2009) shows evidence of rank-heuristic behaviours.[15] Clearly, the effectiveness of on-line review aggregators depends on their credibility. Credibility is undermined by the risk of fake reviews.[16] Some aggregators (e.g. *ClubKviar*) increased the cost of posting fake reviews

[15] Agents engaging in rank-heuristic behaviours tend to focus on the rank, although more precise data are available. In particular, when the rank is associated to a continuous measure, such as a grade, they prefer disproportionately the better ranked option, even when the difference in grade is negligible.

[16] *Tripadvisor* was fined as much as 500k euros by the Italian antitrust authority in 2014, for it failed to adopt

by allowing only certified consumers to post them. Degan (2006); Mayzlin (2006); Luca and Zervasy (2016); Mayzlin et al. (2013) study the phenomenon of manipulated reviews. Dai et al. (2012) proposes an improved econometric methodology to rank options based on reviews and minimise the impact of possibly manipulated reviews.

Much attention has been devoted to the impact on profits of review-based rankings. Aggregators rank firms based on the consumers' rates. Anderson and Magruder (2012) and Luca (2011) estimate the increase in profits due to higher rank for restaurants rated on *Yelp*. These results suggest a short-run business-stealing effect. The effect is larger for restaurants for which few sources of information are available outside *Yelp*. Farronato and Fradkin (2017) uses *Airbnb* data to show that both a business-stealing effect and a market expansion occur. The previous results are consistent with other studies on on-line reviews (e.g. Chevalier and Mayzlin, 2006, considering the impact of book reviews on their sales), as well as on the impact of reviews by professional critics (Reinstein and Snyder, 2005; Hilger et al., 2011) and on off-line word of mouth (Duflo and Saez, 2002; Sorensen, 2006; Moretti, 2011).

Information platforms have been discussed as an example in the literature on multi-sided platforms pioneered by Caillaud and Jullien (2003); Rochet and Tirole (2003). Most of this literature focuses on the platform, rather than on the behaviour of buyers and sellers. Amongst the exceptions, one could cite Galeotti and Moraga-González (2009); Hagiu (2009); Belleflamme and Peitz (2010) and Edelman and Wright (2015). Hagiu (2009); Belleflamme and Peitz (2010), however, impose the use of the platform to the buyers, if they want to connect with the sellers. Galeotti and Moraga-González (2009), Edelman and Wright (2015) and Ronayne (2015) are very close in spirit to my paper. Galeotti and Moraga-González (2009) considers the case of a strategic platform that acts as an intermediary between buyers and sellers. When setting the prices, the platform is able to attract all firms and consumers with probability 1, and extract all the surplus generated, net of any possible surplus that agents may be able to generate, should the platform not operate. The model I propose is less sophisticate in that the platform is not setting prices strategically, however the richer setting that I propose allows to reproduce the "separating equilibrium" in which only some agents and some firms find it profitable to make use of the intermediary. Edelman and Wright (2015) analyses the case of horizontally competing firms that can sell directly or through an intermediary which generates some added value to the parts. A crucial difference with my model is than that the value of the good purchased through the platform is higher than when it is purchased directly. Their focus is on the strategic behaviour when the intermediary can impose price coherence clauses (also known as MFN clauses). In particular they show a

controls to prevent false reviews. The British authority had previously forced *Tripadvisor* to stop advertising that their reviews are accurate.

mechanism through which such price coherence clauses, combined with the added value that the intermediary is able to provide, lead to an overuse of the platform with respect to what is socially optimal, and a possible reduction in welfare is observed. In Edelman and Wright (2015), the platform endogenously set prices, and is able to extract a large share of surplus from producers. Their model is particularly useful to understand markets such as payment cards. In my paper, the intermediary is relegated to a minor and not strategic role, in order to measure the welfare impact related to mismatch costs in markets where the main role of the platform is to eliminate matching issues with experience goods. Clearly, the two elements can co-exist, in which case the results of my model represent a different and complementary channel to the one in Edelman and Wright (2015). Ronayne (2015) considers a platform that fosters price competition and therefore has a lowering-prices effect but simultaneously it charges firms and hence it has an increasing-prices effect. In Ronayne (2015), the product is homogeneous, therefore there are no mismatch costs and hence the main trade-off is between extracting sellers' surplus and fostering competition, while abating the searching cost for final users.

Aggregators may also play a role that is similar to advertisement: Rysman (2004); Busse and Rysman (2005) consider advertising on Yellow Pages, while Evans (2009) focuses on on-line advertising. Johnson and Myatt (2006) studies how advertisement may shape the demand function. Mueller-Frank and Pai (2014) suggests that platforms sell visibility, and studies the welfare implication of it, considering that consumers' attention is displaced, and hence better information on a product reduces the level of information on a competing product. In my model, possible advertising effects are not taken into account.

Clearly, my model is somehow connected to the search literature. From Salop and Stiglitz (1977) to Baye and Morgan (2001) and Janssen et al. (2011) and the literature therein, many papers have focused on an homogeneous good.Searching, there, means looking for the cheapest seller of one single product. Dinerstein et al. (2017) show that platforms can be used by users to search for the best price for a product, nevertheless some frictions ensure price dispersion. They interpret such dispersion as the result of a trade-off faced by the platform between fostering competition and reducing transaction costs. The literature with vertically differentiated products was pioneered by Wolinsky (1986); Anderson and Renault (1999), while the case of horizontal differentiation is considered in Moraga-González and Petrikaitė (2013), where they show some interesting welfare results with relevant policy implications when firms merge in markets with search costs. They show that mergers reduce search costs because the merged firms will gather products: a demand-side efficiency is identified, that may justify mergers. This creates a possible analogy with my model: the platform reunites all products within a single space as if it merged all the firms' web pages, and such merger abates search costs. In my current model it is impossible to disentangle the benefits of the platform between reduction in search costs and in mismatch costs. da Graça and Masson (2013) departs from the search literature and shows how an increase in information may be detrimental to consumers. In their model, agents' priors on the value of an object are randomly distributed around the true valuation of the good, which is the same for all agents. When agents are better informed, their willingness to pay changes and so the behaviour of the monopolist, with the consequence of a reduction in total welfare.

The remainder of the paper is organised as follows: section 2 introduces the model. Section 4 studies the market equilibrium, while section 5 studies the welfare consequences of aggregators. Section 6 concludes. All the proofs are relegated to appendix A.

2 The model

Firms produce an horizontally differentiated product: in total there exist $\bar{N}$ potential varieties (or brands). I consider a market with N (endogenous) competing firms and a mass 1 of consumers. Every firm produces a different variety: $N \leq \bar{N}$. There is free entry in the market, but firms must pay a licence fee to operate, which is denoted f. I focus on the case of (partial) competition and hence I assume f to be small enough to ensure that in equilibrium a monopoly never forms ($N \geq 2$). For the sake of simplicity, firms face no variable production costs. Buyers' preferences over varieties are specified later.

The product is an experience good, meaning that consumers are not able to tell apart varieties until after consumption. This means that a consumer picks a brand, agrees upon a price and only after consumption they will appreciate the variety and therefore bear any mismatch cost (i.e. the cost of consuming a variety that is different from one's preferences). In this *zero-information setting*, consumers can only base their acts on expectations: they consume a randomly selected variety if their expected utility of consumption is larger than the price, and restrain from consumption otherwise. At the moment of transaction, all firms and all consumers look the same. I will restrain my attention to symmetric equilibria.

Suppose now that an information platform (also denoted aggregator) enters the market. Firms may decide to fully disclose the characteristics of their brand through the aggregator. I denote by $n \geq 0$ the (endogenous) number of firms that decide to be listed on the platform, which I define as e-sellers (where e stands for electronic). To be listed, firms pay a fee f^e to the platform. I name c-seller any firm that is not listed online (where c stands for conventional). Agents may use the platform to learn the variety before consumption, however there is a lump sum usage/learning cost u of the platform. I call *surfers* the platform users, and *walkers* any consumer who doesn't use the platform. The aggregator is a non-strategic agent that acts as a device that e-sellers use (upon payment of the fixed and exogenous fee f^e) to credibly transmit to potential consumers information about the variety that they sell (i.e. their location). *Surfers* use the aggregator for free in order to learn the variety of listed products, but they incur in the usage cost.

I model competition using the spokes model (Chen and Riordan, 2007) with $\bar{N} \geq 4$.[17] See subsection 1.1 and Figure 1 for more details about the basic characteristics of the spokes model. Spokes have a length $\frac{1}{2}$. The intersection point is named centre, while the termination of a spoke opposite to the centre is named origin. Consumers, of mass one, are distributed uniformly over all the space, including empty spokes. This is interpreted as the fact that an agent may have a preference for a variety that is not for sale in a given market. Following Chen and Riordan (2007), firms' location is exogenous and it always occurs at the origin of a spoke; furthermore, there is always at most one seller located at each spoke.

I denote generic spokes by i, with $i \in [1, \bar{N}]$. For convenience and without loss of generality, I order them by type of seller and say that e-seller are located on spokes 1 to n, c-seller on spokes $n+1$ to N, and finally spokes $N+1$ to $\bar{N}$ are empty. With a little abuse of notation, I also use i to denote the firm located at the origin of the corresponding spoke.

An agent's valuation of good i is denoted $\hat{v}_i$. As previously discussed in subsection 1.1 and following Chen and Riordan (2007), each agent has two preferred brands: the one produced on the spoke where they are located and another one randomly assigned by nature.[18] Henceforth, I reserve $j \in \left[1, \bar{N}\right]$ to the spoke on which an agent is located, while I denote $k \in \left[1, \bar{N}\right]$, with $k \neq j$, the spoke corresponding to the agent's other preferred brand. The agent's valuation for each of the two preferred brands is $\hat{v}_i = v$, whereas their valuation of any other brand is $\hat{v}_i = 0$. Hence,

$$\hat{v}_i = \begin{cases} v, & \text{if } i = \{j, k\} \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

Furthermore, I use x_i to define distances, so that $x_j \in [0, 1/2]$ is the distance between an agent's location and the origin of the spoke on which they are located, whilst $x_k \in [1/2, 1]$ is the distance between an agent's location and the origin of the other preferred brand. Given that all spokes measure $\frac{1}{2}$, x_k is also the distance from the origin of any spoke other than j, and by construction $x_j + x_k = 1$, so that: $x_i = \begin{cases} x_j, & \text{if } i = j \\ x_k, & \text{otherwise.} \end{cases}$ The location of each agent defines their ideal variety, whilst the distance x between the agent's and a firm's location represents the *Mismatch cost* (disutility) that the agent bears when consuming a variety

[17] Notice that when $\bar{N} = 2$ the spokes model reduces to the standard Hotelling model.

[18] This assumption, as discussed in the introduction, is needed to avoid mass points and discontinuity in demand functions and hence to guarantee the existence of a symmetric pure strategy equilibrium in the standard spokes model (see Chen and Riordan, 2007).

other than their ideal one.[19] I assume unitary mismatch costs, so that the mismatch cost M_i coincides with the distance x_i:

$$M_i = \begin{cases} (1 - x_k), & \text{if } i = j \\ x_k, & \text{if } i \neq j, \end{cases} \tag{2}$$

I can now formally define the utility function of an agent consuming from firm i, which takes the form $U = \hat{v}_i - p_i - x_i$, where p_i is the consumer's price:

$$U = \begin{cases} v - p_i - M_i, & \text{if } i = \{j, k\} \\ -p_i - M_i, & \text{if } i \neq \{j, k\}. \end{cases} \tag{3}$$

Subsection 2.1 studies the equilibrium when the information platform is not active, while subsection 2.2 analyses the case in which the platform is active, all available firms are listed on the platform and all agents use it (i.e. all firms are e-sellers and all consumers are *surfers*). The latter framework is isomorphic to Chen and Riordan (2007) and it's an intermediate step required in order to then move to section 4, where I let firms and consumers endogenously decide whether or not to make use of the aggregator.

2.1 Without aggregator

Consumers always know both their own valuation for each possible brand and their own ideal variety (their location). Therefore, they can compute the mismatch cost of consuming any possible brand. When the information platform is not available, however, consumers are unable to ex-ante recognise a firm's variety. The moment they decide to purchase a product, they can only compute the expected mismatch cost that they would bear shell they purchase. Rephrasing in a more formal way, consumers' ex-ante information set includes valuations $\hat{v}_i$, their own location x_j, their two preferred brands j and k, but they are not able to identify the location i of the firm from which they are considering to buy. After consumption from firm i at price p_i, the mismatch cost M_i is realised.

In this setting without the platform, I'm interested in the equilibrium in which consumers remain uninformed about products, hence I assume that they cannot search for information, or that searching costs are prohibitive. The setting that I propose is then an adaptation of Diamond (1970). The only option left to consumers is to randomly select one of the available sellers $i \in \{1, .., N\}$, observe their selling price and decide whether to buy at that price or to restrain from consumption. This is equivalent to say that agents have a price cut-off (denoted q in Diamond, 1970) and will agree to buy whenever the price of the randomly selected firm is below such cut-off price. If the price is above it, agents don't search further and simply don't

[19] This concept is often referred to as the transport cost, and it's a measure of the distance in preferences.

consume. Agents cut-off price is the one that makes them indifferent between purchasing and not purchasing, i.e. the one for which their expected utility of consumption is zero.[20]

The realisation of the mismatch cost occurs when the consumption decision is irreversible. Hence, the consumption decision is made based on expectations.

Lemma 1. *The expected mismatch cost for an agent consuming from a randomly selected seller is:*

$$EM_i = \left(\frac{\bar{N}-2}{\bar{N}} x_k + \frac{1}{\bar{N}} \right). \tag{4}$$

The expected valuation of a consumer is $2v/\bar{N}$, therefore, the expected utility of an agent is positive if:

$$x_k \leq \frac{\bar{N}}{\bar{N}-2} \left(\frac{2v}{\bar{N}} - p_i - \frac{1}{\bar{N}} \right). \tag{5}$$

Denoting by $\tilde{x}_k$ the agent indifferent between buying and restraining from it, the symmetric, pure strategy interior equilibrium implies that

$$\tilde{x}_k = \frac{1}{\bar{N}-2} \left(v + \frac{\bar{N}-4}{4} \right), \tag{6}$$

$$p_i = p = \frac{v}{\bar{N}} - \frac{1}{4}. \tag{7}$$

Each firm covers a demand $D_i = \frac{(4v-\bar{N})}{2(\bar{N}-2)N}$, and profits are $\pi_i = \frac{(4v-\bar{N})^2}{8(\bar{N}-2)N\bar{N}}$. To ensure an interior equilibrium, $\tilde{x}_k \in [1/2, 1]$ is required. This implies that $v \in \frac{1}{4}\left[\bar{N}, \left(3\bar{N}-4\right)\right]$.

Proof. See appendix A. □

The equilibrium price (7) is the monopoly price. Indeed, according to the so-called Diamond's paradox (Diamond, 1970), the profit-maximising price is the monopolist's one when consumers exerts no search effort and consider that firms ex-ante are all equals. It is interesting to notice (equation 4) that expected mismatch costs are increasing in the number of spokes $\bar{N}$. This comes from the fact that it increases the probability of being located in a spoke where there is no seller. This also means that the location $\tilde{x}_k$ of the indifferent consumer is decreasing in $\bar{N}$, hence the larger the set of potential varieties, the fewer consumers that are willing to consume in the uninformed setting. Instead, expected mismatch costs are not affected by N. This occurs because the two opposed forces cancel out: on the one side

[20] An alternative option that could be considered is the case in which prices are freely observable by all consumers and only locations are unobservable. In that case, firms would compete á la Bertrand, selling an ex-ante homogeneous good, and with avoidable fixed costs. In such case, the equilibrium is analysed in Chaudhuri (1996). In such a case, one firm covers all the market by selling at price equal to the average price and makes zero profit. Considering such type of setting would have little or no impact on this model, a part from any consideration on the equilibrium number of active firms. However, I consider that precisely when it comes to the number of firms, such result is in clear contrast with what can be observed in the kind of market that I'm interested in. Therefore, I consider that the predictions of the Diamond setting are more realistic.

an increase in N reduces the probability of being located in a spoke where there is no seller, but on the other, conditional on being at a spoke with a seller, it equally increases the probability of consuming a meal in a seller on a different spoke from the one where the consumer is located, given that the consumption decision is made before knowing the location of the seller.

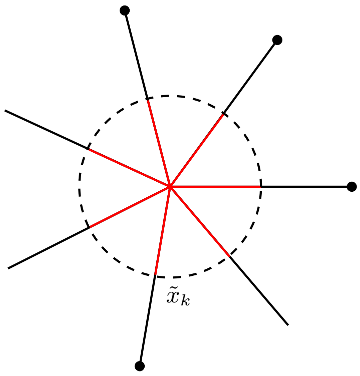

Figure 2: Active consumers without aggregator

From Lemma 1, when the aggregator is not available agents are willing to purchase only as long as they are located sufficiently close to the centre (i.e. consumers within the dashed circle in figure 2). This is a quite surprising result, as it says that – absent information – the share of market which is less likely to be covered is the one closest to firms' location. This is a consequence of the fact that the expected mismatch cost is increasing in x_k: agents have a large $(\frac{\bar{N}-1}{\bar{N}})$ probability of consuming a product located on a spoke other that theirs, hence expected mismatch costs are lower for agents located closer to the centre. The inefficiency becomes clear, the likelihood to consume is inversely related to the ex-post mismatch cost.

2.2 With aggregator

This subsection considers the full information case. An aggregator lists all firms, i.e. all of them are e-seller, hence $n = N$. All consumers make use of the aggregator, i.e. all consumers are *surfers*.

The aggregator allows *surfers* to discover the characteristics (i.e. the location) of a seller before consumption, which means that consumers know ex-ante and for each seller both the mismatch cost and the valuation of the meal in case of consumption. This benchmark case corresponds to the original setting in Chen and Riordan (2007).

Figure 3 depicts a case with four e-seller and no c-seller. Lemma 2 defines the unique, symmetric, pure strategy equilibrium in the market.

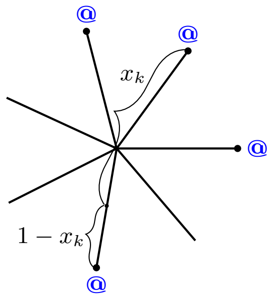

Figure 3: Spokes model with $\bar{N} = 7$, $N = n = 4$

Lemma 2. *The demand faced by one seller is*

$$D_i = \begin{cases} \frac{2}{\bar{N}}(v - p_i) & \text{if } v - p_i \leq \frac{1}{2} \\ \frac{2}{\bar{N}} \frac{1}{(\bar{N}-1)} \left(\sum_{s \neq i; s \leq n} \frac{p_s - p_i + 1}{2} + \left(\bar{N} - n\right)(v - p_i) \right) & \text{if } \frac{1}{2} < v - p_i \leq 1 \\ \frac{2}{\bar{N}} \frac{1}{(\bar{N}-1)} \left(\sum_{s \neq i; s \leq n} \frac{p_s - p_i + 1}{2} + \left(\bar{N} - n\right) \right) & \text{if } v - p_i > 1. \end{cases} \tag{8}$$

The unique symmetric, Nash equilibrium in pure strategies implies that

$$p^a = \begin{cases} v - \frac{1}{2} & \text{if } 1 < v < \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \\ \frac{(n-1)+2\left(\bar{N}-n\right)v}{4\bar{N}-3n-1} & \text{if } \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \leq v < 2 \\ v - 1 & \text{if } 2 \leq v \leq \frac{2\bar{N}-2}{n-1} \\ \frac{2\bar{N}-n-1}{n-1} & \text{if } \frac{2\bar{N}-2}{n-1} < v. \end{cases} \tag{9}$$

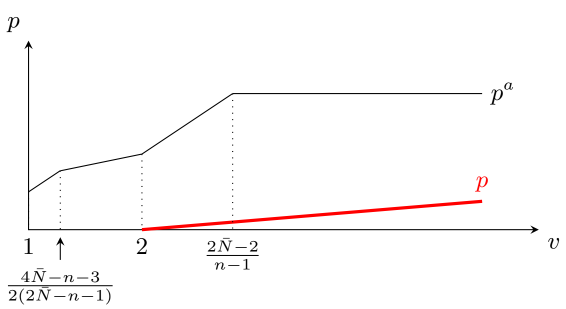

Figure 4: Price schedule. Without aggregator (p, Eq. 7) and with the aggregator (p^a, Eq. 9)

Figure 4 represents the optimal price schedules p - when the aggregator is not available, as defined in Eq. (7) - and p^a - when the aggregator operates in the market, Eq. (9). Notice that the intersection point of p with the horizontal axis occurs at $v = \bar{N}/4$.[21] Finally, notice

[21]In figure 4, the intersection is arbitrary drawn as if $\bar{N} = 8$, hence at $v = 2$.

that p and p^a intersect when $v = \frac{\bar{N}(8\bar{N}-3n-5)}{4(n-1)}$ and p^a is in its last (horizontal) segment, while $p^a < p$ whenever $v > \frac{\bar{N}(8\bar{N}-3n-5)}{4(n-1)}$. A higher product valuation should entail higher prices. This is true in the setting without the aggregator, and hence with no information about the sellers' location. Under full information (i.e. with the aggregator), however, competition becomes fiercer along consumers' valuation and hence the two (countervailing) effects result in a weakly increasing price schedule.

As depicted in figure 4, absent the aggregator and depending on the parameter values, there may be no market when the valuation of the good is low. Instead, when consumers are informed, some transactions always occur in equilibrium. Information allows to expand the market, and hence it is likely to enhance welfare. However, the more relevant and common case is when $v \geq (\bar{N})/4$ and hence a market for the product exists even before the introduction of the aggregator.

3 Entering of the platform

In this section I consider the case in which a review platform is available. In such a case, any consumer is a priori uninformed and their action space includes two options: i) remain uninformed, in which case they decide whether or not to randomly purchase a product, as in section 2.1, or ii) use the platform to gather information, in which case they may purchase online or, if they can't find a suitable product online, they still have the opportunity to randomly purchase offline, as in section 2.1.

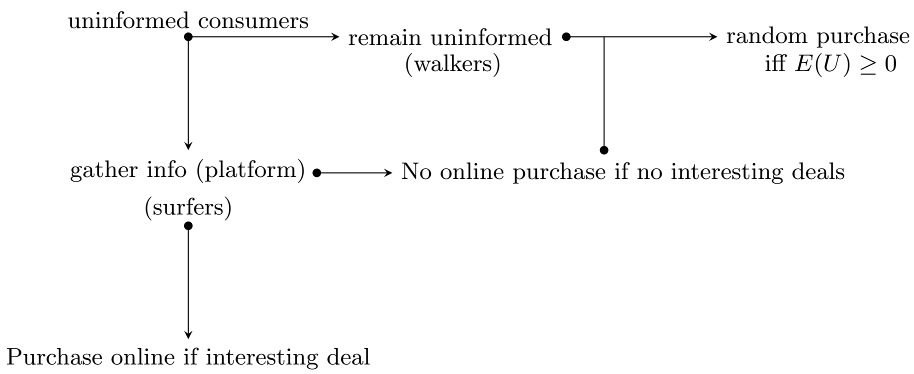

Figure 5: Action diagram

Gathering information through the platform implies some sunk learning costs c, which explains why some users may prefer to randomly consume. This means that a necessary condition for an agent to be willing to become a *surfer* is $EU(x|s) \geq c$.

Lemma 3. *Define $Pr(j)$ as the ex-ante probability for an agent that a firm is located on their preferred spoke j but not on their other preferred spoke k. Similarly, $Pr(k)$ is the probability that spoke j is empty but spoke k is not. $Pr(j \wedge k)$ is then the probability that both spokes j and k have a firm located there and $Pr(0)$ is the probability that both spokes j and k are empty. Then, $Pr(j) = Pr(k) = \frac{n(\bar{N}-n)}{\bar{N}(\bar{N}-1)}$. Furthermore, $Pr(j \wedge k) = \frac{n(n-1)}{\bar{N}(\bar{N}-1)}$ and $Pr(0) = \frac{(\bar{N}-n)(\bar{N}-n-1)}{\bar{N}(\bar{N}-1)}$.*

Proof. See appendix A. □

Lemma 4. *Denote by p^s the equilibrium price in a symmetric equilibrium, and by $\tilde{x}_k^s$ the location of the agent indifferent between being a* surfer *and not consuming. Then it must be that $\tilde{x}_k^s = \frac{(\bar{N}-1)}{(n-1)} + \frac{\bar{N}(\bar{N}-1)}{n(n-1)}c - \frac{(2\bar{N}-n-1)}{(n-1)}(v - p^s)$. Any agent $x_k^s > \tilde{x}_k^s$ strictly prefers to become a* surfer *than to not consume. Agent $\tilde{x}_k^s$ obtains a positive utility from consuming from firm j if and only if $v - p^s < \frac{1}{2} + \frac{\bar{N}(\bar{N}-1)}{2n(\bar{N}-n)}c$. This is also a necessary condition for $\tilde{x}_k^s$ to exist. Finally, agent $\tilde{x}_k^s$ obtains a positive utility from consuming from firm k if $v - p^s > \frac{1}{2} + \frac{\bar{N}}{2n}c$. Any agent located at any $x_k > \tilde{x}_k^s$ strictly prefers to become a surfer than not consuming.*

Lemma 5. *Suppose that c is such that $\tilde{x}_k^s \geq \tilde{x}_k$. The demand function is*

$$D_j^s = \begin{cases} \frac{2}{\bar{N}}\left(1 - \tilde{x}_k^s\right), & \text{if } v - p_j^s \leq \frac{1}{2} + \frac{\bar{N}}{2n}c \\ \frac{2}{\bar{N}}\left(1 - \tilde{x}_k^s\right) + \frac{2(\bar{N}-n)}{\bar{N}(\bar{N}-1)}\left(v - p_j^s - \tilde{x}_k^s\right), & \text{if } v - p_j^s \in \left[\frac{1}{2} + \frac{\bar{N}}{2n}c, 1\right] \\ \frac{2(2\bar{N}-n-1)}{\bar{N}(\bar{N}-1)}\left(1 - \tilde{x}_k^s\right), & \text{if } v - p_j^s > 1. \end{cases} \tag{10}$$

The first piece of the equation represents the case in which each firm is a monopolist selling only to surfers that are located on their own spoke. The last piece of the equation represents the case in which the valuation-price ratio is so low that any surfer is *a priori* interested in purchasing either of the preferred brands. The intermediate piece of the equation represents the case in which any surfer is willing to purchase from their favourite brand j but not all of them are willing to purchase from brand k.

Proposition 1. *The equilibrium price is*

$$p^s = \begin{cases} \frac{2}{\bar{N}}\left(1 - \tilde{x}_k^s\right), & \text{if } v - p_j^s \leq \frac{1}{2} + \frac{\bar{N}}{2n}c \\ \frac{2(\bar{N}-n)(1-\tilde{x}_k^s)}{\bar{N}(\bar{N}-1)} + \frac{2(\bar{N}-1)}{\bar{N}(\bar{N}-1)}\left(v - p_j^s - \tilde{x}_k^s\right), & \text{if } v - p_j^s \in \left[\frac{1}{2} + \frac{\bar{N}}{2n}c, 1\right] \\ \frac{2(2\bar{N}-n-1)(1-\tilde{x}_k^s)}{\bar{N}(\bar{N}-1)}, & \text{if } v - p_j^s > 1. \end{cases} \tag{11}$$

4 Market equilibrium

In this section, I study the equilibrium when an aggregator is available. I suppose that a share α of the population are *walkers*, that is, they never use the aggregator, remain uninformed, and therefore base their consumption decision on expectations and learn their valuation and mismatch cost only after consuming, as in subsection 2.1. The $1-\alpha$ *surfers* always recover the information available. The value α is exogenous.[22]

By definition, c-seller are not listed on-line, hence they do not disclose information, while e-seller are listed on-line. Sellers endogenously decide whether to be listed on-line or not: n represents the number of e-seller, $N-n$ is the number of c-seller. Sellers pay f^e to be listed on-line. *Walkers* randomly buy at any of the N sellers, hence they may consume at a c- or e-seller. *Surfers* use the information available to maximise their utility: they may find a suitable match among the e-seller, or decide to act as a *walker* whenever this is a better strategy.

Therefore, e-seller may serve both groups of consumers: *surfers* and the share of *walkers* that randomly decide to purchase there, while c-seller instead only serve *walkers.* However, with probability $\epsilon = \left(\frac{\bar{N}-n-1}{\bar{N}-1}\right)\left(\frac{\bar{N}-n}{\bar{N}}\right)$ none of the two favourite sellers of a *surfer* is on-line. In such case, *surfers* are free to act like *walkers* and randomly select a seller. I assume that, alike *walkers*, *surfers* buying off-line will randomly purchase from any available seller.[23]

The pricing strategy of e-seller is bounded by the legal environment, the type of technology and the agreement signed with the aggregator. Sub-sections 4.1 and 4.2 consider two plausible alternative situations. In the former, e-seller can treat *surfers* and *walkers* differently, i.e. they can charge p^s to *surfers* and p^w to *walkers.* In the latter, e-seller are bounded to propose one single price p^e to all of their consumers. This may occur for legal reasons, as part of an agreement with the aggregator, or whenever the seller cannot distinguish the two types of buyers as, for example, when reservations are not made directly through the aggregator's platform.

[22] As discussed in the introduction, assuming that a fixed share of the population makes use of the aggregator can be interpreted as the extreme case in which *walkers* have a prohibitive cost of using the aggregator – this could be due to limited IT skills or high opportunity cost of time – while *surfers* have no cost of usage. The appendix discusses the consequences of this assumption.

[23] This assumption, made for tractability reasons, implies that *surfers* cannot randomise within the subset of off-line sellers, excluding e-seller. This assumption is realistic when it is not possible to directly match the on-line firm with the off-line one. This occurs, for example, when the aggregator doesn't provide some crucial contact information before the transaction occurs: a notable case would be the one of *Airbnb*, where the host's phone and address are not revealed. Another case in which the matching is not possible is when the database of firms is large and users focus on the results of an advanced search: when no firms fit the introduced criteria, the user learn that no sellers in the database are a good fit, but for the user it would be too costly to check which firms belong to the database. By relaxing this assumption, any *surfer* acting alike *walkers* has still an informational advantage (the surfer is able to exclude from the set any e-seller, which would be a poor match) hence, the model that I propose underestimates welfare benefits, by over-estimating the mismatch cost for such consumers.

4.1 *e*-seller charge different prices to *surfers* and *walkers*

When e-seller can charge different prices to *surfers* and *walkers*, the on-line and off-line markets can be treated separately. e-seller charge a price p^s to *surfers* who purchase through the aggregator. Both e- and c-seller face the same problem when choosing the price strategy for *walkers*. I denote p^w the price that both types of seller charge to *walkers*.

Amongst *walkers*, the agent that is indifferent between purchasing and restraining from it is

$$\tilde{x}_d^w = \frac{\bar{N}}{(\bar{N}-2)}\left(\frac{2v}{\bar{N}} - \frac{1}{\bar{N}} - p^w\right). \tag{12}$$

The maximisation problems of e- and c-seller are respectively:

$$\max_{p^w,p^s} \frac{2(\alpha+(1-\alpha)\epsilon)}{N}\left(\tilde{x}_d^w - \frac{1}{2}\right)p^w + (1-\alpha)D_r p^s \tag{13}$$

and

$$\max_{p^w} \frac{2(\alpha+(1-\alpha)\epsilon)}{N}\left(\tilde{x}_d^w - \frac{1}{2}\right)p^w, \tag{14}$$

where D_r is defined by equation (8). In both maximisation problems, the first term is the profit from the off-line market.

Noticing the separability between p^s and p^w, it is immediate to conclude that both prices coincide with those obtained in sections 2.1 and 2.2, for the only difference here with respect to the previous sections is due to a resize of the marker.

Lemma 6 summarises the result of the maximisation.

Lemma 6. *The off-line price is* $p^w = \frac{v}{\bar{N}} - \frac{1}{4}$. *The on-line price is*

$$p^s = \begin{cases} v - \frac{1}{2} & \text{if } 1 < v < \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \\ \frac{(n-1)+2(\bar{N}-n)v}{4\bar{N}-3n-1} & \text{if } \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \leq v < 2 \\ v-1 & \text{if } 2 \leq v \leq \frac{2\bar{N}-2}{n-1} \\ \frac{2\bar{N}-n-1}{n-1} & \text{if } \frac{2\bar{N}-2}{n-1} < v. \end{cases} \tag{15}$$

The two prices are equal ($p^w = p^s$) *for* $\tilde{v} = \frac{\bar{N}(8\bar{N}-3n-5)}{4(n-1)}$. *The crossing occurs when* p^s *is in its last region* ($v > \frac{2\bar{N}-2}{n-1}$). *The off-line price is lower* ($p^w < p^s$) *if and only if* $v < \tilde{v}$.

From lemma 6 we learn that e-seller are willing to charge a lower price to *surfers* than the regular one for *walkers*, whenever the good's valuation is sufficiently large. Such a result if compatible with the observed evidence that the sellers that are listed on some aggregators (e.g. *ClubKviar*) propose a substantial discount to users that book through the web-site. However, the opposite is also true: for low valuation goods, firms would prefer to charge *surfers* more than *walkers*. This can occur only when e-seller can identify *surfers* and avoid

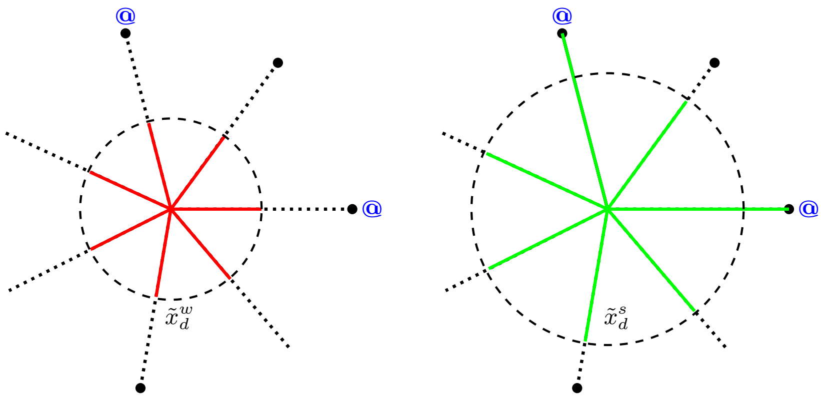

Figure 6: Consumers served: *walkers* in the left chart and *surfers* in the right chart

any arbitrage, as assumed in this subsection. Subsection 4.3 considers the case in which *surfer* can pay the *walkers*' price when this is lower.

Figure 6 shows the consumers that are served. The left chart refers to walkers: within the circle ($x \leq \tilde{x}_d^w$), all *walkers* decide to consume (red, continuous lines), while those located outside it restrain from consuming (black, dotted lines). The right chart refers to *surfers*; the green, continuous lines indicate locations where *surfers* consume: all *surfers* located on any spoke with an *e*-seller consume, as well as any *surfer* within the circle ($x \leq \tilde{x}_d^s$) and located on a spoke without *e*-seller.[24]

Lemma 7. c-*seller sell at the same price as before the aggregator's appearance. However, the size of the population that they serve decreases from* 1 *to* $\alpha + \epsilon(1-\alpha)$. *Therefore, their gross profit shrinks to*

$$\pi_d^c = (\alpha + \epsilon(1-\alpha)) \frac{(4v - \bar{N})^2}{8\left(\bar{N} - 2\right) N \bar{N}}. \tag{16}$$

The e-*seller's gross profit is* $\pi_d^e = (\alpha + \epsilon(1-\alpha)) \frac{(4v-\bar{N})^2}{8\left(\bar{N}-2\right)N\bar{N}} + (1-\alpha)D_r p^s$, *with*

$$D_r p^s = \begin{cases} \frac{1}{\bar{N}}\left(v - \frac{1}{2}\right) & \text{if } 1 < v < \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \\ \frac{\left((n-1)+2\left(\bar{N}-n\right)v\right)^2\left(2\bar{N}-n-1\right)}{\left(4\bar{N}-3n-1\right)^2\bar{N}\left(\bar{N}-1\right)} & \text{if } \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \leq v < 2 \\ \frac{(v-1)\left(2\bar{N}-n-1\right)}{\bar{N}\left(\bar{N}-1\right)} & \text{if } 2 \leq v \leq \frac{2\bar{N}-2}{n-1} \\ \frac{\left(2\bar{N}-n-1\right)^2}{(n-1)\bar{N}\left(\bar{N}-1\right)} & \text{if } \frac{2\bar{N}-2}{n-1} < v. \end{cases} \tag{17}$$

It is immediate to notice that *c*-seller' gross profit is less than what any seller earns when the aggregator is not available, since $\alpha + \epsilon(1-\alpha) < 1$, and that *e*-seller' gross profit is

[24]The dimension of the two circles was arbitrarily set: depending on the parameters values, it may be that $\tilde{x}_d^w > \tilde{x}_d^s$.

larger than the one of c-seller' ($\pi^e \geq \pi^c$): comparing net profits, e-seller are more profitable whenever $f^e < (1-\alpha)D_r p^s$.

4.2 *e*-seller charge a same price to all their consumers

When e-seller cannot charge different prices to *surfers* and *walkers*, they choose one single price that they charge to all their consumers. c-seller may charge a different price. Through this subsection, I consider the case in which e-seller cannot sell at different prices to *surfers* and *walkers*. In this case, e-seller charge a price p^e to all their consumers, while c-seller will set a price p^c. *Walkers* face now an uncertainty about the price that they will pay, since they ignore which type of seller they will attend. The location of the indifferent *walker*, which now depends on the expected price, is now defined by:

$$\tilde{x}_u = \frac{\bar{N}}{(\bar{N}-2)} \left(\frac{2v}{\bar{N}} - \frac{1}{\bar{N}} - \frac{n}{Nt} p^e - \frac{N-n}{Nt} p^c \right), \tag{18}$$

where the subscript u stands for "uncertainty", for *walkers* cannot anticipate the price that they will be charge, because it depends on the type of seller where they consume. This means that an increase in p^e negatively affects the demand for c-seller and, therefore, that the off-line equilibrium price changes with respect to the previous case. The maximisation problem for the e- and c-seller is respectively:

$$\max_{p^e} \left(\frac{2(\alpha + (1-\alpha)\epsilon)}{N} \left(\tilde{x}_u - \frac{1}{2} \right) + (1-\alpha) D_r \right) p^e \tag{19}$$

and

$$\max_{p^c} \frac{2(\alpha + (1-\alpha)\epsilon)}{N} \left(\tilde{x}_u - \frac{1}{2} \right) p^c, \tag{20}$$

From the first order conditions, we obtain that

$$p^c = \frac{N}{N-n} \left(\frac{v}{\bar{N}} - \frac{1}{4} - \frac{n}{2N} p^e \right), \tag{21}$$

Proposition 2. *When* e-*seller must charge the same price to both* walkers *and* surfers*, the equilibrium is defined as follows:* c-*seller charge* $p^{c*} = max p^c, 0$*, where* p^c *is defined by equation* (23)*.* e-*seller charge* $p^{e*} = max\{p^e, 0\}$ *when* $p^{c*} > 0$ *and charge instead* p^s *when [TBA]*

prices p^e *and* p^c *are defined by equations* (22) *and [TBA]. For* v *sufficiently low* $\left(v < \frac{(2\bar{N}-n-1)/(n-1)-\Psi_5^t}{\Psi_5^v} \right)$, *the price* p^e *is less then or equal to* p^s*, which is the price charged to* surfers *in subsection 4.1 (when* e-*seller are able to set two different prices). Both* p^e *and* p^c *are increasing in* v*:* $\partial p^e / \partial v \geq 0$ *and* $\partial p^c / \partial v \geq 0$.

Picture 7 depicts p^e and p^s together, under the assumption that $N < 3n$. The optimal price charged to *walkers* follows a similar behaviour as the one charged to *surfers*: they share the same intervals that define the pieces of the equations, however slopes and intercepts depend on the parameter values and so does the relative position of p^e and p^c. Hence, it is not possible to draw the two in one single graph.

$$p^e = \begin{cases} \Psi_1^v v - \Psi_1^t t & \text{in Region } R^e 1 \\ v - \frac{t}{2} & \text{in Region } R^e 2 \\ \Psi_3^v v + \Psi_3^t t & \text{in Region } R^e 3 \\ v - t & \text{in Region } R^e 4 \\ \Psi_5^v v + \Psi_5^t t & \text{in Region } R^e 5, \end{cases} \tag{22}$$

and

$$p^c = \begin{cases} \hat{\Psi}_1^v v - \hat{\Psi}_1^t t & \text{in Region } R^e 1 \\ \left(\frac{4N^2 - n\bar{N}^2}{2\bar{N}(N-n)}\right) v - \frac{t}{4} & \text{in Region } R^e 2 \\ \hat{\Psi}_3^v v - \hat{\Psi}_3^t t & \text{in Region } R^e 3 \\ \left(\frac{2N - n\bar{N}}{2\bar{N}(N-n)}\right) v - \left(\frac{N-2n}{N-n}\right) \frac{t}{4} & \text{in Region } R^e 4 \\ \hat{\Psi}_5^v v - \hat{\Psi}_5^t t & \text{in Region } R^e 5, \end{cases} \tag{23}$$

where the equations for Ψ_j^i, $\hat{\Psi}_j^i$ and $R^e j$ are defined in the proof of proposition 2.

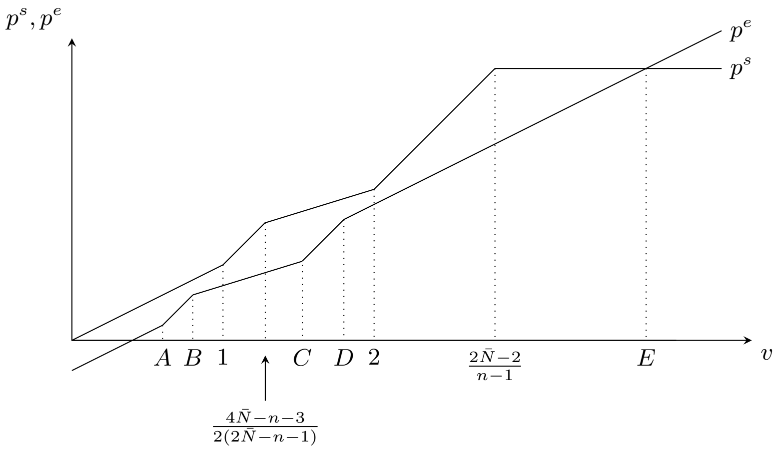

Figure 7: Price schedule. Charging different prices (p^s, Eq. 15) and charging one price (p^e, Eq. 22)

4.3 *e*-seller can offer discounts to *surfers*

In this subsection, I consider the case in which the seller can propose two different prices but cannot tell the two types of buyers apart. Therefore, *e*-seller cannot charge *surfers* more than *walkers*, for the *surfers*' incentive compatibility constraint is binding.

4.4 OLD e-seller charge a same price to all their consumers

When the restriction $p_s^e \leq p_w^e$ is binding, e-seller charge a same price p^e to both *surfers* and *walkers*. The maximisation problems becomes then:

$$\max_{p^e} \left(\frac{2\alpha}{N} \left(\tilde{x}_w - \frac{1}{2} \right) + (1-\alpha) D_r \right) p^e \tag{24}$$

and

$$\max_{p^c} \left(\frac{2\alpha}{N} \left(\tilde{x}_w - \frac{1}{2} \right) + \frac{2(1-\alpha)\epsilon}{N-n} \left(\tilde{x}_s - \frac{1}{2} \right) \right) p^c, \tag{25}$$

with $\tilde{x}_w$ and $\tilde{x}_s$ defined by equation (**??**) and (18), clearly replacing $p_w^e = p^e$.

The F.O.Cs are:

$$\frac{\alpha \left(\frac{t}{2} - \left(\frac{2v}{\bar{N}} - \frac{t}{\bar{N}} - \frac{2n}{N} p^e - \frac{N-n}{N} p^c \right) \frac{\bar{N}}{(\bar{N}-2)} \right)}{N} = \frac{(1-\alpha)}{\bar{N}} \begin{cases} v - p^e & \text{if } v - p^e \leq \frac{t}{2} \\ \frac{(n-1)\frac{t-p^e}{2} + \left(\bar{N}-n\right)(v-2p^e)}{\left(\bar{N}-1\right)} & \text{if } \frac{t}{2} < v - p^e \leq t \\ \frac{(n-1)\frac{t-p^e}{2} + \left(\bar{N}-n\right)t}{\left(\bar{N}-1\right)} & \text{if } v - p^e > t. \end{cases} \tag{26}$$

and

$$\frac{\alpha \left(\frac{t}{2} - \left(\frac{2v}{\bar{N}} - \frac{t}{\bar{N}} - \frac{n}{N} p^e - 2\frac{N-n}{N} p^c \right) \frac{\bar{N}}{(\bar{N}-2)} \right)}{N} = \frac{(1-\alpha)\epsilon}{(N-n)} \left(\frac{2v - t - 2\left(\bar{N}-n\right) p^c}{(\bar{N}-n-2)} - \frac{t}{2} \right). \tag{27}$$

This can be rewritten as

$$\phi_1 v - \phi_2 t - \phi_3 p^e = \phi_4 p^c \tag{28}$$

$$\Psi_1 v - \Psi_2 t - \Psi_3 p^e = \Psi_4 p^c, \tag{29}$$

where:

$$\phi_1 = \frac{2\alpha}{N\left(\bar{N}-2\right)} + \begin{cases} \frac{1-\alpha}{\bar{N}} & \text{if } v - p^e \leq \frac{t}{2} \\ \frac{(1-\alpha)(\bar{N}-n)}{\bar{N}(\bar{N}-1)} & \text{if } \frac{t}{2} < v - p^e \leq t \\ 0 & \text{if } v - p^e > t, \end{cases} \tag{30}$$

$$\phi_2 = \frac{\alpha \bar{N}}{N\left(\bar{N}-2\right)} - \begin{cases} 0 & \text{if } v - p^e \leq \frac{t}{2} \\ \frac{(1-\alpha)(n-1)}{2\bar{N}(\bar{N}-1)} & \text{if } \frac{t}{2} < v - p^e \leq t \\ \frac{(1-\alpha)(2\bar{N}-n-1)}{2\bar{N}(\bar{N}-1)} & \text{if } v - p^e > t, \end{cases} \tag{31}$$

$$\phi_3 = \begin{cases} 2\left(\frac{n\bar{N}}{N} + 1\right) & \text{if } v - p^e \leq \frac{t}{2} \\ \frac{2\alpha n\bar{N}}{N^2\left(\bar{N}-2\right)} + \frac{(1-\alpha)(4\bar{N}-3n-1)}{2\bar{N}(\bar{N}-1)} & \text{if } \frac{t}{2} < v - p^e \leq t \\ \frac{2\alpha n\bar{N}}{N^2\left(\bar{N}-2\right)} + \frac{(1-\alpha)(n-1)}{2\bar{N}(\bar{N}-1)} & \text{if } v - p^e > t, \end{cases} \tag{32}$$

$$\phi_4 = \frac{\alpha \bar{N}(N-n)}{N^2\left(\bar{N}-2\right)}. \tag{33}$$

Notice that $\phi_i > 0$ for $i = 1, 3, 4$, for any $\alpha \in (0, 1)$. The sign of ϕ_2 depends on α: it exist a value $\bar{\alpha} \in [0, 1]$ such that $\phi_2 > 0$ if $\alpha > \bar{\alpha}$.

Lemma 8. *The equilibrium prices, using equations* (28) *and* (29), *are:*

$$p^e = \frac{(\phi_1\Psi_4 - \phi_4\Psi_1)\, v + (\Psi_2\phi_4 - \phi_2\Psi_4)\, t}{\phi_3\Psi_4 - \phi_4\Psi_3} \tag{34}$$

$$p^c = \frac{(\phi_3\Psi_1 - \phi_1\Psi_3)\, v + (\phi_2\Psi_3 - \phi_3\Psi_2)\, t}{\phi_3\Psi_4 - \phi_4\Psi_3}. \tag{35}$$

Proposition 3. *Both prices are increasing in* v $\left(\frac{\partial p^e}{\partial v} > 0, \frac{\partial p^c}{\partial v} > 0\right)$. *The optimal price that* c*-seller charges is always decreasing in transport costs* $\left(\frac{\partial p^c}{\partial t} < 0\right)$, *while in the case of* e*-seller the effect of transport costs depends on the share* α *of* walkers*: it exists a threshold* $\tilde{\alpha}$ *such that* $\frac{\partial p^e}{\partial t} < 0$ *for* $\alpha > \tilde{\alpha}$ *and* $\frac{\partial p^e}{\partial t} > 0$ *for* $\alpha < \tilde{\alpha}$.

Proposition 3 can be easily interpreted. It is natural that an increase in the good valuation, hence in buyers' willingness to pay, leads to an increase in prices. Under no information (hence, in the case of *walkers*), an increase in transport costs has only a negative impact, by decreasing agents' willingness to pay. However, in the case of *surfers*, we observe two countervailing effects: on the one side, agents' net valuation for the good decreases, but transport costs also have an impact on competition, by reducing the number of buyers for which firms compete. When the number of *walkers* is sufficiently large, the first effect prevails and an increase in t is reflected by a decrease in p^e. On the opposite, when e-seller serve mainly *surfers*, the competition effect prevails and an increase in transport costs can lead to an increase in prices.

I restrain my focus on the case of $v \geq (\bar{N}t)/4$, that is, when the market exists even in the absence of the aggregator.

One last point to notice is that with probability $\epsilon = \left(\frac{\bar{N}-n-1}{\bar{N}-1}\right)\left(\frac{\bar{N}-n}{\bar{N}}\right)$ neither of the (two) favourite sellers of a *surfer* is listed on-line. Alike *walkers*, they may decide to randomly select one of the available sellers or restrain from purchasing.

Lemma 9. *When the aggregator is available, it is still optimal for* c*-seller to behave the same as without it and charge* walkers *a price*

$$p^c = \frac{(4v - \bar{N}t)}{4\bar{N}}. \tag{36}$$

However, the size of the population that they serve decreases from 1 *to* $\alpha+\epsilon(1-\alpha)$*. Therefore, their profit is*

$$\pi^c = (\alpha + \epsilon(1-\alpha))\,\frac{(4v - \bar{N}t)^2}{8\left(\bar{N}-2\right)N\bar{N}t}. \tag{37}$$

e*-seller serve* walkers *at the same price as* c*-seller, while the on-line price is*

$$p^e = \begin{cases} \frac{4v-\bar{N}t}{4\bar{N}} & \text{if } \frac{\bar{N}}{4} \leq \frac{v}{t} < \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)} \\ \frac{2\bar{N}-n-1}{n-1}t & \text{if } \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)} < \frac{v}{t}. \end{cases} \tag{38}$$

Profits come from selling both off-line and on-line. The gross profit of on-line firms is

$$\pi^e = \pi^c + (1-\epsilon)(1-\alpha)p^e D_r \tag{39}$$

, where:

$$p^e D_r = \begin{cases} \left(\frac{\bar{N}+n-2}{4\left(\bar{N}-1\right)} + \frac{\left(\bar{N}-n\right)v}{\bar{N}t}\right)\frac{\left(4v-\bar{N}t\right)}{2\bar{N}^2} & \text{if } \frac{v}{t} \in \frac{\bar{N}}{4}\left[1, \frac{3}{\bar{N}-1}\right] \text{ (Region A)} \\ \frac{\left(4v-\bar{N}t\right)\left(2\bar{N}-n-1\right)}{4\bar{N}^2\left(\bar{N}-1\right)} & \text{if } \frac{v}{t} \in \frac{\bar{N}}{4}\left[\frac{3}{\bar{N}-1}, \frac{\left(8\bar{N}-3n-5\right)}{(n-1)}\right] \text{ (Region B)} \\ \frac{\left(2\bar{N}-n-1\right)^2 t}{\bar{N}\left(\bar{N}-1\right)(n-1)} & \text{if } \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)} < \frac{v}{t} \text{ (Region C)}. \end{cases} \tag{40}$$

On-line sellers must pay a fee f^e *to the aggregator. Hence, their net profit is* $\pi^e - f^e$.

Lemma 9 provides interesting insights on the role of competition in this model. Restricting our attention to the case in which the good valuation is large enough for a market to exist even if the aggregator is not available, the fact that *surfers* can always purchase off-line puts an upperbound to prices which limits sellers' profits. If they could, *e*-seller would charge larger prices to *surfers* than to *walkers* any time that $\frac{v}{t} < \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)}$. However, *surfers* can always decide to buy off-line from a seller discovered on-line and hence *e*-seller are constrained to charge $p^e \leq p^c$ to *surfers*. Therefore, in regions A and B, *e*-seller charge everyone the same. In region C, competition on-line is strong enough to play a role in the determination of prices. As a matter of facts, it pushes on-line prices below the off-line ones.

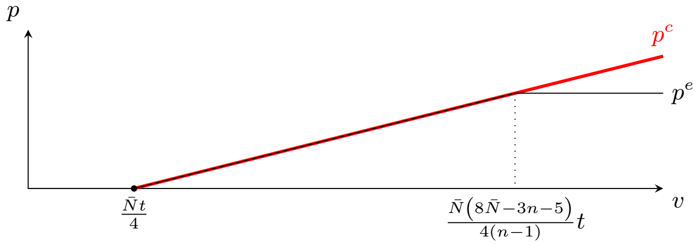

Figure 8: Price schedule. c-seller (p^c, Eq. 36) and e-seller (p^e, Eq. 38)

4.5 Number of firms

The decision to be on-line is endogenous: sellers compare their profit off-line π^c with the profit on-line, net of the aggregator fee, $\pi^e - f^e$. The number of sellers active in each market depends on profitability. To study it, let first formally define the timing considered. The initial condition is the long run equilibrium previous to the entry of the aggregator. In such a setting, the equilibrium condition implies that the number N_0 of active firms is such that profit is equal to the licence cost: $\pi = f$. Following the entry of the aggregator, in the *short run* firms decide whether to be listed on the aggregator or not. Their decision is based on the comparison of profits of e- and c-seller (respectively, π^e and π^c). The number n of e-seller increases as long as it is profitable. The *medium run* equilibrium is reached for $n = n_0$, that is when the net of fees profits equate: $\pi^e - f^e = \pi^c$. The *long run* equilibrium occurs when the total number of active firms is $N = N_1$, where N_1 is the number of active firms such that profits on both markets equal the license cost: $\pi^e - f^e = \pi^c = f$.

The initial number of active sellers N_0, such that $\pi = f$ is $N_0 = \frac{(4v-\bar{N}t)^2}{8(\bar{N}-2)f\bar{N}t}$.

Replacing N_0 in equation (37), it is possible to obtain the short and medium run equilibrium profit for c-seller:

$$\pi^c = (\alpha + \epsilon(1-\alpha))\, f. \tag{41}$$

e-seller serve both *surfers* and *walkers*. From equation (39), it is possible to notice that the number N of c-seller does not affect profits obtained from serving *surfers*.

In the medium run, the number of e-seller adjusts, hence n_0 is such that $\pi^e - f^e = \pi^c$. Noticing that $\pi^e = (\pi^c + (1-\epsilon)(1-\alpha)p^e D_r)$, it is immediate to conclude that n_0 is implicitly defined by:

$$(1-\epsilon)(1-\alpha)p^e D_r = f^e, \tag{42}$$

where $(1-\epsilon) = \frac{n(2\bar{N}-n-1)}{\bar{N}(\bar{N}-1)}$ and $p^e D_r$ is defined by equation (40). Depending on the region and on the value of the parameters (in particular the value of v and t), corner solutions may arise, with therefore $n_0 = 0$ (no seller is listed on-line, and the equilibrium is defined by section 2.1) or $n_0 = N$ (all the sellers are listed on-line, and the equilibrium is defined by section 2.2).

Proposition 4. *In the long run, entry of the aggregator decreases the number of active firms, hence a reduction in variety is observed. The total number of active firms is*

$$N_1 = (\alpha + \epsilon(1-\alpha)) \frac{(4v - \bar{N}t)^2}{8\left(\bar{N}-2\right) f\bar{N}t} = (\alpha + \epsilon(1-\alpha))\, N_0. \tag{43}$$

Proposition 4 is discussed in section 5, together with proposition 5.

5 Welfare analysis

This section uses the results from the previous one to determine the welfare effects of the entry of the aggregator.

Proposition 5. *In the short run, entry of the aggregator enhances on-line firms' profits. In the medium run, firms' entry in the on-line market reduces everyone's profits and firms are locked in a Bertrand supertrap. Indeed, for all firms medium run profits are lower than before the aggregator's entry.*

Figure 9 depicts the evolution of firms' profits in the different equilibria.

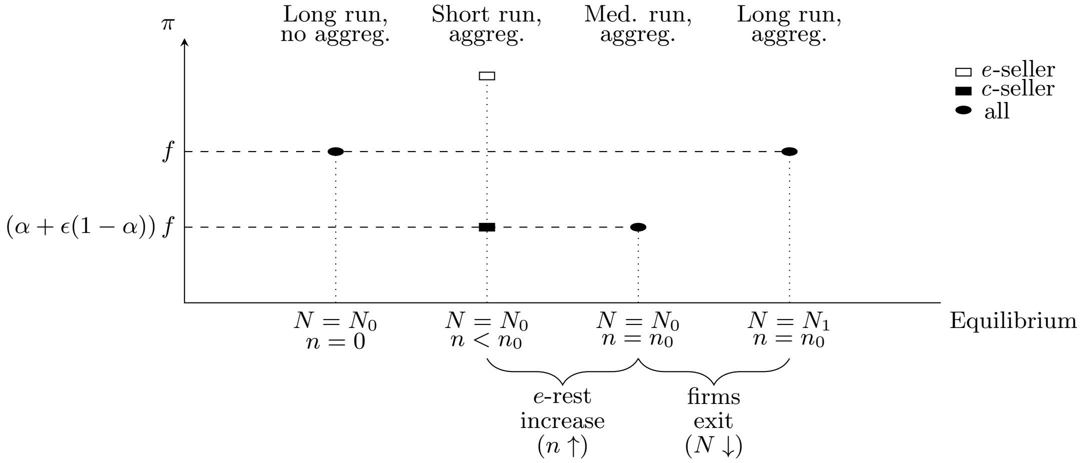

Figure 9: Comparison of profits in the short, medium and long run.

Proposition 5 shows that e-seller benefit from the presence of the aggregator in the short run, but their medium run profit is lower than if the aggregator hadn't entered the market. In other words, sellers face a sort of prisoner dilemma: they use the aggregator to increase their profit in the short run, which is possible for the combined effect of both an increase in the total size of the market and a business stealing mechanism from c- to e-seller. However, being listed on-line is detrimental to medium run profits, for competition increases: for low valuations of the good, on-line e-seller are bound to maintain prices low to compete with c-seller, and when the valuation is high it's the competition amongst e-seller that keeps prices down. Competition in the *walkers* market remains constant, but the size of the market shrinks, for now *surfers* buy on-line. *Ex-post*, all firms are hurt by the presence of the aggregator, but there is nothing that they can do and – given the existence of the aggregator – their optimal strategy may still be to be listed on-line.

The decrease in profits has a direct consequence on variety. Proposition 4, through equation (43), shows that the entry of the aggregator implies a reduction of firms in the long run equilibrium. Firms exit the market, and this could have two consequences on welfare: on the one side, less firms could imply larger transport costs. On the other hand, active firms are responsible of the deadweight loss corresponding to sunk entry costs, hence its reduction would be beneficial for welfare. The standard result in horizontal competition is that there is excess of variety (that is, too many firms enter the market, taking into account the trade-off between transport and sunk costs), hence a reduction in variety is usually welfare enhancing. In this case this result is even stronger. As a matter of fact, in the off-line market, price and equilibrium transport costs do not depend on the number of firms, as explained in subsection 2.1 (for the different forces cancel out). Hence, any reduction in the number of firms has the unique effect of reducing sunk costs. Concerning the on-line market only, the total number of active firms is irrelevant for the equilibrium, and what matters is the number n of on-line firms. Hence, any reduction in the number of firms is irrelevant at any internal solution with $N \geq n$.[25] This implies that, from a welfare perspective, the optimal balance between sunk and transport costs implies $N = n$, that is, all firms are listed on-line.

Proposition 6. *Entry of the aggregator strictly enhances consumers' surplus in the medium and long run. In the long run, the entry of the aggregator always enhances total welfare. The long run total welfare increase due to the entry of the aggregator is:*[26]

$$\Delta W = \pi^a + \frac{(1-\alpha)n}{\bar{N}}\left(\left(S_j^e - S^c\right) + \frac{\bar{N}-n}{\bar{N}-1}\left(S_k^e - S^c\right)\right) > 0. \tag{44}$$

where π^a *is the aggregator's profit,* $S_j^e = \frac{4(v-p^e)-t}{8}$, $S^c = \frac{\tilde{x}_m\left(\frac{2v}{\bar{N}} - p^c - \frac{t}{2}\right)}{2}$

$$S_k^e = \begin{cases} \frac{(v-p^e-t/2)^2}{2t} & if\, \frac{v}{t} < \frac{3\bar{N}}{4(\bar{N}-1)} \\ \frac{4(v-p^e)-3t}{8} & if\, \frac{v}{t} \geq \frac{3\bar{N}}{4(\bar{N}-1)}. \end{cases}$$

The term $\left(S_j^e - S^c\right)$ represents the increase in surplus of a *surfer* consuming from the

[25] Whether the equilibrium conditions n_0 and N_1 satisfy the condition for an internal solution $N \geq n$ depends on the parameter values f and f^e. Whenever this is not the case, by a fixed point argument it is possible to show that the equilibrium would be $N = n \in (N_1, n_0)$.

[26] Notice that $\frac{3\bar{N}}{4(\bar{N}-1)} < \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)}$, hence in the first segment $p^e = p^c$.

spoke where (s)he is located, whereas $(S_k^e - S^c)$ is the increase in surplus of a *surfer* consuming from a spoke different from where (s)he is located.

A revealed preference argument is sufficient to guarantee that consumers' surplus can only be weakly larger with the aggregator. Indeed, consumers' surplus without aggregator is null, and the option of purchasing off-line remains always available to consumers. Therefore, nobody would "become a *surfer*" unless it is weakly profitable.

The increase in consumers welfare comes, at least partially, from the increase in available information that reduces inefficient mismatch costs. Indeed, informed consumers are able to consume the most valuable product, that is the one that maximises the difference between value and transport costs.[27] Such increase in the value of transactions may have an expansionary effect: if $\frac{v}{t} < \frac{3\bar{N}-4}{4}$ (regions A and part of B), the market is partially uncovered without the aggregator. As previously noticed, consumers located closer to the origin of spokes (and hence to firms) are not served in the incomplete information setting – although they are those with the lowest transportation cost – because they show the highest expected transportation cost. In the complete information framework, they are the first to be served and those who most benefit from the transaction. Therefore, we obtain an increase in welfare due to an expansion of the market. Notice that in regions A and B the price is the same with and without the aggregator, which implies that this effect is a consequence of the increase in information and it is not related to the possible change in competition among firms, which only affects the equilibrium price in region C. A further, positive, effect may arise because on-line prices are lower than off-line in region C. Firms, due to increased competition, extract a lower share of surplus.

The total long run welfare is equal to the long run consumers surplus by the zero-profit condition. Therefore, it is immediate to conclude that the increase in total surplus is equal to the increase in the consumers' one.

[27] *Surfers* learn the firms' location before consuming and therefore they are able to avoid unnecessary transport costs and to consume products that they do not value, that is, the aggregator solves the information issue and reduces mismatch costs.

6 Final remarks

I use the spokes model of horizontal competition to analyse the impact of the entry of an on-line review aggregator, such as *ClubKviar* or *Opentable*, on both the market equilibrium and welfare. I show that aggregators are welfare-enhancing.

The increase in welfare comes through three channels. Firstly, aggregators expand the market when it is not initially covered, by allowing for some additional consumers to be reached. This is possible because consumers can learn the location of the seller via the aggregator and thus every efficient transaction takes place. Secondly, the lack of information absent the aggregator is also responsible for *mismatch costs* in the form of inefficient transactions taking place (a consumer may attend a seller which is not her/his best choice and even agree on transactions that generate a negative surplus). Entry of the aggregator guarantees that all, and only, surplus-enhancing transactions take place. Finally, when the consumers' valuation of the good is large enough, entry of the aggregator makes competition fiercer and this may lead to a decrease in prices. To some extent, we can view the aggregator as a device boosting some of the positive effects of the internet, such as the reduction in search costs and the increase in the likelihood of a match occurring, as documented in Rapson and Schiraldi (2013) for the second-hand car market in California.

Profits tend to increase in the *short run*, partly because of a larger share of the market being served, and partly as a business-stealing effect (from off-line to on-line firms). Entry of additional on-line firms pushes both on-line and off-line *medium-run* profits down, however, to a level that is lower than before the aggregator's entry. Therefore, firms face a prisoner's dilemma (or Bertrand supertrap) situation, in which it is optimal for firms to resort to the aggregator as a deviation from the previous equilibrium, yet they would be better off if they did not.

In the long run, the zero profit condition induces a reduction in the active number of firms in the market, hence variety decreases. This could affect consumers' surplus if they have a strong taste for variety. However, any such decrease in welfare is compensated by the dynamics described above. Furthermore, as it is standard in the horizontal competition literature, the total number of firms tends to exceed the optimum when we account for both consumers' transport costs and firms' sunk entry costs. Taking all different forces into consideration, the total welfare effect is always positive.

The model provides several testable predictions, including the number of active firms shrinking when an aggregator enters a market; profits increasing in the short run for the firms listed on-line first, and long run profits remaining constant.

Appendix A Proofs

Proof of Lemma 1. An agent located on spoke j consumes from a randomly selected seller. With probability $Pr(j > N) = \frac{\bar{N}-N}{\bar{N}}$, there are no firms located on spoke j and therefore the mismatch cost will be x_k regardless of which firm the agent selects. With probability $Pr(j \leq N) = \frac{N}{\bar{N}}$, one firm is located on spoke j. Then, with probability $Pr(i = j) = \frac{1}{N}$, the agent consumes from the firm located on their spoke and bears a cost $(1 - x_k)$, otherwise the mismatch cost is again x_k:

$$\begin{aligned} EM_i &= Pr(j > N)x_k + Pr(j \leq N)\left(Pr(i = j)(1 - x_k) + Pr(i \neq j)x_k\right) \\ &= \frac{\bar{N} - N}{\bar{N}}x_k + \frac{N}{\bar{N}}\left(\frac{1}{N}(1 - x_k) + \frac{N-1}{N}x_k\right) \\ &= \left(\frac{\bar{N} - 2}{\bar{N}}x_k + \frac{1}{\bar{N}}\right). \end{aligned} \tag{45}$$

The expected valuation of a consumer is $2v/\bar{N}$, where $2/\bar{N}$ is the probability that an agent randomly consumes either j or k. Therefore, the expected utility of an agent is positive if:

$$\begin{aligned} 0 \leq& \frac{2v}{\bar{N}} - p_i - EM_i \\ 0 \leq& \frac{2v}{\bar{N}} - p_i - \left(\frac{\bar{N} - 2}{\bar{N}}x_k + \frac{1}{\bar{N}}\right) \\ x_k \leq& \frac{\bar{N}}{\bar{N} - 2}\left(\frac{2v}{\bar{N}} - p_i - \frac{1}{\bar{N}}\right). \end{aligned} \tag{46}$$

Hence $\tilde{x}_k = \frac{\bar{N}}{\bar{N}-2}\left(\frac{2v}{\bar{N}} - p_i - \frac{1}{\bar{N}}\right)$ and it is also possible to derive the price cut-off below which an agent is willing to buy, which is $\tilde{p}_i = \left(\frac{2v}{\bar{N}} - \frac{\bar{N}-2}{\bar{N}}x_k - \frac{1}{\bar{N}}\right)$. For a given equilibrium price p_i, all agents located between the centre and $\tilde{x}_k$ are willing to consume, while agents located between $\tilde{x}_k$ and the origin of any spoke don't even try to consume. All those who try to consume will observe a selling price that is below or equal to their cut-off price and therefore will purchase at the first and unique shop that they visit.

Since consumers randomly choose where to consume, each firm faces the same demand $D_i = \frac{1}{N}\frac{2}{\bar{N}}\bar{N}\left(\tilde{x}_k - \frac{1}{2}\right) = \frac{2}{N}\left(\tilde{x}_k - \frac{1}{2}\right)$. A restaurant's profit function is $\pi_i = p_i D_i - f = \left(\frac{2v}{\bar{N}} - \left(\frac{\bar{N}-2}{\bar{N}}\tilde{x}_k + \frac{1}{\bar{N}}\right)\right)\frac{2}{N}\left(\tilde{x}_k - \frac{1}{2}\right) - f$. Maximising profit, the first order condition implies that $\tilde{x}_k = \frac{1}{\bar{N}-2}\left(v + \frac{\bar{N}-4}{4}\right)$. The equilibrium price and the other results in the lemma directly follow. □

Proof of Lemma 2. Consumers $(x_m; l_j; l_k)$ can be of three types: type-0 consumers are those with both $j > n$ and $k > n$, i.e. no restaurant with positive valuation is available; type-I consumers are those with either $j < n$ or $k < n$, i.e. only one restaurant with positive valuation is available; type-II consumers are those with both $j < n$ and $k < n$, i.e. both restaurants with positive valuation are available. Clearly, type-0 consumers are not active on the market, and can be disregarded.

For any $j \neq k$, it is never rational for firm k to have $|p_k - p_j| > 1$, for then all consumers would always find it more convenient to purchase from firm j. Therefore, I focus on the case $|p_k - p_j| < 1$. To construct the demand faced by firm r, I consider type-I and type-II consumers separately. By construction, x_m is the distance of a consumer from the origin of any spoke m other than the own. With a little abuse of notation, define x_r as the distance of a consumer from the origin of spoke r. Then,

$$x_r = \begin{cases} 1 - x_m & \text{if } r = j \\ x_m & \text{if } r = k \end{cases} \tag{47}$$

Because type-I consumers positively value only one available product, firm r is a monopolist for the consumers interested in its product. Consumer $(x_m; l_j; l_k)$ is willing to buy from firm r if $v - p_r - x_r \geq 0$, which is equivalent to say $x_r \leq v - p_r$. Therefore, the demand that firm r faces is

$$D_r^I = \begin{cases} \frac{2}{\bar{N}} \frac{(\bar{N}-n)}{(\bar{N}-1)} (v - p_r) & \text{if } v - p_r \leq 1 \\ \frac{2}{\bar{N}} \frac{(\bar{N}-n)}{(\bar{N}-1)} & \text{if } v - p_r > 1, \end{cases} \tag{48}$$

where $\frac{2}{\bar{N}}$ represents the density of the distribution of consumers, while $\frac{(\bar{N}-n)}{(\bar{N}-1)}$ is the probability $Pr(j = r \wedge k > n \vee j > n \wedge k = r)$ (i.e. the probability that the agent is of type-I, with r as the unique valuable product). The type-I market is covered if and only if $v - p_r \geq 1$.

In the case of type-II consumers, firm r competes with each firm $s \neq r$ (with $s \leq n$) for both consumers $(x_m; l_r; l_s)$ and $(x_m; l_s; l_r)$. Such consumers prefer to purchase from firm r as long as $x_r \leq \frac{p_s - p_r + 1}{2}$. Hence, the demand faced by firm r is

$$D_r^{II} = \frac{2}{\bar{N}} \frac{1}{(\bar{N} - 1)} \sum_{s \neq r; s \leq n} \frac{p_s - p_r + 1}{2}. \tag{49}$$

The demand faced by firm r is obtained by summing (48) and (49), as long as the equilibrium price p is such that $v - p > \frac{1}{2}$, otherwise firms are never serving anyone that is not located on their own spoke. In such case, each firm is a monopolist on its spoke, it faces a demand $D_r = \frac{2}{\bar{N}} \tilde{x}_m$ with $\tilde{x}_m = v - p$. The unique profit maximising equilibrium under such circumstances is $p = \frac{v}{2}$.

Hence, the total demand is

$$D_r = \begin{cases} \frac{2}{\bar{N}}(v-p_r) & \text{if } v-p_r \leq \frac{1}{2} \\ \frac{2}{\bar{N}}\frac{1}{(\bar{N}-1)}\left(\sum\limits_{s\neq r; s\leq n} \frac{p_s - p_r + 1}{2} + \left(\bar{N}-n\right)(v-p_r)\right) & \text{if } \frac{t}{2} < v-p_r \leq 1 \\ \frac{2}{\bar{N}}\frac{1}{(\bar{N}-1)}\left(\sum\limits_{s\neq r; s\leq n} \frac{p_s - p_r + 1}{2} + \left(\bar{N}-n\right)\right) & \text{if } v-p_r > 1. \end{cases} \tag{50}$$

It directly follows, from the maximisation problem, that the optimal price schedule is

$$p^a = \begin{cases} \frac{v}{2} & \text{if } v \leq 1 \\ v - \frac{1}{2} & \text{if } 1 < v < \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \\ \frac{(n-1)+2\left(\bar{N}-n\right)v}{4\bar{N}-3n-1} & \text{if } \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \leq v < 2 \\ v-1 & \text{if } 2 \leq v \leq \frac{2\bar{N}-2}{n-1} \\ \frac{2\bar{N}-n-1}{n-1} & \text{if } \frac{2\bar{N}-2}{n-1} < v. \end{cases} \tag{51}$$

however, under the assumptions that $\bar{N} \geq 4$ and $v \geq \frac{\bar{N}}{4}$, we can disregard the first interval. □

Proof of Lemma 3. The probability of only one amongst j and k to be online is given by the equation

$$Pr(j) = Pr(k) = \frac{\binom{\bar{N}-2}{n-1}}{\binom{\bar{N}}{n}} = \frac{\left(\bar{N}-2\right)!}{(n-1)!\left(\bar{N}-n-1\right)!}\frac{n!\left(\bar{N}-n\right)!}{\bar{N}!} = \frac{n\left(\bar{N}-n\right)}{\bar{N}\left(\bar{N}-1\right)}. \tag{52}$$

The probability of both j and k to be online is given by the equation

$$Pr(j \wedge k) = \frac{\binom{\bar{N}-2}{n-2}}{\binom{\bar{N}}{n}} = \frac{n\,(n-1)}{\bar{N}\left(\bar{N}-1\right)}. \tag{53}$$

Finally, the probability of neither j nor k to be online is given by the equation

$$Pr(0) = \frac{\binom{\bar{N}-2}{n}}{\binom{\bar{N}}{n}} = \frac{\left(\bar{N}-n\right)\left(\bar{N}-n-1\right)}{\bar{N}\left(\bar{N}-1\right)}. \tag{54}$$

□

Proof of Lemma 4. By construction, an agent prefers to become a *surfer* than not to consume if they are located where $EU(x_k) \geq c$. In a symmetric equilibrium with all e-sellers charging p^s, this means that $(Pr(j) + Pr(j \wedge k))\,(v - p^s - (1-x_k)) + Pr(j)\,(v - p^s - x_k) \geq c$. It immediately follows that the left hand side must be positive and because $x_k \in \left[\frac{1}{2}, 1\right]$, within the left hand side the first term is larger than the second. A necessary condition then for the sum of the two terms to be positive is that at least the first term is positive. Hence, $(v - p^s - (1-x_k)) > 0$.

Replacing the probabilities by their value and solving $(Pr(j) + Pr(j \wedge k))\,(v - p^s - (1 - x_k^s)) + Pr(j)\,(v - p^s - x_k^s) = c$, it is immediate to identify the indifferent consumer $\tilde{x}_k^s = \frac{(\bar{N}-1)}{(n-1)} + \frac{\bar{N}(\bar{N}-1)}{n(n-1)}c - \frac{(2\bar{N}-n-1)}{(n-1)}(v - p^s)$. Furthermore, any agent $x_k^s \geq \tilde{x}_k^s$ strictly prefers to become a *surfer* than not to consume. Replacing the expression for $\tilde{x}_k^s$ in $(v - p^s - (1 - x_k)) > 0$, we obtain that $v - p^s < \frac{1}{2} + \frac{\bar{N}(\bar{N}-1)}{2n(\bar{N}-n)}c$. Replacing the expression for $\tilde{x}_k^s$ in $(v - p^s - x_k) > 0$, we obtain that $v - p^s > \frac{1}{2} + \frac{\bar{N}}{2n}c$. □

Proof of Lemma 5. *Surfers* may be of different types: type-0 corresponds to those with both $j > n$ and $k > n$, i.e. neither of the two restaurants with positive valuation is available, hence they don't consume and can be disregarded.

Type-I corresponds to those with only one restaurant with positive valuation available. Type-Ij *surfers* are those with $j < n$ and $k > n$, whereas type-Ik are those with $j > n$ and $k < n$. Finally, type-II *surfers* are those with both $j < n$ and $k < n$, i.e. both restaurants with positive valuation are available.

By construction, an agent becomes a surfer if and only if $x_k^s \geq \tilde{x}_k^s$. Conditional on being a *surfer*, consuming from firm j always yields a positive payoff, as ensured by the statement in lemma 4 that $(v - p^s - (1 - x_k^s)) > 0$. Therefore, all type-Ij *surfers* purchase from firm j.

Among consumers of type-Ik, conditional on being a *surfer* agents consume when $v - p^s \geq x_k^s$. This means that agents located at $x \in [\tilde{x}_k^s, v - p^s]$ are consuming their k product when their j product is not available. This implies that $v - p^s - \tilde{x}_k^s$ (when positive) represents the length of spoke inhabited by type-Ik *surfers* that are going to be active on the market.

In order to compute the demand that an e-seller will face, we first examine the demand coming from *surfers* of type-I. Of the two brands that agents value positively, one is always the brand located on the same spoke as they are. This means that all the agents on a firms' spoke must be either of type-Ij or type-II. More specifically, a share $\frac{Pr(j\wedge k)}{Pr(j)+Pr(j\wedge k)} = \frac{n-1}{\bar{N}-1}$ is of type-II, while $\frac{Pr(j)}{Pr(j)+Pr(j\wedge k)} = \frac{\bar{N}-n}{\bar{N}-1}$ are of type-Ij. Similarly, the share of agents of type-Ik is $\frac{Pr(k)}{Pr(k)+Pr(j\wedge k)} = \frac{\bar{N}-n}{\bar{N}-1}$.

This means that the demand from type-I consumers is

$$\frac{2}{\bar{N}}\frac{\bar{N}-n}{\bar{N}-1}\left((1 - \tilde{x}_k^s) + \begin{cases} 0, & \text{if } p^s \in [v - \tilde{x}_k^s, v + \tilde{x}_k^s - 1] \\ (v - p^s - \tilde{x}_k^s)\,, & \text{if } p^s \in [v - 1, v - \tilde{x}_k^s] \\ (1 - \tilde{x}_k^s)\,, & \text{otherwise.} \end{cases}\right) \tag{55}$$

where $\frac{2}{\bar{N}}$ is the density of the population. The first piece of the equation accounts only for *surfers* of type-Ij, for the price is too high for type-Ik agents to buy. The second piece corresponds to the case in which some of the type-Ik agents are buying too. Finally, the last piece corresponds to the case in which all agents of type-I are purchasing.

Notice that an agent of type-II prefers to purchase from firm j than to seller k if and only if $v - p_j - (1 - x_k) > v - p_k - x_k$, hence if they are located at any $x_k > \frac{p_j - p_k + 1}{2}$. Hence, the demand of type-II *surfers* that an e-seller covers is

$$\frac{2(n-1)}{\bar{N}\left(\bar{N}-1\right)}\left(\min\left\{1-\tilde{x}_k^s, \max\left\{0, 1-\frac{p_j^s - p_k^s + 1}{2}\right\}\right\} + \min\left\{1-\tilde{x}_k^s, \max\left\{0, 1-\tilde{x}_k^s - \frac{p_j^s - p_k^s + 1}{2}\right\}\right\}\right) \tag{56}$$

Notice that clearly it can never be optimal for a firm to set a price that is larger than their competitors' price by more than 1, that is, it will never occur that $|p_j - p_k| \geq 1$.

With this information, it is now possible to construct the demand that an e-seller faces, which is also defined by pieces:

$$D_j^s = \frac{2\left(\bar{N}-n\right)\left(1-\tilde{x}_k^s\right)}{\bar{N}\left(\bar{N}-1\right)} + \begin{cases} \frac{2(n-1)}{\bar{N}\left(\bar{N}-1\right)} \min\left\{1-\tilde{x}_k^s, \max\left\{0, \frac{1-p_j^s+p_k^s}{2}\right\}\right\}, & \text{if } v - p_j^s \leq \frac{1}{2} + \frac{\bar{N}}{2n}c \\ \frac{2\left(\bar{N}-n\right)}{\bar{N}\left(\bar{N}-1\right)}\left(v - p_j^s - \tilde{x}_k^s\right) + \frac{2(n-1)}{\bar{N}\left(\bar{N}-1\right)}\left(\min\left\{1-\tilde{x}_k^s, \max\left\{0, \frac{1-p_j^s+p_k^s}{2}\right\}\right\} + \right. & \\ \qquad \left. \min\left\{1-\tilde{x}_k^s, \max\left\{0, \frac{1-2\tilde{x}_k^s-p_j^s+p_k^s}{2}\right\}\right\}\right), & \text{if } v - p_j^s \in \left[\frac{1}{2} + \frac{\bar{N}}{2n}c, 1\right] \\ \frac{2\left(\bar{N}-n\right)\left(1-\tilde{x}_k^s\right)}{\bar{N}\left(\bar{N}-1\right)} + \frac{2(n-1)}{\bar{N}\left(\bar{N}-1\right)}\left(\min\left\{1-\tilde{x}_k^s, \max\left\{0, \frac{1-p_j^s+p_k^s}{2}\right\}\right\} + \right. & \\ \qquad \left. \min\left\{1-\tilde{x}_k^s, \max\left\{0, \frac{1-2\tilde{x}_k^s-p_j^s+p_k^s}{2}\right\}\right\}\right), & \text{if } v - p_j^s > 1. \end{cases} \tag{57}$$

Taking into account that $|p_j - p_k| < 1$, that we are interested in symmetric equilibria, and the restriction imposed by each piece of the equation on the value of the parameters, it is possible to simplify the previous equation and obtain

$$D_j^s = \begin{cases} \frac{2}{\bar{N}}\left(1-\tilde{x}_k^s\right), & \text{if } v - p_j^s \leq \frac{1}{2} + \frac{\bar{N}}{2n}c \\ \frac{2\left(\bar{N}-n\right)\left(1-\tilde{x}_k^s\right)}{\bar{N}\left(\bar{N}-1\right)} + \frac{2\left(\bar{N}-n\right)}{\bar{N}\left(\bar{N}-1\right)}\left(v - p_j^s - \tilde{x}_k^s\right) + & \\ \frac{2(n-1)}{\bar{N}\left(\bar{N}-1\right)} \max\left\{\min\left\{1-\tilde{x}_k^s, \frac{1-p_j^s+p_k^s}{2}\right\}, \frac{3-4\tilde{x}_k^s-p_j^s+p_k^s}{2}\right\}, & \text{if } v - p_j^s \in \left[\frac{1}{2} + \frac{\bar{N}}{2n}c, 1\right] \\ \frac{4\left(\bar{N}-n\right)\left(1-\tilde{x}_k^s\right)}{\bar{N}\left(\bar{N}-1\right)} + \frac{2(n-1)}{\bar{N}\left(\bar{N}-1\right)} \max\left\{\min\left\{1-\tilde{x}_k^s, \frac{1-p_j^s+p_k^s}{2}\right\}, \frac{3-4\tilde{x}_k^s-p_j^s+p_k^s}{2}\right\}, & \text{if } v - p_j^s > 1. \end{cases} \tag{58}$$

One can notice that $\max\left\{\min\left\{1-\tilde{x}_k^s, \frac{1-p_j^s+p_k^s}{2}\right\}, \frac{3-4\tilde{x}_k^s-p_j^s+p_k^s}{2}\right\} = \left(1-\tilde{x}_k^s\right)$ in any neighbourhood of $p_j^s = p_k^s$. Since I am interested in studying symmetric equilibria, I can therefore simplify the equation further (postponing the proof that the symmetric equilibrium exists) and obtain

$$D_j^s = \begin{cases} \frac{2}{\bar{N}}\left(1-\tilde{x}_k^s\right), & \text{if } v-p_j^s \leq \frac{1}{2}+\frac{\bar{N}}{2n}c \\ \frac{2\left(\bar{N}-1\right)\left(1-\tilde{x}_k^s\right)}{\bar{N}\left(\bar{N}-1\right)}+\frac{2\left(\bar{N}-n\right)}{\bar{N}\left(\bar{N}-1\right)}\left(v-p_j^s-\tilde{x}_k^s\right), & \text{if } v-p_j^s \in \left[\frac{1}{2}+\frac{\bar{N}}{2n}c, 1\right] \\ \frac{2\left(2\bar{N}-n-1\right)\left(1-\tilde{x}_k^s\right)}{\bar{N}\left(\bar{N}-1\right)}, & \text{if } v-p_j^s > 1. \end{cases} \tag{59}$$

The first piece of the equation represents the case in which each firm is a monopolist selling only to surfers that are located on their own spoke. The last piece of the equation represents the case in which the valuation-price ratio is so low that any surfer is *a priori* interested in purchasing either of the preferred brands. The intermediate piece of the equation represents the case in which any surfer is willing to purchase from their favourite brand j but not all of them are willing to purchase from brand k. □

Proof of Lemma 11. Firm j maximise profits on the online market, which are $\pi_j^s = D_j^s p_j^s$. The first order condition is $\frac{\partial D_j^s}{\partial p_j^s}p_j^s + D_j^s = 0$. Given that $\frac{\partial \tilde{x}_k^s}{\partial p_j^s} = \frac{\left(2\bar{N}-n-1\right)}{n-1}$, p_j^s must be such that

$$\begin{cases} \frac{2}{\bar{N}}\frac{\left(2\bar{N}-n-1\right)}{n-1}p_j^s = \frac{2}{\bar{N}}\left(1-\tilde{x}_k^s\right), & \text{if } v-p_j^s \leq \frac{1}{2}+\frac{\bar{N}}{2n}c \\ \frac{2}{\bar{N}}\frac{\left(2\bar{N}-n-1\right)^2}{\left(\bar{N}-1\right)(n-1)}p_j^s + \frac{2}{\bar{N}}\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)}p_j^s = \frac{2\left(1-\tilde{x}_k^s\right)}{\bar{N}}+\frac{2\left(\bar{N}-n\right)}{\bar{N}\left(\bar{N}-1\right)}\left(v-p_j^s-\tilde{x}_k^s\right), & \text{if } v-p_j^s \in \left[\frac{1}{2}+\frac{\bar{N}}{2n}c, 1\right] \\ \frac{2}{\bar{N}}\frac{\left(2\bar{N}-n-1\right)^2}{\left(\bar{N}-1\right)(n-1)}p_j^s = \frac{2\left(2\bar{N}-n-1\right)\left(1-\tilde{x}_k^s\right)}{\bar{N}\left(\bar{N}-1\right)}, & \text{if } v-p_j^s > 1. \end{cases} \tag{60}$$

and therefore

$$\begin{cases} \frac{\left(2\bar{N}-n-1\right)}{n-1}p_j^s = \left(1-\tilde{x}_k^s\right), & \text{if } v-p_j^s \leq \frac{1}{2}+\frac{\bar{N}}{2n}c \\ \frac{\left(2\bar{N}-n-1\right)^2}{\left(\bar{N}-1\right)(n-1)}p_j^s + 2\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)}p_j^s = \left(1-\tilde{x}_k^s\right)+\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)}\left(v-\tilde{x}_k^s\right), & \text{if } v-p_j^s \in \left[\frac{1}{2}+\frac{\bar{N}}{2n}c, 1\right] \\ \frac{\left(2\bar{N}-n-1\right)}{n-1}p_j^s = \left(1-\tilde{x}_k^s\right), & \text{if } v-p_j^s > 1. \end{cases} \tag{61}$$

$$\begin{cases} p_j^s = \frac{v}{2} - \frac{n\left(\bar{N}-n\right)+\bar{N}\left(\bar{N}-1\right)c}{2n\left(2\bar{N}-n-1\right)}, & \text{if } v-p_j^s \leq \frac{1}{2}+\frac{\bar{N}}{2n}c \\ \frac{\left(2\bar{N}-n-1\right)^2}{\left(\bar{N}-1\right)(n-1)}p_j^s + 2\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)}p_j^s = \left(1-\tilde{x}_k^s\right)+\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)}\left(v-\tilde{x}_k^s\right), & \text{if } v-p_j^s \in \left[\frac{1}{2}+\frac{\bar{N}}{2n}c, 1\right] \\ p_j^s = \frac{v}{2} - \frac{n\left(\bar{N}-n\right)+\bar{N}\left(\bar{N}-1\right)c}{2n\left(2\bar{N}-n-1\right)}, & \text{if } v > \frac{n\left(3\bar{N}-n-2\right)-\bar{N}\left(\bar{N}-1\right)c}{n\left(2\bar{N}-n-1\right)}. \end{cases} \tag{62}$$

□

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