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ABSTRACT: Online review aggregators (e.g., booking.com or ClubKviar) provide detailed information about experience goods, such as restaurants and hotels. This study fosters the understanding of how such aggregators modify competition, profits and welfare. Using a spokes model of horizontal competition, I show that review aggregators enhance total welfare mainly by making valuable information available to consumers. The effect on welfare goes through different channels: 1) realised transactions are more valuable for the match between producers and consumers is more accurate; 2) the costumer base enlarges, for more agents find a suitable product; 3) the equilibrium price weakly decreases for competition amongst firms is more intense. However, firms face a prisoner dilemma: firms best response to the status quo is to appear on the aggregator's web so as to enlarge their market share, however, this leads to lower profits than if they all agreed not to use the aggregator.

JEL Codes: D43, D61, D83, L11, L13, L15

Keywords: Horizontal competition, spokes model, welfare, review aggregators, online booking, ClubKviar, experience goods, mismatch costs

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1 Introduction

A review aggregator is a platform that regroups opinions and makes them available, allowing both objective and subjective information on a product to be easily accessible to potential consumers. Prior to the internet era, tourist and restaurant guides (e.g., *Lonely Planet* or the *Michelin* guide) were probably the closest approximation to a review aggregator, providing both objective information (e.g., location and contacts) and a subjective review. However, the available technology didn't allow for constant updates, and having only one review was also a limitation. *Online* review aggregators appeared in the second half of 2000s and enjoyed a rapid expansion ever since.[1] Review aggregators enhanced guides by allowing consumers to post their reviews, ensuring an up to date monitoring of the firm, more variety in reviews and less risk of bribery.[2] Furthermore, online aggregators can be empowered with instruments that bring search costs (almost) to zero: for example, they embed a search engine that allows users to refine their search, the availability service ensures that only available products are displayed, finally some aggregators offer personalised suggestions based on previous purchases.

Aggregators differ from each other in several dimensions.[3] Despite their heterogeneity, they all operate in markets with asymmetric information related to experience goods. The lack of information alters both consumers' expected utility and total welfare by inducing *mismatch costs*. By mismatch costs I refer to the welfare loss that occurs in three different cases: i) poor match of consumers with products (*i.e.*, alternative transactions would produce a larger surplus), ii) welfare decreasing transactions (*i.e.*, the *ex-post* consumer's valuation of the good is lower than the costs), and iii) failure to generate surplus enhancing transactions (*i.e.*, a consumer refrains from consumption, while at least one welfare enhancing transaction is feasible). Mismatch costs occur both with horizontally and vertically differentiated goods. The *market for lemons* framework (Akerlof, 1970) is a notable case of mismatch costs under vertically differentiated goods: quality goods are not traded even in presence of a demand for it, for consumers fear to buy low-quality goods. A common solution is to resort to insurances and warranties.

However, insurances are not effective with horizontally differentiated goods, as the perception of quality is subjective. Producers may release information on product characteristics, but they may fail to be credible. Furthermore, search costs may be sizeable if consumers

[1] *Booking* and *HotelClub* operate in the lodging sector, while *Tripadvisor* in the travels sector. *Clubkviar, LaFourchette, OpenTable, RatesToGo* and *Urbanspoon* are specialised in catering. *Foursquare*, *Quintessentially* and *Yelp* are active in several sectors.

[2] For example, an average of 70+ reviews per restaurant is currently available on *LaFourchette*.

[3] This includes membership policy, source of information and offered complementary services. For example, on *Tripadvisor* and *Yelp* anyone can leave a review. On *Clubkviar* reviews are left by own staff and certified consumers to reduce the risk of fraud in reviews. *Clubkviar* offers to book online with a 30% discount; a search engine allows to refine searches by location, day, price, atmosphere, etc.

want to compare several different products. Reputation and word-of-mouth may help solving the issue, but they tend to have limited effects, especially in markets in which most of the consumers tend not to be frequent visitors, such as holiday hotels, exclusive restaurants, or museums.

The distinguishing element of review aggregators is that they make information credible, for they are an independent entity with an own reputation. They effectively inform customers and help in the matching process. Reducing the mismatch costs, they affect both the quantity and quality of transactions, hence impacting social welfare from the demand side. In addition, they may play a role in fostering competition among firms, so that both the market equilibrium and welfare would also be altered from the supply side.

This work provides a theoretical framework aimed at understanding the impact of review aggregators on pricing, consumer behaviour and welfare. Without loss of generality, I focus on aggregators operating in the catering sector, and propose a stylised model inspired by *Clubkviar* and *LaFourchette*.[4] Both represent instructive examples of online services that restaurants can use to attract more consumers, and consumers can use to reduce the mismatch cost.

I focus on the horizontal component, and assume that restaurants differ in variety but not in quality. This is because aggregators specialise on a quality level, similarly to what happens with restaurant guides (think, for example, of the *Michelin* guide): the reputation of the aggregator becomes the guarantee of the vertical positioning.[5] Horizontal differentiation depends on the combination of several components, such as the cuisine (Asian, French, Italian) or the dining atmosphere (bistro, brasserie, traditional, trendy). Agents' information is a crucial element of the analysis, for meals are an experience good. Without aggregator, consumers have no information about restaurants and they base their decision about whether or not to consume on expectations about their surplus in case of consumption. If they decide to consume, they choose the restaurant randomly. On the opposite, the aggregator credibly reveals the relevant information about restaurants.[6] The interest of this study is to under-

[4] Interesting stylised facts about *LaFourchette* are available on the French web page of the firm. Stewart Masters, CEO of *ClubKviar*, shared with me – off the record – several insights about the functioning of *ClubKviar*. The model that I propose tries to be as general as possible, and therefore it should not be considered as a description of the aforementioned firms, but rather as a general tool to be used to understand the main driving forces in the aggregators' market. *LaFourchette* and *Clubkviar* both operate in the European market. The former belongs to *Tripadvisor* since 2014. The latter 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).

[5] *ClubKviar*, for example, specialises in high quality restaurants.

[6] An aggregator provides detailed information about location, type of cuisine, menu, price, atmosphere, and several other characteristics. An internal research engine allows customers to narrow down the search. Restaurants could inform consumers through their own web instead of resorting to the aggregator. However, they would lack credibility. Furthermore, a restaurant's web pages would not provide the important service of gathering together the information of several restaurants, which is crucial to abate the searching cost and

stand the market changes due to the entry of an aggregator. I first study the equilibrium without and with an aggregator. In the latter case, restaurants endogenously decide whether to be indexed on the aggregator or not. Then, I compare the two equilibria and compute the change in welfare that follows. I focus on the impact of entry of the first aggregator on a market, while the interesting analysis of the role of competition in the aggregators market is left for future studies.

To describe the aforementioned setting, I use the *spokes model* of horizontal differentiation, which is an extension of the Hotelling model, and also a special case of Hart (1985). Figure 1 illustrates it graphically.

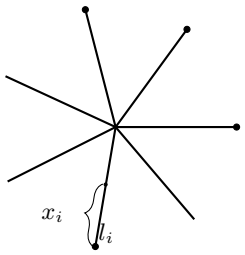

Figure 1: Spokes model with 7 spokes ($\bar{N} = 7$) and 4 firms ($N = 4$)

The general properties of the spokes model are studied and discussed in Chen and Riordan (2007). Whereas the Hotelling model has the form of a single line, the spokes model takes the form of an asterisk: it could be seen as the union of several Hotelling lines of equal length. The conjunction of all the spokes is denoted as the centre. Every spoke (denoted l_i) has an origin, that is the point on the segment opposite to the centre. On each and every spoke there can be at most one firm, located at the origin of the spoke. Consumers are distributed over the spokes. Transport costs are a function of the distance that a consumer travels to reach a product/firm.

As discussed in Chen and Riordan (2007), the spokes model is characterised by the fact that – contrary to the circular model à la Salop – entry and exit of firms don't imply an unrealistic relocation of firms. This is a particularly convenient and realistic feature when it comes to aggregators. Indeed, in the presence of the aggregator, a same firm is likely to face a different set of competitors *on-* and *off-line*, but the Salop model may fail to adapt to this case. Another feature that makes the spokes model more realistic and better at describing the catering market is that it doesn't require the market to be fully covered, hence entry of the aggregator may have an expansion effect.

The standard spokes model has a technical limitation when there is no firm located on

hence to attract consumers online.

some spokes and transport costs are low enough for firms to be willing to serve customers located on a spoke other than theirs. 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 inhibit the existence of a pure strategy equilibrium. Chen and Riordan (2007) discuss this issue, the possible ways to deal with it and the disadvantages of each. The weakest condition to avoid this issue is to assume that consumers attach a positive valuation to consumption only to a (randomly selected) finite number of products. Following Chen and Riordan (2007), I assume that each consumer positively values two products. An alternative solution to deal with the existence of an equilibrium problem would be to assume that agents have different valuation for each restaurant. Notice that this assumption is redundant in the setting of section 2.1, but it is necessary for the remaining ones.

I assume that agents' valuation is large enough to ensure that some transactions are *ex-ante* profitable even when agents are uninformed about the characteristics (location) of restaurants. When the aggregator is available, agents choose whether to use it or not. Using the aggregator allows them to learn the location of all the restaurants indexed therein. However, it is a fact that only a share of the population uses review aggregators. This may be due to some agents' lack of technological skills, the interface learning costs, or the fact that using aggregators may also be time consuming. One could assume that consumers are heterogeneous in their usage cost, and they face a trade-off between expected gains and costs from using the aggregator. This would result in a share of agents willing to use the aggregator in equilibrium, which depends on the assumptions over the distribution of costs amongst the population. For the sake of tractability, I consider the most extreme (and simplifying) distribution of costs and assume that a share of the population – denoted *surfers* – bears no cost of using the aggregator, while the remaining – denoted *walkers* – has a prohibitive cost. Consequently, *surfers* always make use of the aggregator, while *walkers* never do and choose the restaurant out of a list (yellow pages) or randomly walking.[7]

Restaurants trade off the benefits of being online (*i.e.*, the possibility to expand their customer base) and its costs (*i.e.*, the aggregator's fee), and they endogenously choose to be listed on the aggregator or not. I denote e-restaurants the former and c-restaurants the latter, where e stands for "electronic" while c stands for "conventional". C-restaurants are not listed on the aggregator's web, hence they can only serve *walkers*. E-restaurants are available both online and offline, hence they can serve both *surfers* and *walkers*. Restaurants can charge a different price in each market. All restaurants pay an entry fee (e.g., a license). Furthermore, they pay a fee to the aggregator to be listed online. I assume the fees to be

[7] Appendix A.1 discusses the robustness of the results towards this assumption.

fixed and to be paid once every period. This allows to distinguish between the short, medium and long run.[8]

The model provides a rationale for the existence of a separating equilibrium, in which only some firms and some consumers decide to use the aggregator (*i.e.*, *e*-restaurants and *surfers*). For this to occur in equilibrium, it is enough to have some heterogeneity in the consumers' cost of using the aggregator. This model can be extended to allow for a different product valuation for *walkers* and *surfers*.[9] In such a case, the aggregator may serve another important role, which is to allow the firm to distinguish between two types of consumers – *walkers* and *surfers* – with different willingness to pay. Hence, the aggregator becomes an instrument for the restaurant through which it is possible to price discriminate.[10] Price discrimination is not considered in the baseline model, in order to disentangle the welfare effects of the aggregator from the standard welfare effects of price discrimination. Subsection 1.1 briefly discusses the literature on the welfare impact of 3rd price discrimination, while Appendix A.2 discusses the extension of the baseline model in this direction.

The uncertainty in the absence of the aggregator reduces agents' *ex-ante* willingness to pay, which in turns decreases the rent that firms can extract from consumers and may also lead to a partially uncovered market. It is interesting to notice that, because of the incomplete information, the share of market that is uncovered (if any) consists of the consumers located closest to the firm. This means that in a situation in which restaurants propose very extreme and possibly unconventional products (*i.e.*, avant-garde cuisine), active consumers are among those with the least extravagant tastes, while those who like unorthodox products will refrain from consuming. The intuition is that the uninformed average consumer knows that all the restaurants offer a product that is neither very close nor too far from what (s)he likes. On the opposite, the eccentric consumer knows that a few restaurants offer her/his preferred product, but most of them offer something that is extremely far from it. As a consequence, the best strategy for the eccentric and uninformed consumer is to not consume, because the probability of randomly selecting a good match is too low. I show that the aggregator solves the information problem, but it strengthen competition. Hence, consumers surplus tend to increase, but firms are not necessarily able to profit from it. I conclude that aggregators have

[8] I begin with a long run equilibrium without aggregator. The aggregator enters the market and, in the short run, some firms react by entering the online market. In the medium run, the market adjust to the entry of the aggregator and the number of *e*-restaurants adjusts so that profits online and offline are equal. In the long run, the total number of competing firms adjust to restore the zero-profit condition.

[9] *Surfers* are characterised by a low cost of using the aggregator. Both if we interpret it as a low opportunity cost of time or as a tech-friendly profile, one may expect *surfers* to also have a lower willingness to pay for restaurants.

[10] If both groups have the same valuation for the product, there is no room for price discrimination. As long as valuation is either positively or negatively correlated with one's status, *e*-restaurants can use the aggregator as a device to recognise the types of consumers.

an impact on profits (positive in the short run, negative in the medium run), on the long run equilibrium number of firms (negative), and on the share of consumers served and their surplus (positive). Firms face a prisoner's dilemma for each, individually, has an incentive to be listed on the aggregator, but this results in a decrease in profits for all of them. I show that total welfare increases in the long run, and this should be interpreted as a combination of three different factors: the aggregator reduces the inefficiencies due to asymmetric information, it expands the market that is covered, and finally it increases competition among firms.

1.1 Related literature

Besides the aforementioned literature on the spokes model, this model is interconnected with several strands of literature. Firstly, online review aggregators represent an example of two-sided market. Although this model departs from the issues treated within this branch of literature, the general insights hold, especially if one is interested in extending the model to the case with more than one aggregator. For a review of the literature on two-sided markets, see Roson (2005); Rysman (2009); Filistrucchi et al. (2013, 2014).

Online aggregators can be considered as a further evolution within the internet economics and management. The economic literature has thoroughly analysed strengths and weaknesses of the different internet selling and advertising methods, and their impact on market competition and welfare. Alba et al. (1997) and Bakos (1997) are among the first to discuss electronic selling. Jin and Kato (2007) discusses possible advantages and disadvantages of online selling. Anderberg and Andersson (2003); Arabshahi (2010); Dholakia (2010); Byers et al. (2011); Jing and Xie (2011) and Chen and Zhang (Forthcoming), consider group buying and the *Groupon* experience. Edelman et al. (2011) examine 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) focus on referral-reward programs, Shaffer and Zhang (2002) on one-to-one promotion, and Xie and Shugan (2001) on advance selling. 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 online advertising. In my model, possible advertising effects are not taken into account.

Review aggregators could be seen as an electronically enhanced Yellow Pages service or more generally a search engine. Both aggregators and search engines can list firms and provide some basic and objective characteristics. In the practice, search engines tend to differ from review aggregators in a few respects, although it would be technologically feasible for a search engine to integrate the features of a review aggregator. First and most importantly, search engines do not allow users to leave reviews, which is the main channel of transmission

of 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, an aggregator charges the same price to all the listed firms, and treat them equally. When the aggregator ranks firms, it makes it based on the measures decided by the user (price, location, availability, other users' ranking, etc.). However, 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) study 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.

Review aggregators 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. The latter is the case for example of Davis et al. (2015) who use 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.[11] Much attention has been devoted to the impact of reviews on profits. Aggregators rank firms based on the consumers' rates. Anderson and McLaren (2012) and Luca (2011) estimate the increase in profits for restaurants rated on *Yelp* due to higher rank. The effect is larger for restaurants for which few sources of information are available outside *Yelp*. Their results are consistent with other studies on online 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 of offline word of mouth (Duflo and Saez, 2002; Sorensen, 2006; Moretti, 2011). The results on the impact of reviews on profit suggest that vertical differentiation within a single aggregator is unlikely to be long lasting. In equilibrium and given a firm's horizontal location, we should expect vertical convergence within the aggregator.[12] Both the theoretical (Vial and Zurita, 2013) and empirical (Cabral and Hortaçsu, 2010) literature indeed suggest that - in the long run - poorly ranked firms either disappear or converge to the competitors' quality.

Clearly, the effectiveness of online review aggregators depends on their credibility. Credibility is undermined by the risk of fake reviews.[13] Some aggregators (e.g., *ClubKviar*) in-

[11] 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.

[12] Anecdotal evidence suggests that aggregators specialise on different price ranges.

[13] *Tripadvisor* was fined as much as 500k euros by the Italian antitrust authority in 2014, for it failed to adopt controls to prevent false reviews. The British authority had previously forced *Tripadvisor* to stop advertising

creased the cost of posting fake reviews by only allowing certified consumers to post them. Degan (2006); Martinelli (2006); Luca and Zervasy (2013); Mayzlin et al. (2013) study the phenomenon of manipulated reviews. Dai et al. (2012) propose the best econometric methodology to rank options based on reviews and minimise the impact of possibly manipulated review.

The aggregator allows restaurants to tell *surfers* and *walkers* apart. As previously discussed, when status is correlated with valuation, restaurants can use this information to price discriminate. The idea of selective discounting first appeared in Varian (1980) and Narasimhan (1984, 1988). In the baseline model, I deliberately avoid any price discrimination effect, to be able to focus on the impact of the aggregator on welfare through the reduction in mismatch costs. However, in appendix A.2 I investigate the role of selective pricing in this framework. Price discrimination may be welfare-improving as it allows to serve weaker markets which would otherwise be cut out (Schofield, 1981; Varian, 1985; Stigler, 1987). When 3rd price discrimination doesn't affect the equilibrium quantity exchanged, nor the identity of the consumers, then it decreases welfare when the demand function is linear, while it may increase it otherwise (Aguirre et al., 2010; Aguirre, 2011; Chen and Schwartz, Forthcoming).

In the model, gathering information is prohibitively costly without the aggregator, and there is no search costs when using the aggregator. This seems reasonable when available information provided by the firm itself is not credible and hence agents do not engage in searching activity. This setting could be relaxed, by assuming that agents can invest in searching when the aggregator is not available, in which case it would seem reasonable to assume that search costs without the aggregator are larger. The aggregator can therefore be easily interpreted as a device to reduce search costs in the limit case of costs being either infinite or zero. The literature on search costs has used different models depending on whether goods are homogeneous or not. For the former case, see Janssen et al. (2011) and the literature therein. The literature with differentiated products was pioneered by Wolinsky (1986); Anderson and Renault (1999). Moraga-González and Petrikaitė (2013) 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. Should the baseline model be generalised to the case in which agents incur search costs when the aggregator is not available, the welfare enhancing effect of the aggregator could be seen as the sum of the reduction in search costs and in transport costs. Assuming that searching is not viable implies an over-estimated reduction of transport costs and an under-estimated reduction of search costs.

The remainder of the paper is organised as follows: section 2 introduces the baseline

that their reviews are accurate.

model: subsections 2.1 and 2.2 consider the case when the aggregator is not available and when the aggregator is available, respectively. Section 3 studies the market equilibrium, while section 4 studies the welfare consequences of aggregators. Section 5 concludes. Appendix A includes some extensions of the baseline model. All the proofs are relegated to appendix B.

2 The model

Consider a spokes city, as described in figure 1, with $i = 1, .., \bar{N}$ spokes populated by a uniformly distributed population of mass one and $\bar{N} \geq 3$.[14] Each spoke – denoted l_i – has a length $\frac{1}{2}$; the conjunction of all spokes is named centre, while the termination of a spoke opposite to the centre is named origin. There are $j = 1, .., N$ active restaurants, with $N \in \left[2, \bar{N}\right]$, all located at the origin of different spokes. Numbering spokes based on the presence of a restaurant, it is possible to say that there is a restaurant at any spoke $l_i \leq l_N$, while there is no restaurant located on spokes $l_i \in (l_N, l_{\bar{N}}]$. I use j to identify the restaurant located at the origin of spoke l_j,[15] and by extension for the meal variety that it sells. Each restaurant must pay a yearly fixed fee f to be active. For the sake of simplicity, variable production costs are normalised to 0. Restaurant j sells at a price p_j.

Following the literature on spokes, each consumer has two preferred spokes – the one where (s)he is located and another – randomly assigned – one. 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). It should be noticed that this assumption is redundant and has no consequences in section 2.1, however, in guarantees the existence of the equilibrium in section 2.2 and after. The assumption means that consumers assign a positive value v only to meals from restaurants located on their two preferred spokes. Instead, their valuation for any other meal is 0. In other words, a consumer located on spoke l_j has a valuation $v \neq 0$ for a meal from either restaurant j or k, where $k \neq j$ is random.

For an agent located on spoke l_j, define the distance between the own location and the origin of the spoke by $x_j \in [0, 1/2]$, then $x_m = (1 - x_j) \in [1/2, 1]$ is the distance from the origin of any other spoke $l_i \neq l_j$. It is now possible to define by $(x_m; l_j; l_k)$ the consumer located on spoke l_j at location x_m and with valuation $v > 0$ for meals served at l_j and l_k. Consumers incur in a linear transport cost t. Hence the transport cost for consumer $(x_m; l_j; l_k)$ when buying from restaurant r is

$$T_r(x_m; l_j; l_k) = \begin{cases} (1 - x_m)t & \text{if } r = j \\ x_m t & \text{if } r \neq j, \end{cases} \tag{1}$$

[14] Notice that when $\bar{N} = 2$ the spokes model reduces to the standard Hotelling model.
[15] Remember that the origin of a spoke is located opposite to the centre of the asterisk.

where $(1 - x_m)$ and x_m are the distances travelled in each case.

2.1 Without aggregator

We use the afore described setting to study the equilibrium when the aggregator is not available. In such a case, consumers know their own valuation v, their type $(x_m; l_j; l_k)$, and they can consume a meal in any restaurant $j \in \{1, .., N\}$. However, meals are an experience good and therefore they cannot distinguish them (*i.e.*, they ignore restaurants' locations) until after consumption. This means that agents take their consumption decision ignoring their *ex-post* transport cost. Therefore, they base their decision on the expected utility of consumption.

Lemma 1. *The expected transport cost for an agent consuming a meal in a randomly selected restaurant is:*

$$ET = t\left(\frac{\bar{N}-2}{\bar{N}}x_m + \frac{1}{\bar{N}}\right). \tag{2}$$

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

$$x_m \leq \frac{\bar{N}}{\bar{N}-2}\left(\frac{2v}{\bar{N}t} - \frac{p}{t} - \frac{1}{\bar{N}}\right). \tag{3}$$

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

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

$$p = \frac{v}{\bar{N}} - \frac{t}{4}. \tag{5}$$

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

It is interesting to notice (equation 2) that expected transport 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 restaurant. Instead, expected transport costs are not affected by N. This occurs because the two opposed forces cancel out: on the one side an increase in N reduces the probability of being located in a spoke where there is no restaurant, but on the other, conditional on being at a spoke with a restaurant, it equally increases the probability of consuming a meal in a restaurant 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 restaurant.

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. 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 transport cost is increasing in x_m: agents have a large $(\frac{\bar{N}-1}{\bar{N}})$ probability of consuming a product located on a spoke other that theirs, hence expected transport costs are lower for agents located closer to the centre.

2.2 With aggregator

This section considers the opposite extreme case, in which there is no offline market. I compute the equilibrium for the case in which an aggregator – e.g., *ClubKviar* – is available. The aggregator allows its users to discover the characteristics (*i.e.*, the location) of a restaurant before consumption. Assume that $n \leq N$ restaurants are indexed on the aggregator. Let call them e-restaurants, as opposed to the $(N-n)$ conventional c-restaurants, which are not indexed on the aggregator. A c-restaurant serves only consumers that book offline (*walkers*), while e-restaurants accept bookings both online and offline (*i.e.*, they can serve both *walkers* and *surfers*). The l_i spokes can be numbered as follows: $i \in [1, .., n]$ corresponds to spokes with an e-restaurant, $i \in (n, N]$ corresponds to spokes with a c-restaurant, while $i \in \left(N, \bar{N}\right]$ corresponds to spokes with no restaurant.

In order to focus on online selling, I assume that all buyers are *surfers* and they always purchase from an e-restaurant. Therefore, in the eyes of the consumers (and for the equilibrium) there is no difference between spokes with a c-restaurant and those empty. This is equivalent to assuming that $n = N$, that is, all restaurants are online.

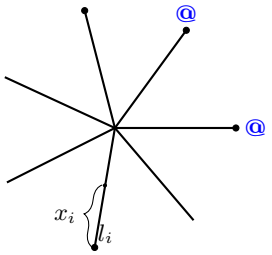

Figure 2: Spokes model with $\bar{N} = 7$, $N = 4$, $n = 2$

Figure 2 depicts a case with two e-restaurants and one c-restaurant. 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.

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,

$$x_r = \begin{cases} 1 - x_m & \text{if } r = j \\ x_m & \text{if } r = k \end{cases} \tag{6}$$

Lemma 2 defines the unique, symmetric, pure strategy equilibrium in the market.

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

$$D_r = \begin{cases} \frac{2}{\bar{N}} \frac{v - p_r}{t} & \text{if } v - p_r \leq \frac{t}{2} \\ \frac{2}{\bar{N}} \frac{1}{\left(\bar{N}-1\right)} \frac{1}{t} \left(\sum_{s \neq r; s \leq n} \frac{p_s - p_r + t}{2} + \left(\bar{N} - n\right)(v - p_r) \right) & \text{if } \frac{t}{2} < v - p_r \leq t \\ \frac{2}{\bar{N}} \frac{1}{\left(\bar{N}-1\right)} \frac{1}{t} \left(\sum_{s \neq r; s \leq n} \frac{p_s - p_r + t}{2} + \left(\bar{N} - n\right) t \right) & \text{if } v - p_r > t. \end{cases} \tag{7}$$

The unique symmetric, Nash equilibrium in pure strategies implies that

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

3 Market equilibrium

In this section – using the results obtained in subsections 2.1 and 2.2 – I study the change in equilibrium when an aggregator enters the market. Suppose that a share α of the population never uses the aggregator (*walkers*), while the remaining share $(1 - \alpha)$ uses it (*surfers*).[16]

Surfers learn the location of e-restaurants by means of the aggregator. Once a *surfer* knows the location of a restaurant, it would never be rational for her/him to book online should the online price (p^e) be larger than the offline one (p^c). Indeed *surfers* can always use the information acquired through the aggregator and book that same restaurant in the conventional way. Therefore, a restaurant will never charge *surfers* more than *walkers*.

[16] 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.

Lemma 3. *When the aggregator is available, it is still optimal for* c*-restaurants to behave the same as without it and charge* walkers *a price*

$$p^c = \frac{(4v - \bar{N}t)}{4\bar{N}}. \tag{9}$$

However, the size of the population that they serve decreases from 1 *to* α*. Therefore, their profit is*

$$\pi^c = \alpha \frac{(4v - \bar{N}t)^2}{8\left(\bar{N}-2\right)N\bar{N}t}. \tag{10}$$

E*-restaurants serve* walkers *at the same price as* c*-restaurants, while the online price is*

$$p^e = \begin{cases} \frac{4v-\bar{N}t}{4\bar{N}} & \text{if } \frac{v}{t} < \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)} \\ \frac{2\bar{N}-n-1}{n-1}t & \text{if } \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)} < \frac{v}{t}. \end{cases} \tag{11}$$

Profits come from selling both to surfers *and to their share of* walkers*. The gross profit of online firms is* $\pi^e = \pi^c + (1-\alpha)p^e D_r$*, where:*

$$p^e D_r = \begin{cases} \frac{4v-\bar{N}t}{8\bar{N}^3 t}\left(4\bar{N}v - 4v + \bar{N}t\right) & \text{if } \frac{v}{t} < \frac{1}{4}\frac{\bar{N}}{\bar{N}-1} \text{ (Region A)} \\ \left(\frac{\bar{N}+n-2}{4\left(\bar{N}-1\right)} + \frac{\left(\bar{N}-n\right)v}{\bar{N}t}\right)\frac{\left(4v-\bar{N}t\right)}{2\bar{N}^2} & \text{if } \frac{v}{t} \in \frac{1}{4}\frac{\bar{N}}{\bar{N}-1}[1,3] \text{ (Region B)} \\ \frac{\left(4v-\bar{N}t\right)\left(2\bar{N}-n-1\right)}{4\bar{N}^2\left(\bar{N}-1\right)} & \text{if } \frac{v}{t} \in \frac{\bar{N}}{4}\left[\frac{3}{\bar{N}-1}, \frac{\left(8\bar{N}-3n-5\right)}{(n-1)}\right] \text{ (Region C)} \\ \frac{\left(2\bar{N}-n-1\right)^2 t}{\bar{N}\left(\bar{N}-1\right)(n-1)} & \text{if } \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)} < \frac{v}{t} \text{ (Region D)}. \end{cases} \tag{12}$$

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

Lemma 3 provides interesting insights on the role of competition in this model. On the online market, competition becomes fiercer along consumers' valuation. When $\frac{v}{t} < 1$, firms are monopolist in their own market. The larger v, the more intensely firms compete and therefore the lower are prices. If they could, e-restaurants would charge larger prices to *surfers* than to *walkers* any time that $\frac{v}{t} < \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)}$. This implies that – when the aggregator operates –the impact of increased competition is not always enough to imply a decrease in prices, because competition increases together with agents' valuation. However, *surfers* can always decide to buy offline from a restaurant discovered online and hence e-restaurants are constrained to charge $p^e \leq p^c$ to *surfers*. Therefore, in regions A, B and C, e-restaurants charge everyone the same, and only in region D competition plays a role by pushing online prices down.

The decision to be online is endogenous: restaurants compare their profit offline π^c with the profit online, net of the aggregator fee, $\pi^e - f^e$.

3.1 Number of firms

The number of restaurants 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-restaurants (respectively, π^e and π^c). The number n of e-restaurants 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 $N = N_1$, which 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 restaurants 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 (10), it is possible to obtain the short run equilibrium profit for c-restaurants:

$$\pi^c = \alpha f. \tag{13}$$

E-restaurants serve both *surfers* and *walkers*. From equation (12), it is possible to notice that the number N of c-restaurants does not affect profits obtained from serving *surfers*.

In the medium run, the number of e-restaurants adjusts, hence n_0 is such that $\pi^e - f^e = \pi^c$. Noticing that $\pi^e = (\pi^c + (1-\alpha)p^e D_r)$, it is immediate to conclude that n_0 must be such that $(1-\alpha)p^e D_r = f^e$.

$$n_0 = \begin{cases} \{0, \bar{N}\} & \text{in Region A} \\ \frac{\bar{N}(2t\psi+(\bar{N}-2)t+4(\bar{N}-1)v)}{4(\bar{N}-1)v-\bar{N}t} & \text{in Region B} \\ \left(2\bar{N}-1\right)+\psi & \text{in Region C} \\ \{n_1^D, n_2^D\} & \text{in Region D,} \end{cases} \tag{14}$$

where $\psi = -\frac{4\bar{N}^2(\bar{N}-1)}{(4v-\bar{N}t)(1-\alpha)} f^e$.

Clearly, in Region A π^e does not depend on n and the solution is at a corner: $n = \{0, \bar{N}\}$. In Regions B and C the solution is unique. In Region D, the number of online firms can take two values, which are the two real roots of a second degree polynomial.[17]

Proposition 1. *In the long run, entry of the aggregator decreases the number of active firms,*

[17] $-n^2 + \left(2\left(2\bar{N}-1\right) + \frac{\bar{N}(\bar{N}-1)}{(1-\alpha)t} f^e\right) n - \left(\left(2\bar{N}-1\right)^2 + \frac{\bar{N}(\bar{N}-1)}{(1-\alpha)t} f^e\right) = 0.$

hence a reduction in variety is observed. The total number of active firms is

$$N_1 = \alpha \frac{(4v - \bar{N}t)^2}{8\left(\bar{N} - 2\right) f\bar{N}t} = \alpha N_0. \tag{15}$$

Proposition 1 is discussed in section 4, together with proposition 2.

4 Welfare analysis

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

Proposition 2. *In the short run, entry of the aggregator enhances online firms' profits. However, the presence of the aggregator makes competition fiercer. In the medium run, firms' entry in the online market reduces everyone's profits and firms are locked in a Bertrand supertrap. Indeed, medium run profits are lower than before the aggregator's entry for all firms.*

Proposition 2 shows that e-restaurants benefit from the presence of the aggregator in the short run, but their medium run profit is lower than if the aggregator didn't enter the market. In other words, restaurants 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-restaurants. However, being listed online is detrimental to medium run profits, for competition increases. *Ex-post*, all firms are hurt by the presence of the aggregator.

The decrease in profits has a direct consequence on variety. Proposition 1, through equation (15), 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 firm 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 offline 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 online market only, the total number of active firms is irrelevant for the equilibrium, and what matters is the number n of online firms. Hence, any reduction in the number of firms is irrelevant at any internal solution with

$N \geq n$.[18] This implies that, from a welfare perspective, the optimal balance between sunk and transport costs implies $N = n$.

Proposition 3. *Entry of the aggregator strictly enhances consumers' surplus in the medium and long run. In the long run, the entry of the aggregator is always welfare enhancing.*

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 offline 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.[19] Such increase in the value of transactions may have an expansionary effect: if $\frac{v}{t} < \frac{3\bar{N}-4}{4}$ (regions A, B and part of C), 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, B and C 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 D. A further, positive, effect may arise because online prices are lower than offline in region D. Firm, due to increased competition, extracts 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.

5 Final remarks

I use the spokes model of horizontal competition to analyse the impact of the entry of an online review aggregator, such as *ClubKviar* or *Opentable*, both on the market equilibrium

[18] 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 $N = n \in (N_1, n_0)$.

[19] *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.

and on welfare. I show that aggregators are welfare enhancing.

The increase in welfare comes through three channels: first, aggregators expand the market when it is not initially covered, by allowing some consumers to be reached. This is possible because consumers can learn the location of the restaurant through the aggregator and this way every efficient transaction takes place. Second, the lack of information absent the aggregator is also responsible of *mismatch costs* in the form of inefficient transactions taking place (a consumer may attend a restaurant 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.

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

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

Appendix A Discussions and Extensions

A.1 Endogenous use of the aggregator

The model requires that an exogenous fraction α of consumers never uses the aggregator, while the remaining always does. The implicit assumption behind is that the cost of using the aggregator is prohibitive for *walkers* and null for *surfers*. Relaxing this assumption may have consequences on the results of the model.

Notice that, if *surfers* bare a cost of using the aggregator, this reduces their surplus and hence welfare decreases. However, by revealed preference, any consumer choosing to use the aggregator will always find its use welfare enhancing. Therefore, the change on welfare would only be quantitative but not qualitative.

What may have a larger impact on the results is the fact of endogenising the decision to become a *surfer*. Suppose that consumers bare a cost c of using the aggregator, and that c is heterogeneously and randomly distributed following a continuous c.d.f. Φ. Given the own location and the equilibrium online price, an agent is indifferent between being a *surfer* or a *walker* when the expected surplus online is equal to the usage cost (remember that the expected surplus of *walkers* is null). *Surfers* are then characterised by the equation $\frac{n}{\bar{N}}(v - p^e - (1 - x_m)t) + \frac{n(\bar{N}-n)}{\bar{N}(\bar{N}-1)}(v - p^e - x_m t) \geq c$. The left side of the equation is always positive, therefore, depending on the distribution of c, it is possible to obtain the equilibrium share of *surfers*, which depends on Φ.

This approach allows to identify a mechanism that in my model is ignored. As in any two-sided market, agents' decision to use the aggregator depends on prices and on the number of e-restaurants. Meanwhile, the number of restaurants depends on the number of consumers. Intuitively, α should be increasing in the number of e-restaurants, and decreasing in prices. The number of restaurants should increase with the number of consumers and decrease with the price. If an equilibrium exists, it is reasonable to expect that it will be qualitatively similar to the one in the baseline model. However, the existence of an equilibrium is not ensured, because combining the heterogeneity in transport costs with the one to access the aggregator may produce a mass of indifferent consumers as well as some discontinuities and non-linearities in the demand function. The main drawback, besides the reduced mathematical tractability, is that both the existence conditions and the results depend dramatically on the shape of Φ.

A.2 Price discrimination

Available upon request.

Appendix B Proofs

Proof of Lemma 1. The expected transport cost for an agent consuming a meal in a randomly selected restaurant is:

$$\begin{aligned} ET &= t\left(Pr(j>N)x_m + Pr(j\leq N)\left(Pr(r=j)(1-x_m) + Pr(r\neq j)x_m\right)\right) \\ &= t\left(\frac{\bar{N}-N}{\bar{N}}x_m + \frac{N}{\bar{N}}\left(\frac{1}{N}(1-x_m) + \frac{N-1}{N}x_m\right)\right) \\ &= t\left(\frac{\bar{N}-2}{\bar{N}}x_m + \frac{1}{\bar{N}}\right). \end{aligned} \tag{16}$$

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

$$\begin{aligned} 0 \leq& \frac{2v}{\bar{N}} - p - ET \\ 0 \leq& \frac{2v}{\bar{N}} - p - t\left(\frac{\bar{N}-2}{\bar{N}}x_m + \frac{1}{\bar{N}}\right) \\ x_m \leq& \frac{\bar{N}}{\bar{N}-2}\left(\frac{2v}{\bar{N}t} - \frac{p}{t} - \frac{1}{\bar{N}}\right). \end{aligned} \tag{17}$$

From equation (3) follows that $p = \frac{2v}{\bar{N}} - t\left(\frac{\bar{N}-2}{\bar{N}}\tilde{x} + \frac{1}{\bar{N}}\right)$. Notice that each firm faces the same demand $D = \frac{1}{N}\frac{2}{\bar{N}}\bar{N}\left(\tilde{x} - \frac{1}{2}\right) = \frac{2}{N}\left(\tilde{x} - \frac{1}{2}\right)$. The equilibrium price and the other results in the lemma follow directly from the firms profit maximisation problem. □

Proof of Lemma 2. For any $j \neq k$, it is never rational for firm k to have $|p_k - p_j| > t$, for then all consumers would always find it more convenient to purchase from firm j. Therefore, I focus on the case $|p_k - p_j| < t$. To construct the demand faced by firm r, I consider type-I and type-II consumers separately.

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 $v - p_r - x_r t \geq 0$, which is equivalent to say $x_r \leq \frac{v-p_r}{t}$. Therefore, the demand that firm r faces is

$$D_r^I = \begin{cases} \frac{2}{\bar{N}}\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)}\frac{v-p_r}{t} & \text{if } v - p_r \leq t \\ \frac{2}{\bar{N}}\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)} & \text{if } v - p_r > t, \end{cases} \tag{18}$$

where $\frac{2}{\bar{N}}$ represents the density of the distribution of consumers, while $\frac{\left(\bar{N}-n\right)}{\left(\bar{N}-1\right)}$ 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 $v - p_r \geq t$.

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 $x_r \leq \frac{p_s - p_r + t}{2t}$. Hence, the demand faced by firm r is

$$D_r^{II} = \frac{2}{\bar{N}} \frac{1}{\left(\bar{N}-1\right)} \sum_{s \neq r; s \leq n} \frac{p_s - p_r + t}{2t}. \tag{19}$$

The demand faced by firm r is obtained by summing (18) and (19), as long as the equilibrium price p is such that $v - p > \frac{t}{2}$, 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 $D_r = \frac{2}{\bar{N}}\tilde{x}$ with $\tilde{x} = \frac{v-p}{t}$. The unique profit maximising equilibrium under such circumstances is $p = \frac{v}{2}$.

Hence, the total demand is

$$D_r = \begin{cases} \frac{2}{\bar{N}} \frac{v - p_r}{t} & \text{if } v - p_r \leq \frac{t}{2} \\ \frac{2}{\bar{N}} \frac{1}{\left(\bar{N}-1\right)} \frac{1}{t} \left(\sum_{s \neq r; s \leq n} \frac{p_s - p_r + t}{2} + \left(\bar{N} - n\right)(v - p_r) \right) & \text{if } \frac{t}{2} < v - p_r \leq t \\ \frac{2}{\bar{N}} \frac{1}{\left(\bar{N}-1\right)} \frac{1}{t} \left(\sum_{s \neq r; s \leq n} \frac{p_s - p_r + t}{2} + \left(\bar{N} - n\right) t \right) & \text{if } v - p_r > t. \end{cases} \tag{20}$$

□

Proof of Lemma 3. As previously discussed, prices online can be at most as large as offline price. To obtain the price online, we must then compare prices in equation (8) with the offline price.

- ◇ $\frac{v}{t} \leq 1$: Solving $\frac{v}{2} > \frac{4v - \bar{N}t}{4\bar{N}}$, it is immediate to obtain condition $v\left(\frac{\bar{N}-2}{2\bar{N}}\right) > -\frac{t}{4}$, which is always verified.

- ◇ $1 < \frac{v}{t} < \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)}$**:** Solving $v - \frac{t}{2} > \frac{4v - \bar{N}t}{4\bar{N}}$, the condition obtained is $v > \frac{\bar{N}}{\bar{N}-1}\frac{1}{4}t$, which is always verified for $1 < \frac{v}{t}$ and $\bar{N} > 2$.

- ◇ $\frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} \leq \frac{v}{t} < 2$**:** Solving $\frac{(n-1)t + 2\left(\bar{N}-n\right)v}{4\bar{N}-3n-1} < \frac{4v - \bar{N}t}{4\bar{N}}$, the condition obtained is

$$\left(4\bar{N} + n - 5\right)\frac{\bar{N}}{4} < \left(4\bar{N} - 3n - 1 - 2\bar{N}^2 + 2n\bar{N}\right)\frac{v}{t}.$$

  This must be solved separately, depending on the sign of the right hand side.
  If $\left(4\bar{N} - 3n - 1 - 2\bar{N}^2 + 2n\bar{N}\right) < 0$, then $\frac{(n-1)t + 2\left(\bar{N}-n\right)v}{4\bar{N}-3n-1} < \frac{4v - \bar{N}t}{4\bar{N}}$ if and only if $\frac{v}{t} < \frac{\left(4\bar{N}+n-5\right)}{\left(4\bar{N}-3n-1-2\bar{N}^2+2n\bar{N}\right)}\frac{\bar{N}}{4}$, but the RHS is negative, hence the condition is never verified for $\frac{v}{t} > \frac{4\bar{N}-n-3}{2(2\bar{N}-n-1)} > 0$.

Moving to the case of $\left(4\bar{N}-3n-1-2\bar{N}^2+2n\bar{N}\right) > 0$, the condition boils down to $\frac{v}{t} > \frac{\left(4\bar{N}+n-5\right)}{\left(4\bar{N}-3n-1-2\bar{N}^2+2n\bar{N}\right)}\frac{\bar{N}}{4}$. For this condition to be verified withing the interval of existance, one needs $\frac{\left(4\bar{N}+n-5\right)}{\left(4\bar{N}-3n-1-2\bar{N}^2+2n\bar{N}\right)}\frac{\bar{N}}{4} < 2$, which is equivalent to say $\left(5\bar{N}-8\right)\left(3n-4\bar{N}+1\right) > 0$, and hence $n > \frac{4\bar{N}-1}{3}$. However, $\frac{4\bar{N}-1}{3} > \bar{N}$, and it cannot be that $n > \bar{N}$. Hence, the interval is empty and always $\frac{(n-1)t+2\left(\bar{N}-n\right)v}{4\bar{N}-3n-1} > \frac{4v-\bar{N}t}{4\bar{N}}$.

- $\diamond$ $2 \leq \frac{v}{t} \leq \frac{2\bar{N}-2}{n-1}$**:** Solving $v - t > \frac{4v-\bar{N}t}{4\bar{N}}$, the condition obtained is $v > \frac{3}{4}\frac{\bar{N}}{\bar{N}-1}t$, which is always verified for $2 \leq \frac{v}{t} \leq \frac{2\bar{N}-2}{n-1}$ and $\bar{N} > 2$.

- $\diamond$ $\frac{2\bar{N}-2}{n-1} < \frac{v}{t}$**:** Solving $\frac{2\bar{N}-n-1}{n-1}t < \frac{4v-\bar{N}t}{4\bar{N}}$, the condition obtained is $\frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)} < \frac{v}{t}$. Noticing that $\frac{2\bar{N}-2}{n-1} < \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)}$ for any $\bar{N} \geq 3$, the interval $\left[\frac{2\bar{N}-2}{n-1}, \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)}\right]$ is non-empty, and we have that $\frac{2\bar{N}-n-1}{n-1}t > \frac{4v-\bar{N}t}{4\bar{N}}$ for $\frac{v}{t} \in \left[\frac{2\bar{N}-2}{n-1}, \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)}\right]$, while $\frac{2\bar{N}-n-1}{n-1}t < \frac{4v-\bar{N}t}{4\bar{N}}$ for $\frac{v}{t} > \frac{\bar{N}\left(8\bar{N}-3n-5\right)}{4(n-1)}$.

□

Proof of proposition 1. In the long run, the number of firms active on the market adjusts, and $\pi^e - f^e = \pi^c = f$. The result follows immediately. □

Proof of proposition 2. By construction the medium run profit is such that $\pi^e - f^e = \pi^c$. Replacing π^e with its equation, we obtain that $\pi^c + (1-\alpha)p^eD_r - f^e = \pi^c$, that means that $(1-\alpha)p^eD_r = f^e$. However, from equation (13) we have that $\pi^c = \alpha f$, hence we obtain that in the medium run $\pi^e - f^e = \pi^c = \alpha f$.

This is clearly lower than the firms profits before the entry of the aggregator, which was $\pi = f$. Hence, all firms' medium run profits are lower than their profit in the no-aggregator equilibrium. □

Proof of proposition 3. To prove that consumers surplus increases, we should first notice that absent the aggregator, consumers surplus is zero. Consumers are all acting under a veil of ignorance and buy as long as the expected utility is zero. In equilibrium, the *ex-post* utility of an agent may be either positive or negative, although the average remains zero by construction. After the entry of the aggregator, the surplus of *walkers* remains zero for the same reason.

Furthermore, notice that the zero-profit condition guarantees that long run profits are null both before and after the entry of the aggregator. Then, proving a welfare increase reduces to prove that consumers' welfare in the online market is positive.

The proof of Lemma 3 is based on the identification of the indifferent buyers, that is, agents that – given the equilibrium price and their transport costs – are indifferent between purchasing and restraining from it. Any other active consumer, in equilibrium, is located closer to the restaurant than the indifferent buyers. All buyers have the same valuation for the good, therefore, any active consumer has the same valuation but lower transport costs than the indifferent voter. Therefore, it is immediate to conclude that their surplus in equilibrium is positive and so does the total consumers surplus.

□

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