`Information Doesn't Want to Be Free': Informational Shocks with Anonymous Online Platforms

Amedeo Piolatto

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Amedeo Piolatto *
UAB & BGSE & IEB & MOVE

Abstract

Anonymous information platforms (e.g. Airbnb) provide information about experience goods while keeping agents’ identity hidden until the transaction is completed. In doing so, they generate heterogeneity in the information levels across consumers. In this paper, I show that such platforms induce a weak increase of offline prices and that only low-valuation goods are cheaper online than offline. Platforms always lead to an increase in profits. In terms of consumer welfare, the platform equilibrium is Pareto superior for low- and high-valuation goods, while for intermediate ranges some buyers benefit while others lose from the presence of the platform.

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*Autonomous University of Barcelona (UAB), Barcelona Graduate School of Economics (BGSE), Barcelona Economics Institute (IEB) and MOVE. E-mail: amedeo.piolatto@uab.es

1 Introduction

Online platforms that directly or indirectly reveal some characteristics of a good (e.g. through users' comments), which the merchant cannot directly disclose in a credible way, are now present in a wide range of markets. Such platforms are also known as 'information aggregators', given their ability to collect and make information available to consumers.

Information is crucial for all sorts of decisions and, ceteris paribus, it is always preferable to have access to high quality information.Information asymmetries can, however, trigger reactions on the part of all (strategic) agents involved, potentially producing unexpected consequences. Indubitably, the internet, through dedicated information platforms, is a major source of information for most buyers.

Information aggregators can be arbitrarily sorted into three categories: i) information *repositories*, such as travel guides, ii) *non-anonymous* booking/selling platforms, such as Booking, and iii) *anonymous* booking platforms, such as Airbnb. The first category includes platforms that only provide information about third-party products. They do not provide purchasing or booking services. Meanwhile, the two remaining types of platforms allow to directly purchase or reserve a product. They crucial differ however, in that non-anonymous platforms reveal the parties' identities before the transaction is concluded. Hence, agents can finalise the transaction outside the platform. Anonymous platforms instead do not disclose the identity of the seller until the transaction has been completed through the platform.

One of the main challenge for non-anonymous platforms is to avoid 'showrooming', where potential customers use the platform to collect information but purchase elsewhere. This can occur, for example, when the platform is in direct competition with the producer, who has a clear incentive to undercut the platform to avoid commissions. Agreements under 'most favoured nation' (MFN) clauses restrict the action space of producers, who commit to not undercutting the platform.[1] Many authorities consider MFN clauses to be an anti-competitive and welfare decreasing practice. Together with non-anonymous platforms, they have been extensively studied in the literature (see Section 1.1 for a brief review).

This paper focuses instead on anonymous platforms, and is, to the best of my knowledge, the first attempt to specifically study this kind of platform. Airbnb is possibly the most well-known platform of this type, but it is certainly not the only one. Others, such as Homeaway, Hotwire, and Housify, also ensure that buyers cannot match the information online with offline sellers. Holidays Auto was also anonymous until recently. Note that anonymous platforms may indirectly affect the information available offline if buyers can update their expectations about product availability.[2]

In my model, each firm produces one horizontally differentiated product. In the benchmark model, transactions only occur offline. Once the (unique) platform operates in a market, firms can sell on- and offline simultaneously. Unitary-demand buyers can choose to buy on- or offline; they can also decide not to buy.

The purpose of the model is to capture the important trade-off that anonymity inevitably produces. The platform provides information to increase the quality of matches between the two market sides. Yet, it cannot disclose all the relevant information, given that it

[1]Under 'narrow' MFN, providers are free to undercut on competing platforms, but cannot do so directly. Under 'broad' MFN, they cannot undercut on competing platforms either.

[2]Information may thus matter for both parties. I assume here that the only buyers seek information. However, platforms do also allow firms to gather information about consumers' tastes and, hence, on potential demand for new products (Jullien and Pavan, 2019) or other buyer characteristics (Fradkin, 2019).

must guarantee anonymity.[3] Hence, the information observable online must be distinct from that observable offline. To reproduce this trade-off in the model, I assume that buyers care about two unrelated attributes of the good, which I denote as *location* and *value*. *Location* is only observable offline while *value* is only observable online. *Location* may refer to the physical position of the seller, or any other attribute of the seller that is easily observed offline. A typical example would consist of the seller's chain (i.e. loyalty schemes). Similarly, *value* is any attribute that cannot be directly observed before consumption (e.g. experience goods) but that can be inferred when using the platform, directly or through comments from previous customers. *Value* must be something that cannot be credibly revealed by the seller. Importantly, the *value* attribute determines the willingness of an agent to pay for a good (hence the name). However, consumers have heterogeneous preferences over the attribute, such that *value* remains an element of horizontal differentiation across consumers.

I based my model on the 'spokes' model of non-localised horizontal competition, which is an extension of Hotelling. Its general properties are discussed in the seminal paper by Chen and Riordan (2007) and in Reggiani (2020), and it has been used in a wide and heterogeneous set of environments (see Caminal and Claici, 2007; Caminal and Granero, 2012; Germano and Meier, 2013; Reggiani, 2014; Mantovani and Ruiz-Aliseda, 2016).[4] I depart from the original setting in several respects: two selling channels are active (online and offline) and, crucially, consumers' information set, which depends on the selling channel, is never perfect. The spokes model is a particularly appropriate choice for the context under analysis. For one, it accommodates market expansions even when firms are already actively competing. Furthermore, non-localised competition is essential to meaningfully represent firms that are simultaneously competing on- and offline.[5]

Another important property of the spokes model is that buyers may be on an 'empty' or an 'occupied' spoke.[6] Agents on empty spokes are equidistant from all active firms, while those on occupied spokes are asymmetrically located with respect to firms; that is, they are closer to one than to the others.

Offline purchases minimise transport costs, a feature that is related to *location*. Online purchases instead minimise mismatch cost, a feature related to *value*. Agents' *location* determines whether a consumer prefers to buy on- or offline. In the equilibrium with the platform, agents belong to one of three groups: *inactive*, *surfers* (i.e. online buyers) and *walkers* (i.e. offline buyers). In equilibrium, the willingness to pay and the demand elasticity of an agent depend on the market (on- or offline) and on whether an agent is on an empty or occupied spoke. Firms anticipate the different elasticities and consequently charge different prices on- and offline.

My model shows that the price offline is always weakly higher with the platform than without. However, the platform also indirectly increases the quality of matches for offline buyers, making it possible to have regions (in terms of good valuation) for which the presence of the platform is Pareto preferred by all walkers. The online price is lower than the price without the platform if and only if the good valuation is very low. In terms of welfare, the platform increases the expected value of transactions. Hence, it is again possible that an

[3]If agents could match information on- and offline, this would allow them to circumvent anonymity, collect information online (known as showrooming) and ultimately buy offline.

[4]Somaini and Einav (2013) and Edelman and Wright (2015) propose models that are isomorphic to the spokes model in order to study competition when customers suffer partial lock-in.

[5]Neither of these features is present under Hotelling or Salop.

[6]I further explain the meanings of 'empty' and 'occupied' in Section 2.

agent is better off even when paying a larger price.

In terms of the supply side, the generated profit is larger with the platform. In my model, the platform is free of use (one could assume that their revenue comes from advertisement) and all the profit goes to firms. If the assumption were made that the platform charges firms, the results would still hold as long as fees are non-distorting (lump-sum), and the increase in profit is shared between the platform and firms based on their bargaining power. Overall, the equilibrium with the platform is Pareto superior when the good has either a very low or very high valuation. For intermediate values, welfare depends on the combination of several parameters.

Section 1.1 briefly discusses how this study relates to the existing literature. Section 2 then introduces and solves the model. Section 3 compares the equilibrium with and without the platform and studies the consequences of anonymous platforms on both sides of the market. Section 4 concludes. The proofs are provided in Appendix A.

1.1 Related Literature

This study builds on a large body of work on platforms, which covers a variety of aspects from multiple perspectives. Spulber (2019) provides an overview with interesting insights on the broad links between the economics of platforms and the standard partial and general equilibrium literature. He also discusses the link between platforms and innovation. The most recent contributions extensively study competition across platforms[7] and multihoming (Armstrong, 2006; Anderson et al., 2019; Bryan and Gans, 2019; Casadesus-Masanell and Campbell, 2019; Halaburda and Yehezkel, 2019; Karle et al., 2020), as well as showrooming and the most-favoured-nation clause (Edelman and Wright, 2015; Foros et al., 2017; Johnson, 2017; Calzada et al., 2019; Johansen and Vergé, 2020; Ronayne and Taylor, 2020; Wang and Wright, 2020). While most of the platform literature is static, Cabral (2019); Kanoria and Saban (2020) are notable exceptions. My work departs from this literature by considering anonymous platforms.

Mueller-Frank and Pai (2014) suggest that platforms sell visibility, and study the consequent welfare implications. They consider that consumers' attention is displaced, hence more information on one product reduces information on the competing products. I instead assume that the platform equally reveals the characteristics of all the listed products.

Information about goods plays a crucial role in this work. Within the broad theoretical literature interested in consumers' information, it is possible to distinguish three focuses: homogeneous goods, vertical differentiation and horizontal differentiation. When goods are homogeneous, consumers cannot observe prices and seek the cheapest seller (See Baye and Morgan, 2001; Janssen et al., 2011; Dinerstein et al., 2018; Marshall, 2020, and the literature therein).[8] Ronayne (2020); Ronayne and Taylor (2020) study the case where online platforms are used to search for the cheapest price. I similarly assume that firms operate both directly and through the platform and, like these authors, find that when the platform is active, prices (weakly) increase both for platform users and non-users. Beyond the fact that I consider

[7] Arya et al. (2007) assess a seller that operates directly and through a retailer. Strictly speaking, a retailer is not a platform, but their model would also fit well with a platform. They focus on the competition induced by the fact that the seller is competing again themselves, by using two channels simultaneously.

[8] This literature also extends to the case of 'search with heterogeneous goods'. See, for example, Anderson and Renault (1999); Armstrong et al. (2009); Moraga-González and Petrikaitė (2013); Bar-Isaac et al. (2012) and the related literature.

horizontally differentiated goods, a crucial difference in my model is, once again, that the platform is anonymous.

When goods are vertically differentiated, information may play a simple screening role or, as in Miklós-Thal and Schumacher (2013), produce incentives for sellers by reducing moral hazard. The theoretical models in Klein et al. (2016); Vial and Zurita (2017) suggest that, in the presence of platforms, the vertical component may be secondary. Quality on a platform converges in equilibrium because 'lemons' either disappear or are forced to reach higher quality standards. In the same spirit, Cabral and Hortaçsu (2010) use Ebay data to show that - in the long run - poorly ranked firms either disappear or converge to their competitors' quality; Hossain et al. (2011) obtain the same result in an experimental setting.

In my work, goods are solely horizontally differentiated. This is similarly the case in Galeotti and Moraga-González (2009), who focus on non-anonymous platforms. Meanwhile, Romanyuk and Smolin (2019) look specifically at the seller-buyer match: the platform decides how much information to reveal in order to maximise their own profit. In both Anderson and Renault (2009) and Janssen and Teteryatnikova (2016), each firm unilaterally chooses how much information to disclose about their (horizontally differentiated) product and that of their competitor. They find that information improves match quality but also pushes prices upward. Jullien and Pavan (2019) observe similar results in a two-sided market setting. My findings are comparable, but for different reasons and through a distinct mechanism. Among other things, in my model, agents endogenously choose if they want to acquire the information (despite the consequent increase in price) and firms can disclose information only about their own product.

Showing a similar interest in the role of information, Armstrong and Zhou (2020) adopt a complementary perspective to that used here. In my study, the type of information gathered online is fixed, and the focus is on the incentives to gather information in the first place. Consumers may or may not acquire information (surfers and walkers, respectively), affecting their willingness to pay and, consequently, the equilibrium. Armstrong and Zhou (2020) instead look specifically at the information that may be transmitted. All buyers receive a signal[9] and the authors endeavour to discern how different information signals affect the equilibrium. Put differently, they conduct an analysis of a firm or a platform's optimal choice relative to the information to be disclosed.

The empirical literature on online reviews generally disregards possible differences between price search, vertical and horizontal differentiation. Some analyses focus on the effectiveness of reviews in shaping consumers' behaviour (DellaVigna and Pollet, 2009; Pope, 2009; Ghose et al., 2012), while others examine the phenomenon of manipulated reviews (Dellarocas, 2006; Martinelli, 2006; Dai et al., 2012; Mayzlin et al., 2013; Luca and Zervas, 2016). Chevalier and Mayzlin (2006); Anderson and Magruder (2012); Luca (2016) explore the link between reviews and profits.

The focus here is on anonymous platforms, a characteristic which, to the best of my knowledge, has not been specifically used in previous analyses. While Celik (2009) utilises anonymous platforms to motivate his work, and employs a similar setting in that goods are horizontally differentiated and the platform does not disclose all the attributes of the good, he focuses on the profit maximising amount of information to disclose, in line with Romanyuk and Smolin (2019).

Airbnb is perhaps the most well-known anonymous platform, and my study thus contrib-

[9]Translated into my model, this would imply that everyone is forced to buy online.

utes to the (mostly empirical) literature on this online marketplace. Farronato and Fradkin (2019), for example, study competition between regular hotels and Airbnb, showing that the latter increases welfare when hotels are at full capacity. In the model here, I restrict my attention to the case in which all sellers are on the same platform (which would correspond to the case of competition across listings on Airbnb). A possible spin-off of my work might therefore study competition between two platforms, one anonymous and the other non-anonymous. While in the analysis that follows only buyers are interested in the quality of the match, on Airbnb hosts and guests are both looking for a high-quality match. To this regard, Fradkin (2019) studies how Airbnb attempts to solve this problem, maximising the quality of matches on both sides. Finally, I simply assume that the platform is able to convey valuable information. Fradkin et al. (2019) study how reviews may be sincere or strategic on Airbnb, depending on technical details determining when reviews are made public.

2 The Model

In what follows, I construct my model based on the spokes model (Chen and Riordan, 2007). I begin by presenting some of its general characteristics, introducing the terminology and discussing several technical aspects that are common to any spokes-based model. Section 2.1 then formally describes the model, while Sections 2.2 and 2.3 solve it respectively for the benchmark case (without the platform) and the equilibrium with the platform.

As its name suggests, the spokes model takes the shape of a star, uniting several Hotelling lines (spokes) of equal length. The two extremes of a spoke are the *origin* and the *termination*. Spokes connect through their terminal, forming a radial shape as portrayed in Figure 1.

In this spokes model, a good has two attributes and both are elements of horizontal differentiation. The first attribute has a one to one correspondence with the position in the network, and is thus referred to as the *location*.[10] The second attribute determines the willingness to pay for the good, and is thus referred to as the *value*.

The position of a firm defines the first attribute of the good, i.e. its *location*. Firms, by assumption, can only be located at the spoke origins and cannot overlap.[11] This means that the set of origins corresponds to the set of *potential varieties* (in terms of the first attribute) that could be produced. The cardinality of the set (number of *potential varieties*) is then equal to the number of spokes (N).

By definition, a spoke is *empty* if no firm is located at its *origin* and, therefore, the corresponding *potential variety* is not produced. A spoke is *occupied* if a firm is located at its *origin*; the *potential variety* thus materialises as a *brand*.[12]

Consumers have unitary demand and are uniformly distributed over all the spokes.[13] Consumers' position in the network represents their preference in terms of the (horizontal) *location* attribute. Consumers experience a 'nuisance', often referred to as transport cost, that is linearly increasing in the distance between their and the product's position. This

[10]The spatial dimension can refer to the physical location of a shop or, more abstractly, as any observable attribute of the good (for example, Mark and Reggiani, 2020 studies the case of automobile repair shops: in that case, 'location' represents the car manufacturer to whom the repair shop is associated).

[11]This makes firms indifferent to their location: all spokes are identical. Reggiani (2014) extends the model to allow firms to endogenously locate at any point.

[12]In other words, *brands* are the *potential varieties* that are produced in equilibrium.

[13]Note that, by construction, consumers are uniformly distributed over all spokes, including empty ones.

transport cost is interpreted as the disutility from consuming a good whose *location* attribute is different from that desired.

Beyond *location*, each *potential variety* is characterised by the second relevant attribute: the *value*. Preferences over the latter are independent across agents and space, hence this is a second element of horizontal heterogeneity. For example, in the lodging industry, the *value* attribute could depend on certain elements (possibly relevant only for some customers) such as flexible check-in and check-out, the policy towards pets, presence of sport installations or bathtubs, etc. In the case of a restaurant, this could be related, for example, to background music (if any), with each consumer having a potentially different ranking in terms of genre.[14]

The spokes model does have a technical limitation, due to the presence of empty spokes. Suppose that each consumer were indifferent, in terms of *value*, across all *potential varieties*. Then, agents on empty spokes would form a mass willing to switch *brand* at any marginal price change. The consequent discontinuity in demand would inhibit the existence of a pure strategy equilibrium. Chen and Riordan (2007) discuss this issue in detail as well as possible strategies to adopt. This problem disappears as soon as each consumer ranks *potential varieties* according to at least one strict inequality. In line with Chen and Riordan (2007), the *value* of every *potential variety* is binary. For the sake of simplicity, for each consumer only one *potential variety* represents a good match in terms of the *value* attribute, while all the others are a poor match.[15]

A crucial difference between Chen and Riordan (2007) and this model is related to the information available to consumers. In the original spokes model, agents have full information: before purchase they can observe both *location* and *value* for all *brands*. The purpose of this paper is to assess the case of (experience) goods for which one attribute (in this case, *value*) is not directly observable, but that the platform is able to reveal.

As discussed in Section 1, platforms are *non-anonymous* if they openly reveal the identity of merchants and *anonymous* if they hide the latter until the transaction is completed. I restrict my attention to the latter. Anonymity has two major consequences: i) 'showrooming' (searching online but buying offline) is sensibly discouraged[16] and ii) in order to prevent showrooming, the platform must ensure that one cannot match information on- and offline. Hence, the *brand*'s attribute *location* must be hidden, which in turn introduces uncertainty on the transport cost.

Consumers have two purchasing options. *Surfers* use the platform to buy online. *Walkers* instead buy offline, but they may have searched on the platform beforehand. Both *walkers* and *surfers* have the outside option of not buying.

Firms can sell offline (traditional sales), online (electronic sales) or both. If use of the platform is sufficiently costly (for consumers or firms), an equilibrium where at least some agents operate offline is immediately obtained. To keep the mechanism as clean as possible, I assume that the platform is free for both firms and consumers. Under this assumption, the dominant strategy for all firms is to be active online, with *walkers* verifying ex-ante that one of the *brands* for sale is a good match for them.[17] Not intuitively, adding a usage cost for

[14]In both examples, the spatial dimension could be either the physical location of the property or other characteristics, such as the menu for restaurants.

[15]Chen and Riordan (2007) assume two high quality matches and introduce additional restrictions on which varieties can represent a good match.

[16]Searching online still provides valuable information to offline buyers, by revealing the set of *brands* currently being produced.

[17]Free usage implies that I cannot replicate an equilibrium with some firms selling only offline.

consumers would tip the balance in favour of consuming online, given that it would increase the uncertainty in the offline market. A usage cost for firms would, instead, favour the offline market, because some *brands* would not be available online.[18] I show that in equilibrium, *walking* is optimal for some agents even under free usage. While I assume that firms cannot sell online outside the platform, this has no major consequences under free usage.

In a traditional market, agents are uninformed and firms are all offline. When a platform enters the market, all agents connect to the platform and all firms sell online under the assumption that it's free. The first effect of the platform is trivial: some customers discover that none of the *brands* are valuable to them and restrain from buying. This represents a welfare improvement. Amongst all other customers, some will *walk* (buy offline), others will *surf* (buy online) and finally some will decide not to buy. Fig. 1 summarises the set of possible behaviours on the part of an agent.

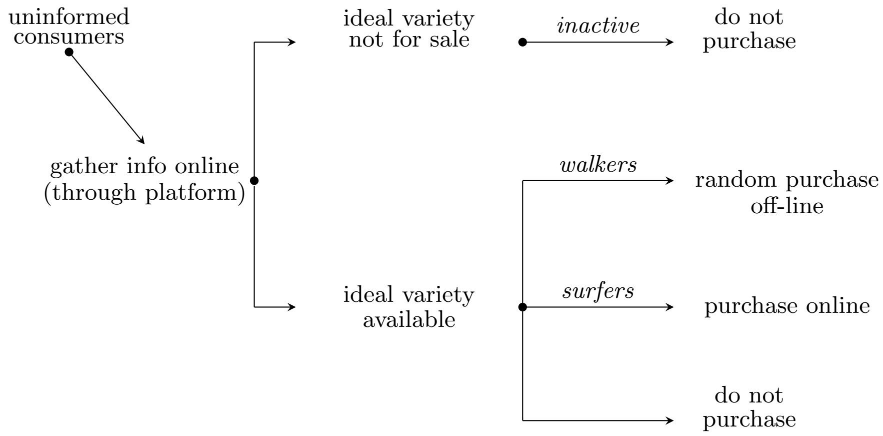


Figure 1: Set of possible behaviours of an agent

2.1 Formal structure

There exist $N \geq 4$ spokes of length $\frac{1}{2}$. The origin of each spoke corresponds to a variety (in terms of the *location* attribute that could be produced, hence, the set of *potential varieties* has cardinality N. I assume that $n \in [2, N-1]$ firms are active. By construction, each firm locates at the origin of a different spoke, hence there are n occupied and $N-n$ empty spokes.[19] Therefore, the set of *brands* (subset of *potential varieties* that is produced) has cardinality n.

The unitary mass of agents is uniformly distributed across the entire network. The location of an agent on spoke i is defined by x_i, i.e. their distance from the origin of the same spoke. By construction, the distance between the agent and the origin of any other spoke $i' \neq i$ is $1 - x_i$.

[18] With usage costs, results are qualitatively similar, though it becomes harder to disentangle the different forces. Quantitatively, the number of *walkers* and of agents that do not directly buy depend on the assumptions on usage costs.

[19] Assuming $n > 2$ guarantees that the market is not a monopoly, while $n < N - 1$ is meant to ensure that at least one spoke is empty.

Each *potential variety* has two relevant attributes, which horizontally differentiate it from the others. The attributes, referred to as *location* and *value*, are orthogonal to each other. Each agent's preference over *location* depends on their position in the network. The distance between an agent and a *brand* determines the transport cost. An agent also has a preference over the attribute *value*. Specifically, every agent is randomly matched to exactly one of the *potential varieties*.[20] The quality of the match is binary: for an agent whose high-quality match is of variety k, the *value* $\hat{v}$ is

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

Each *potential variety* has the same ex-ante probability $1/N$ of being a good match (i.e. $\hat{v} = v$).[21] Under full information, the willingness of an agent x_i to pay to consume *brand* j depends on the transport cost (distance between x_i and j) and the quality of the match (whether or not j is a high-quality match for x_i).

As the *location* of a *brand* is observable, consumers can anticipate their transport cost. The *value* attribute has an 'experience' component. That is, the buyer cannot directly observe it before consumption, but an online platform can reveal it. Differently from the previous literature, I focus on *anonymous* platforms. Hiding the identity of a merchant implies hiding its *location*. A novel trade-off appears: either one buys offline and observes *location* but not *value*, or one buys online and observes *value* but not *location*.

Section 2.2 solves the benchmark model without the platform. There, buyers can only choose between not buying and buying under a veil of ignorance, gambling over the expected value of a purchase. Section 2.3 computes the equilibrium with an active anonymous platform.

In what follows, subscript o refers to occupied spokes, while e refers to empty ones. Superscript t refers to the traditional setting (without the platform). When the platform is instead active, superscript s refers to *surfers* and online sales, while superscript w refers to *walkers* and offline sales.

2.2 Traditional selling (benchmark without the platform)

Without the platform, buyers cannot observe the *value*. Each *potential variety* has an expected *value* $E(\hat{v}) = \frac{1}{N}v$. All that matters for the decision to buy is the observable transport cost, which is x_i if consuming a *brand* produced at the origin of the spoke where the buyer is located, or $1 - x_i$ otherwise. The optimal strategy for an agent on an occupied spoke is therefore to buy the *brand* on their own spoke. For agents on an empty spoke, all brands are expected to be equally good and thus they will randomly pick one (if they consume).

The expected utility of an agent, conditional on being on an occupied spoke, is $E(U_o^t) = \frac{v}{N} - p_i^t - x_i$, where p_i^t is the price paid. Hence, the expected utility is positive for any agent located at $x_i \leq \frac{v}{N} - p_i^t \equiv \hat{x}_o^t$. The expected utility of an agent, conditional on being on an empty spoke, is $E(U_e^t) = \frac{v}{N} - p_i^t - (1 - x_i)$. Hence, the expected utility is positive for any agent located at $x_i \geq 1 - \frac{v}{N} + p_i^t \equiv \hat{x}_e^t$.

[20] The assumption can be relaxed, as long as the number of matches is strictly less than the number of spokes, but doing so doesn't produce any additional insight.

[21] Despite some differences in the interpretation, up to this point the structure is equivalent to Chen and Riordan (2007), with one exception. Specifically, these authors assume that agents enjoy a good match with two *potential varieties*, where the additional match always occurs with the *potential variety* on the spoke where the agent is located.

The total demand served by firm j is then

$$D_j^t = \begin{cases} \frac{2}{N}\left(\frac{v}{N} - p_j^t\right) & \text{if } \frac{v}{N} - p_i^t \leq \frac{1}{2} \\ \frac{2}{N}\left(\frac{1}{2} + \frac{N-n}{n}\left(\frac{v}{N} - p_j^t - \frac{1}{2}\right)\right) & \text{if } \frac{v}{N} - p_i^t \in \left[\frac{1}{2}, 1\right). \end{cases} \quad (2)$$

The first segment refers to the case where the firm serves only agents on its spoke, while the second segment materialises when some agents on empty spokes are also buying. In the latter case, firm j covers a share $\frac{1}{n}$ of the $(N-n)$ empty spokes.

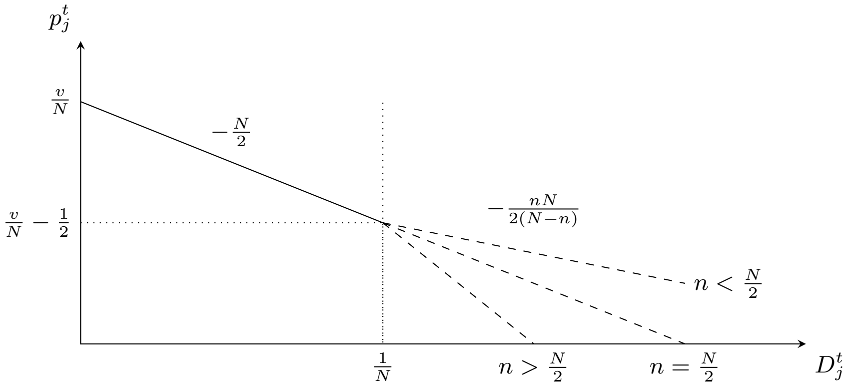


Figure 2: Inverse demand without platform

Fig. 2 illustrates the inverse demand function. At $D_j^t = \frac{1}{N}$, the slope changes from $-\frac{N}{2}$ to $-\frac{nN}{2(N-n)}$. This point corresponds to the moment when firms start serving spokes other than their own. If there are as many empty spokes as occupied ones ($n = \frac{N}{2}$), then each firm will serve (on average) one additional spoke and the slope remains the same. If instead there are less occupied than empty spokes ($n < \frac{N}{2}$), then each firm will serve (on average) more than one additional spoke and the slope flattens (the opposite occurs if $n > \frac{N}{2}$).

Lemma 1. *Solving the profit maximisation problem ($\max_{p^t} \pi_j^t = D_j^t p_j^t$), the equilibrium price without the platform is defined by Eq.* (3) *when $n \geq \frac{N}{2}$ and by Eq.* (4) *when $n < \frac{N}{2}$. Fig. 3 shows the results.*

$$p^t = \begin{cases} \frac{v}{2N} & \text{if } v < N \\ \frac{v}{N} - \frac{1}{2} & \text{if } v \in \left[N, \frac{N^2}{2(N-n)}\right] \\ \frac{v}{2N} - \frac{N-2n}{4(N-n)} & \text{if } v \in \left(\frac{N^2}{2(N-n)}, \frac{(3N-2n)N}{2(N-n)}\right). \end{cases} \quad (3)$$

$$p^t = \begin{cases} \frac{v}{2N} & \text{if } v < \frac{N+N\sqrt{n/(N-n)}}{2} \\ \frac{v}{2N} - \frac{N-2n}{4(N-n)} & \text{if } v \in \left(\frac{N+N\sqrt{n/(N-n)}}{2}, \frac{(3N-2n)N}{2(N-n)}\right). \end{cases} \quad (4)$$

Interestingly, $\frac{\partial p^t}{\partial N} < 0$, while $\frac{\partial p^t}{\partial n} \geq 0$. The interpretation of both signs is the same. When the number of spokes N increases (given the number of brands), so does the number of empty spokes, which means that the demand is more elastic. The same occurs if the number of brands n decreases, given the total number of spokes.

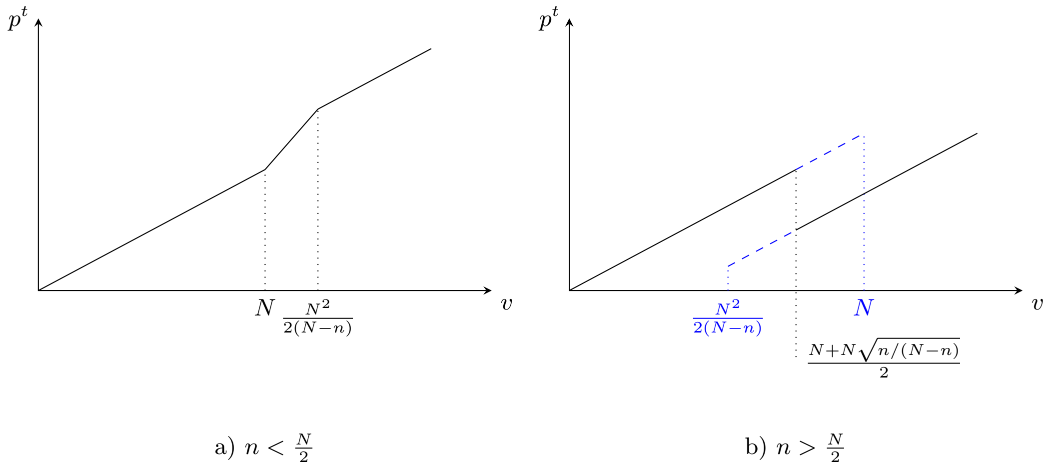


Figure 3: Inverse demand without platform

2.3 Equilibrium with the platform

Since the platform is free for everyone, selling through both channels (on- and offline) is optimal for all firms.

Any agent planning to purchase will scout online to make sure that one of the *brands* for sale is a good match for them (i.e. the one for which $\hat{v} = v$). With probability $(N-n)/N$, this is not the case and the agent does not buy. Such cases are referred to as *inactive*. Henceforth, inactive agents are always implicitly excluded from statements, unless the contrary is specified.

With complementary probability, $\frac{n}{N}$, agents observe online that one *brand* generates $\hat{v} = v$ for them. They must then decide if they prefer to *surf* (buy online), to *walk* (buy offline) or to not buy. As we will see, their decision depends on a combination of the equilibrium prices and agents' locations over the network. The platform being anonymous, *surfers* observe the *value* ($\hat{v}$) but they cannot compute the transport cost, while the opposite is true for *walkers*.

The expected utility of a *surfer* located at x_i will be:

$$E(U_i^s) = \begin{cases} v - (1 - x_i) - p_j^s & \text{if spoke } i \text{ is empty} \\ v - \left(\frac{1}{n}x_i + \frac{n-1}{n}(1 - x_i)\right) - p_j^s & \text{if spoke } i \text{ is occupied.} \end{cases} \tag{5}$$

The expected utility of consumption of a *walker* located at x_i will be:

$$E(U_i^w) = \begin{cases} \frac{v}{n} - (1 - x_i) - p_j^w & \text{if spoke } i \text{ is empty} \\ \frac{v}{n} - x_i - p_j^w & \text{if spoke } i \text{ is occupied.} \end{cases} \tag{6}$$

Using Eqs. (5) and (6), I compute the location of agents that are indifferent between two options. On empty spokes:

- $\hat{x}_e^s = 1 - v + p_j^s$ is indifferent between *surfing* and not buying, with $x_i \in \left(\hat{x}_e^s, \frac{1}{2}\right)$ being the locations where buying online is strictly preferred to not buying.
- $\hat{x}_e^w = 1 - \frac{v}{n} + p_j^w$ is indifferent between *walking* and not buying. For $x_i \in \left(\hat{x}_e^w, \frac{1}{2}\right)$ buying offline is strictly preferred.

On occupied spokes:

- $\hat{x}_o^s = \frac{n}{n-2}\left(\frac{n-1}{n} - v + p_j^s\right)$ is indifferent between *surfing* and not buying, with $x_i \in \left(\hat{x}_o^s, \frac{1}{2}\right)$ being the locations where buying online is strictly preferred to not buying.
- $\hat{x}_o^w = \frac{v}{n} - p_j^w$ is indifferent between *walking* and not buying. For $x_i \in (0, \hat{x}_o^w)$ buying offline is strictly preferred.
- $\tilde{x}_o = \frac{1}{2}\left(\frac{n}{n-1}(p_j^s - p_j^w) + 1 - v\right)$, agents are indifferent between *surfing* and *walking*. If $x_i \in (0, \tilde{x}_o)$ they prefer to *walk*, while if $x_i \in \left(\tilde{x}_o, \frac{1}{2}\right)$ they prefer to *surf*.

I restrict my attention to when at least some agents *surf*. The corresponding necessary and sufficient condition is thus that $v > \frac{1}{2}$. Lemma 2 and Fig. 4 depict all potential scenarios in which some *surfers* are active.

Lemma 2. *In equilibrium, one of three scenarios can materialise.*
On occupied spokes, walkers (if any) always concentrate near the origin: $x_i \in (0, \hat{x}_o^w)$ *and* $x_i \in (0, \tilde{x}_o)$ *respectively under scenarios A) and B). Nobody walks in scenario C). Surfers always concentrate around the terminal:* $x_i \in \left(\hat{x}_o^s, \frac{1}{2}\right)$ *and* $x_i \in \left(\tilde{x}_o, \frac{1}{2}\right)$ *respectively under A) and B). Under scenario C), everyone surfs. On occupied spokes, the market remains uncovered only in scenario A), where nobody buys for* $x_i \in (\hat{x}_o^w, \hat{x}_o^s)$.
In all three scenarios, on empty spokes agents at $x_i \in \left(\hat{x}_e^s, \frac{1}{2}\right)$ *buy online, the remaining agents do not buy.*

Proof. See Appendix A ☐

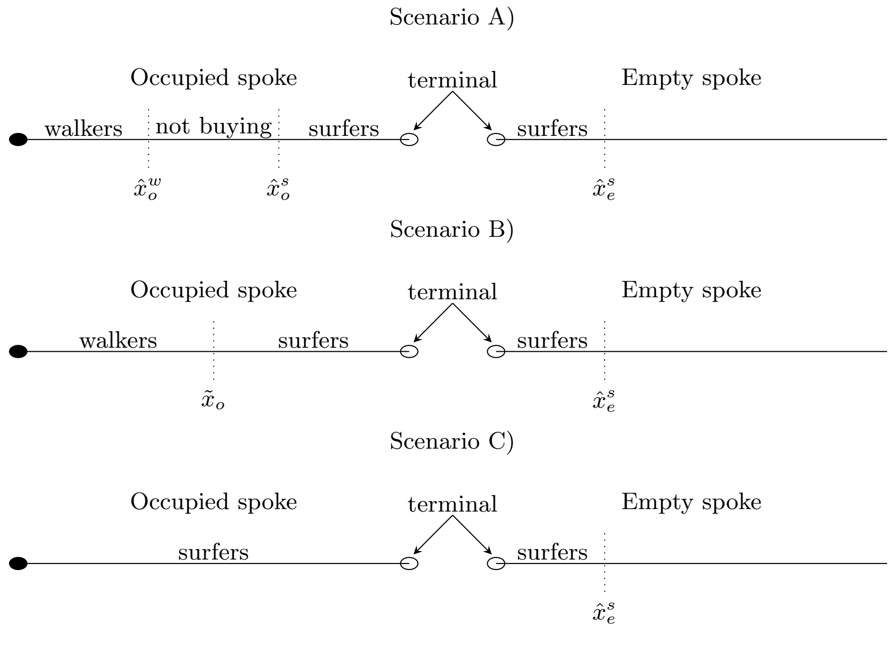


Figure 4: Potential scenarios: occupied spokes on the left side, empty spokes on the right side

Every firm is selling both on- and offline. Hence, their profit is given by $\pi = p_j^w D_j^w + p_j^s D_j^s$, where D_j^w and D_j^s represent the demand off- and online, respectively. Firms choose both prices simultaneously and I focus on symmetric equilibria.

Demands are piece-wise defined, depending on the value of v and, hence, on the scenario.[22] In Region A, corresponding to Scenario A), $v < \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$; in Region B, corresponding to Scenario B), $v = \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$; in Region C, corresponding to Scenario C), $v > \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$;.

$$D_j^w = \begin{cases} \frac{2}{N}\frac{n}{N}\hat{x}_o^w, & \textit{(Region A)} \\ \frac{2}{N}\frac{n}{N}\tilde{x}_o, & \textit{(Region B)} \\ 0, & \textit{(Region C)}, \end{cases} \tag{7}$$

$$D_j^s = \begin{cases} \frac{2}{N}\frac{1}{N}\left(n(\frac{1}{2} - \hat{x}_o^s) + (N-n)(\frac{1}{2} - \hat{x}_e^s)\right), & \textit{(Region A)} \\ \frac{2}{N}\frac{1}{N}\left(n(\frac{1}{2} - \tilde{x}_o) + (N-n)(\frac{1}{2} - \hat{x}_e^s)\right), & \textit{(Region B)} \\ \frac{2}{N}\frac{1}{N}\left(\frac{n}{2} + (N-n)(\frac{1}{2} - \hat{x}_e^s)\right), & \textit{(Region C)}, \end{cases} \tag{8}$$

Given the symmetry of the model, I focus on symmetric Bertrand-Nash equilibria in pure strategy. All firms in equilibrium set the same prices p^w and p^s, serve the same amount of *walkers* and *surfers* and earn the same profit.

Proposition 1. *The piece-wise-defined symmetric equilibrium prices p^w and p^s are reported in Eqs.* (9) *and* (10) *respectively.*

$$p^w = \begin{cases} \frac{v}{2n}, & \textit{if } v \in \left[\frac{1}{2}, \frac{(3n-4)n}{2(n+2)(n-1)}\right) & \textit{(A)} \\ \frac{v}{2n}\left(1 + \frac{(n+2)(n-1)\alpha}{n^3+(n-2)\alpha}\right) - \frac{(3n-4)\alpha}{4(n^3+(n-2)\alpha)}, & \textit{if } v \in \left[\frac{(3n-4)n}{2(n+2)(n-1)}, \frac{\alpha+n(N-n)}{(n+2)(N-n)}\right) & \textit{(B)} \\ \frac{1}{2n}\left(v + \frac{nN-2(N-n)}{2(N-n)}\right), & \textit{if } v \in \left[\frac{\alpha+n(N-n)}{(n+2)(N-n)}, \frac{3N-2n}{2(N-n)}\right) & \textit{(C)}, \end{cases} \tag{9}$$

$$p^s = \begin{cases} \frac{v}{2} - \frac{1}{4}, & \textit{if } v \in \left[\frac{1}{2}, \frac{(3n-4)n}{2(n+2)(n-1)}\right) & \textit{(A)} \\ \frac{v}{2}\left(1 + \frac{(n+2)(n-1)n}{n^3+(n-2)\alpha}\right) - \frac{(n-2)\alpha+4n^2(n-1)}{4(n^3+(n-2)\alpha)}, & \textit{if } v \in \left[\frac{(3n-4)n}{2(n+2)(n-1)}, \frac{\alpha+n(N-n)}{(n+2)(N-n)}\right) & \textit{(B)} \\ \frac{v}{2} - \frac{N-2n}{4(N-n)}, & \textit{if } v \in \left[\frac{\alpha+n(N-n)}{(n+2)(N-n)}, \frac{3N-2n}{2(N-n)}\right) & \textit{(C)}, \end{cases} \tag{10}$$

where $\alpha = nN - 2N + 2n$.

Corollary. *In Region C, walkers are not active. Occupied spokes are fully covered and all agents are surfers ($\tilde{x}_o = 0$). Empty spokes are partially covered, with the upper limit of Region C representing the case in which the entire market is covered, including on empty spokes.*

Proof. See appendix A. □

Figs. 5 and 6 depict consumption and prices in equilibrium. The following proposition compares p^w and p^s.

[22] The proof of Proposition 1 includes additional details on regions and the corresponding demand functions.

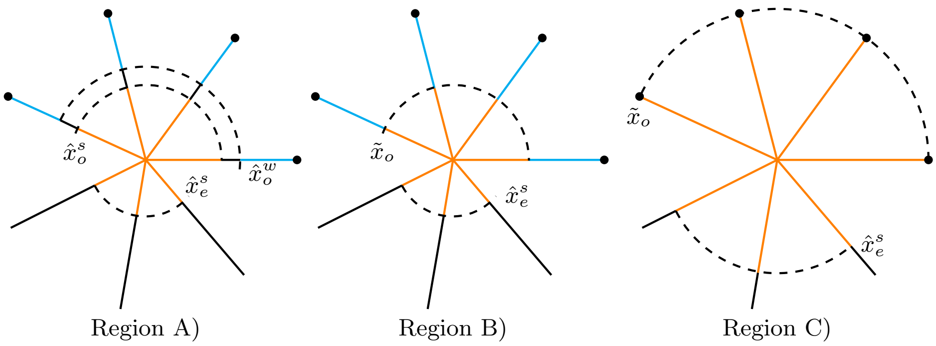


Figure 5: Consumption in equilibrium: cyan=*walkers*, orange=*surfers*, black=*not buying*

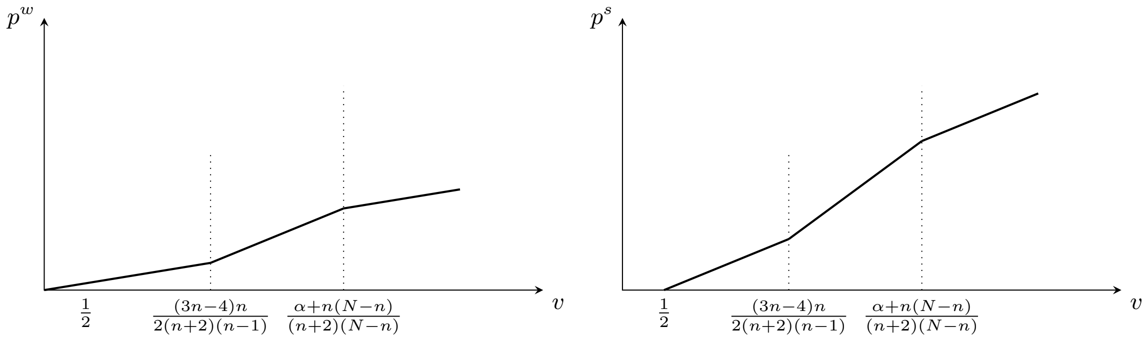


Figure 6: Equilibrium prices with platform

Proposition 2. *As long as $n \in (3, 4)$ and $N > \frac{4n}{4-n}$ do not simultaneously hold, then a unique value $\hat{v}(n, N)$ exists, such that $p^s > p^w$ if and only if $v > \hat{v}(n, N)$ (Fig. 7, left panel).*

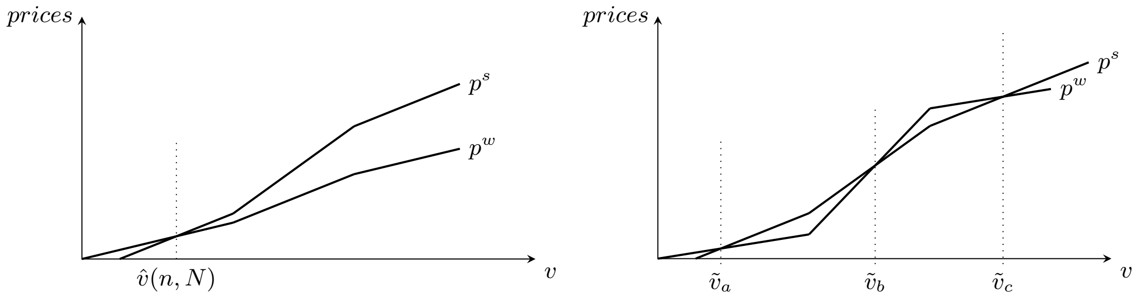
If $n \in (3, 4)$ and $N > \frac{4n}{4-n}$ simultaneously hold, then values $\tilde{v}_a$, $\tilde{v}_b$ and $\tilde{v}_c$ exist, such that $p^s > p^w$ if $v \in (\tilde{v}_a, \tilde{v}_b)$ or $v > \tilde{v}_c$, while $p^s < p^w$ if $v < \tilde{v}_a$ or $v \in (\tilde{v}_b, \tilde{v}_c)$ (Fig. 7, right panel).

Corollary. *In regions A and C, the slope of p^w is $\frac{1}{2n}$, hence p^w is flatter than p^s, whose slope is $\frac{1}{2}$. Both price functions are steeper in Region B than in their two neighbouring regions. When $N\frac{n(n^2+n-4)}{2(n-2)}$, then p^w is steeper than p^s.*

Proof. See appendix A. □

One can immediately observe from Proposition 2 and Fig. 7 that the online price is always above the offline price for sufficiently large v, while the opposite is always true for sufficiently small v. These results imply that for valuable goods, the added value of the platform comes from the reduction in the risk of a poor match, for which buyers are willing to pay. Conversely, for low-value goods, the platform undercuts the price of the offline market.

In most cases (left panel in Fig. 7), prices cross only once. However, when n is very small ($2 < n < 3$) and N sufficiently large ($N > \frac{4n}{4-n}$), prices will cross once in each region. These parameters correspond to a situation with very few brands, compared to the set of potential varieties. Such a scenario is likely to occur if the market exhibits high entry costs. Then, for intermediate-value goods, it becomes harder to anticipate whether the price online will be



In the left panel, conditions $n \in (3,4)$ and $N > \frac{4n}{4-n}$ hold simultaneously. The right panel covers all other cases, with the caveat that crossing of p^w and p^s could occur in any region of the graph, depending on the relative size of n and N.

Figure 7: Comparison p^w and p^s

lower or higher than the offline one. While it remains true that the online price is higher for topmost-valued goods, this is now also the case for lower-middle valued goods. Furthermore, while it is still the case that the online price is lower for bottom-valued goods, this also now true for the upper-middle valued goods.

3 Analysis of previous results and welfare

Any regulation or policy recommendation related to the presence of *anonymous* platforms should be based on a welfare analysis. In this section, I first look at the domain of v for which results hold, then I compare prices with and without the platform. Finally, I look at profits and consumers' utility.

Regarding the domain, it is immediately obvious that the platform is only active for $v \geq \frac{1}{2}$. It is simple to show that, indeed, no one would ever *surf* for smaller values of the good; the platform would have no purpose. Furthermore, the upper bound of the domain is set by $v \leq \frac{3N-2n}{2(N-n)}$.[23] It is immediate to prove that $\frac{3N-2n}{2(N-n)} < N$, hence, the domain without the platform is wider both above and below.

Proposition 3 relates prices with and without the platform.

Proposition 3. *The walkers price (p^w) is always weakly larger than the price without the platform (p^t), with $p^w = p^t$ in Region A and $p^w > p^t$ in Region B and C.*

The surfers price (p^s) is smaller than the price without the platform for v below some threshold, and larger above it. The unique crossing occurs in Region A if and only if $n > 3$. When $n \leq 3$, crossing will occur either in Regions B or C.

Proof. See the appendix (where the above-mentioned thresholds are properly defined). □

The increase in price follows the logic of da Graça and Masson (2013): when buyers are better informed, they attach a higher value to the good and sellers will try to extract more surplus from them. Ronayne (2020) and Ronayne and Taylor (2020) obtain similar results for the case of platforms selling homogeneous goods through *non-anonymous* platforms. It is important to bear in mind that the rise in price reflects an increase in valuation, hence the welfare consequences are not immediately obvious.

[23] Technically, the upper bound with the platform is arbitrarily set for when the market is fully covered and the model could allow for larger v, which would simply translate into an increase in prices.

This analysis of profits requires one further consideration. Long-run profits would inevitably tend to zero in this simple model, absent barriers to entry. For the sake of simplicity, I proceed with the most standard setting, where firms pay an entry cost to operate. Entry naturally stops as soon as an additional firm is unable to fully recover the entry cost. I assume that entry costs are the same with and without the platform. Henceforth, *gross profits* and *net profits* refer respectively to when entry costs are excluded or included.

Moreover, it should be clarified that the entry condition that allows to endogenously set entry is non-linear and cannot be defined explicitly in a tractable way. Nevertheless, the long-run equilibrium condition that gross profits π must equate entry costs F, together with Lemma 3 are enough to obtain Proposition 4.

Lemma 3. *Comparing net profits in two scenarios, say x and y, if $\pi^x > \pi^y$, then $n^x > n^y$.*

Proposition 4. *Gross profit is larger with the platform than without it.*

Corollary. *The number of active firms with the platform must be at least as large as without it.*

Proof. See Appendix A. □

Proposition 4 provides a first important result. The supply side is better off with the platform. In this model, the platform has two effects. On the one hand, it improves the quality of matches and hence the willingness of some consumers to pay. On the other hand, it allows firms to price discriminate between informed and uninformed consumers, which would not be possible with *non-anonymous* platforms. This implies that more value is generated through the better matching system, and that such value is, at least partially, appropriated by the supply side.

Technically speaking, the model suggests that the increase in profit directly translates into a benefit for firms. This is a consequence of the assumption that the platform operates for free. The current setting, with only one active platform facing firms with some market power, is not equipped to analyse the bargaining process between firms and the platform: one could easily justify a bargaining outcome that leads to any possible split of the surplus across players. Hence, the most honest (albeit loose) interpretation of Proposition 4 is that the platform generates a surplus that will be split across n firms and the platform, depending on the relative bargaining power.

With regard to the demand side, several simultaneous effects are potentially at work: change in the number of available varieties n, change in price and change in the probability of a good match. An increase in n could lead to a weak increase in consumers' welfare by increasing the amount of high quality matches that can be made. An increase in prices would decrease consumers' welfare. Finally, a greater probability of a high quality match would increase welfare.

Lemma 4. *The equilibrium with the platform is weakly Pareto superior for all agents that are inactive without the platform (i.e. $x_i > \frac{v}{2N}$ on occupied spokes and all agents on empty spokes).*

Proof. See Appendix A. □

One can consequently focus on agents that are active without the platform.

Proposition 5. *Within the boundaries of Region A, the scenario with a platform Pareto dominates that without it.*
In Regions B and C, there are always some agents that are strictly better off with the platform. Depending on the specific parameter values, the platform setting may or may not Pareto dominate the opposing one.
In Region C, it is possible to identify a threshold for v above which the platform scenario Pareto dominates that without it. Furthermore, $n > 4.4$ is a sufficient (yet not necessary) condition for the entire Region C to lie above the previously mentioned threshold on v.

Proof. See Appendix A. □

Together, Propositions 4 and 5 provide a very clear picture of the welfare consequences of the entry of anonymised platforms in a market. First of all, in a quite mechanical way, the platform provides better information to consumers, hence we observe a higher quality of matches, with some agents who stop consuming because they are able to anticipate that the product of their choice is not produced.

Less immediate results include, looking at the supply side, an increase in the total surplus that firms can extract from consumers. This occurs through three combined channels: i) more transactions are carried out, ii) the value of the transactions is larger and iii) sellers are able to distinguish between two groups of consumers with different degrees of willingness to pay and, because of anonymity, can set different prices to extract the surplus.

In terms of consumers' welfare, the platform scenario always Pareto dominates that without it for any v either sufficiently small (Region A) or sufficiently large (part of or possibly all of Region C). For intermediate values of v, the welfare effect on consumers is mixed. On the one hand, consumers' expected value from consumption increases, but on the other hand, price also increases. The speed at which value and price rise depend on the model's parameters. Thus, while there can be cases in which everyone is better off with the platform, it is equally plausible that some agents benefit from the platform while others lose from it.

4 Final remarks

The previous literature has tended to focus on platforms that reveal the seller's identity before the transaction is concluded. This inevitably allows for showrooming, where potential buyers can easily match information online and offline and then buy where it is cheaper. To prevent this from happening, many platforms use most 'favoured nation clauses' (also known as 'price parity') to diminish the incentive to showroom. However, this practice has often been seen as anti-competitive by the competent authorities. Meanwhile, academic research has shown that it may lead to significant welfare losses.

Other platforms, Airbnb possibly being the most successful, have adopted a different model. Their platform is *anonymous*, and thus prevents any possible contact outside the platform. This makes showrooming virtually impossible and means that firms can set different prices on- and offline.

To the best of my knowledge, this article is the first attempt to specifically study the consequences of an *anonymous* platform entering a previously offline market. I show that the offline price is weakly increasing with the platform while the online price is smaller than that without platform for low-valued goods and larger otherwise.

While the platform always brings in new consumers, some consumers stop buying. These are all agents who would have had a low-quality match in a traditional market, inducing a negative ex-post utility. I show that profits are always larger when the platform is active.

In terms of consumers' welfare, the platform setting Pareto dominates that without it when buyers' valuation is either sufficiently low or sufficiently high. However, for intermediate valuations, the specific combination of parameter values matters: under most configurations the platform Pareto dominates, yet under other configurations some agents are better off with the platform at the expenses of the remaining agents.

Note that the possible loss in surplus for some consumers is due only to the increase in price. In other words, it derives from a transfer and not from a proper loss, which means that overall welfare always increases. If side-compensations were feasible, then it would be possible to conclude that *anonymous* platforms are always Pareto superior to the setting without a platform.

The model suggests that *anonymous* platforms should, in most cases, be incentivised, particularly where it is possible to compensate buyers in the unlikely event of agents who lose from the presence of the platform.

Appendix A Proofs

Proof of Lemma 2. The lemma restricts its attention to cases in which at least some agents are buying online.

The proof is organised by showing that:

1. having some people buying offline on empty spokes is sufficient to imply that nobody will buy online (neither on empty nor on occupied spokes),
2. having non-served empty spokes (i.e. nobody located on empty spokes is buying) implies that nobody will buy online on occupied spokes either,
3. the two results together imply the lemma.

1. On an empty spoke, an agent prefers to walk than to surf if and only if $v < \frac{n}{n-1}(p^s - p^w)$.

On an occupied spoke, agents prefer to walk than to surf if $x_i < \tilde{x}_o$, while they prefer to surf than to walk if $x_i > \tilde{x}_o$. If $\tilde{x}_o > \frac{1}{2}$, all agents on an occupied spoke prefer to walk. This occurs if $v < \frac{n}{n-1}(p^s - p^w)$.

Hence, if the condition is met to have some walkers on empty spokes, it follows both that i) at any location on empty spokes, agents prefer to walk than to surf, and ii) at any location on occupied spokes, agents prefer to walk than to surf.

If the condition is not met, then some agents may surf on occupied spokes and at all locations on empty spokes agents will certainly either surf or not buy.

Hence, we can already exclude any equilibrium in which some agents walk on empty spokes and, simultaneously, some agents surf on occupied spokes.

This suffices to conclude that, restricting on equilibria where at least some agents surf, there cannot be an equilibrium in which agents on empty spokes buy offline.

2. Suppose that nobody is willing to buy online on empty spokes. This requires that the expected utility of being a surfer is negative at all locations on empty spokes, which occurs if and only if $v < p^w + \frac{1}{2}$.

We are interested in equilibria where at least some agents buy online. If empty spokes are not served, then there must be some agents buying online on occupied spokes. The condition for the surfers' expected utility to be positive on occupied spokes is $v > p^w + \frac{1}{2}$, which is incompatible with the previous condition.

3. Point 1 of this proof shows that having some agents that buy offline on empty spokes implies that there cannot be surfers on occupied spokes.

Point 2 shows that if nobody buys on empty spokes then there cannot be surfers on occupied spokes.

In both cases, it means that nobody would buy online. Hence, putting the two results together, it follows that the only possible way to have some surfers on occupied spokes is to also have surfers on empty spokes. □

Proof of Proposition 1. Using the definitions of $\hat{x}_o^w$, $\hat{x}_o^s$, $\hat{x}_o$ and $\hat{x}_e^s$ in Eqs. (7) and (8) it follows that

$$D_j^w = \begin{cases} \frac{2}{N}\frac{n}{N}\left(\frac{v}{n} - p_j^w\right), & \textit{(Region A)} \\ \frac{n}{N^2}\left(\frac{n}{(n-1)}(p_j^s - p_j^w) + 1 - v\right), & \textit{(Region B)} \\ 0, & \textit{(Region C)}, \end{cases} \tag{11}$$

and

$$D_j^s = \begin{cases} \frac{2}{N^2}\left(v - \frac{1}{2} - p_j^s\right)\left(\frac{nN-2N+2n}{n-2}\right), & \textit{(Region A)} \\ \frac{1}{N^2}\left(n\left(v - \frac{n}{n-1}(p_j^s - p_j^w)\right) + 2(N-n)\left(v - p_j^s - \frac{1}{2}\right)\right), & \textit{(Region B)} \\ \frac{2}{N^2}\left(\frac{n}{2} + (N-n)\left(v - p^s - \frac{1}{2}\right)\right), & \textit{(Region C).} \end{cases} \tag{12}$$

I compute the candidate equilibrium price for Regions A and C first, leaving Region B at the end. Each firm j maximises simultaneously online and offline profits. In each region, the demand that each firm faces is different, however the maximisation problem of firm j can be written as:

$$\max_{p_j^w, p_j^s} \pi = p_j^w D^w + p_j^s D^s. \tag{13}$$

With a little abuse of notation, let's denote $\pi_k(p^w, p^s)$, p_k^w and p_k^s, with $k = \{a, b, c\}$, respectively the profit function, and the equilibrium prices off- and on-line in Region k.

Region A) Suppose an equilibrium satisfies the condition $v < \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$. The lower bound is arbitrarily assumed to be $v \geq \frac{1}{2}$, to ensure that some agents buy online.

Using in Eq. (13) the demand off- and on-line for Region A as defined in Eqs. (11) and (12), the problem is well defined and the solution of the first order conditions leads to

$$p_a^w = \frac{v}{2n}, \tag{14}$$

$$p_a^s = \frac{v}{2} - \frac{1}{4}. \tag{15}$$

Replacing these prices in the existence condition $v < \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$, we obtain the value of v that defines Region A:

$$v \in \left(\frac{1}{2}, \frac{(3n-4)n}{2(n+2)(n-1)}\right). \tag{16}$$

Furthermore, $\pi_a = \frac{1}{2N^2}\left(\frac{v^2}{n} + \left(v - \frac{1}{2}\right)^2\left(\frac{nN-2N+2n}{n-2}\right)\right)$, $\hat{x}_o^w = \frac{v}{2n}$, $\hat{x}_o^s = \frac{n}{2(n-2)}\left(\frac{3n-4}{2n} - v\right)$, $\hat{x}_e^s = \frac{3}{4} - \frac{v}{2}$.

Region C) Suppose an equilibrium satisfies the condition $v > \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$. As an upper bound we consider when $\hat{x}_e^s \geq 0$, which implies that empty spokes are fully covered.

The first order conditions are:

$$\frac{n}{N^2}\left(\frac{n}{(n-1)}(p_j^s - 2p_j^w) + 1 - v\right) + \frac{1}{N^2}p_j^s\frac{n^2}{n-1} = 0 \tag{17}$$

$$\frac{1}{N^2}\left(n\left(v - \frac{2n}{n-1}(p_j^s - p_j^w)\right) + 2(N-n)\left(v - 2p^s - \frac{1}{2}\right)\right) = 0 \tag{18}$$

From Eq. (17) we immediately obtain $\frac{n}{(n-1)}(p_j^s - 2p_j^w) = \frac{n-1}{(n)}(1-v)$, which implies that $\tilde{x}_o = 0$. This means that, under this equilibrium, only surfers are active.

Solving the system of Eqs. (17) and (18), we obtain:

$$p_c^w = \frac{1}{2n}\left(v + \frac{nN - 2(N-n)}{2(N-n)}\right) \tag{19}$$

$$p_c^s = \frac{v}{2} - \frac{N-2n}{4(N-n)} \tag{20}$$

At these prices, the existence conditions $v > \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$ and $\hat{x}_e^s \geq 0$ translate into

$$v \in \left(\frac{2N(n-1) - n(n-2)}{(n+2)(N-n)}, \frac{3N-2n}{2(N-n)}\right). \quad (21)$$

Profit is $\pi_c = \frac{(N-n)}{2N^2}\left(v - \frac{N-2n}{2(N-n)}\right)^2$.

Region B) Suppose an equilibrium satisfies the condition $v = \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$. The existence conditions of the region are defined below.

In this region, the maximisation problem in Eq. (13) is constrained by condition $p^s = \frac{n-1}{n}\left(\frac{n+2}{n}v - 1 - \frac{n-2}{n-1}p^w\right)$. The first order condition leads to

$$p_b^w = \frac{v}{2n}\left(1 + \frac{(n+2)(n-1)(nN-2N+2n)}{n^3 + (n-2)(nN-2N+2n)}\right) - \frac{(3n-4)(nN-2N+2n)}{4(n^3 + (n-2)(nN-2N+2n))}, \quad (22)$$

$$p_b^s = \frac{v}{2}\left(1 + \frac{(n+2)(n-1)n}{n^3 + (n-2)\alpha}\right) - \frac{(n-2)\alpha + 4n^2(n-1)}{4(n^3 + (n-2)\alpha)} \quad (23)$$

By construction, at this equilibrium $v = \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$. This is a very unstable condition: the demand here has a kink. Any marginal reduction in one of the prices would imply that $v > \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$ and we would jump to Region C and its equilibrium. Similarly, any marginal increase in one of the prices would imply that $v < \frac{n}{n+2}\left(1 + \frac{n}{n-1}p^s + \frac{n-2}{n-1}p^w\right)$ and we would jump to Region A and its equilibrium.

In order for prices in Eqs. (22) and (23) to be an equilibrium, a slight decrease of either price should not increase profits. Therefore, $\frac{\partial \pi_c(p^w,p^s)}{\partial p^w}\big|_{p_b^w;p_b^s} > 0$ and $\frac{\partial \pi_c(p^w,p^s)}{\partial p^s}\big|_{p_b^w;p_b^s} > 0$. This translates into conditions:

$$1 - v + 2\frac{n}{n-1}(p_b^s - p_b^w) > 0 \quad (24)$$

$$nv - 2\frac{n^2}{n-1}(p_b^s - p_b^w) + 2(N-n)\left(v - 2p_b^s - \frac{1}{2}\right) > 0. \quad (25)$$

Both restrictions lead to condition $v < \frac{2N(n-1)-n(n-2)}{(n+2)(N-n)}$, which represents the upper bound for Region B. It is immediate to notice that this is also the lower bound for Region C.

Moving to the other end of Region B: in order for prices in Eqs. (22) and (23) to be an equilibrium, a slight increase of either price should not increase profits to prevent jumps from Region B to Region A. Therefore, $\frac{\partial \pi_a(p^w,p^s)}{\partial p^w}\big|_{p_b^w;p_b^s} < 0$ and $\frac{\partial \pi_a(p^w,p^s)}{\partial p^s}\big|_{p_b^w;p_b^s} < 0$. This translates into conditions:

$$\frac{v}{n} - 2p_b^w < 0 \quad (26)$$

$$n\left(\frac{1}{2} - \frac{n-1}{n-2} + \frac{n}{n-2}v - \frac{2n}{n-2}p_b^s\right) + (N-n)(v - \frac{1}{2} - 2p_b^s) < 0 \quad (27)$$

Both restrictions lead to condition $v < \frac{n(3n-4)}{2(n+2)(n-1)}$, which represents the lower bound for Region B. It is immediate to notice that this is also the upper bound for Region A. □

Proof of Proposition 2. Since p^w and p^s are both linear and defined over the same intervals, it is a matter of simple algebra to compare slopes, intercepts and crossings.

For Region A: $p_a^s - p_a^w = \frac{2(n-1)v-n}{4n}$. This is weakly positive if and only if $v \geq \frac{n}{2(n-1)} \equiv \overline{v}_a$. Comparing this threshold with the one that delimits Region A, it is immediate to find that $\frac{(3n-4)n}{2(n+2)(n-1)} > \frac{n}{2(n-1)}$ if and only if $n > 3$. Therefore, p_a^s and p_a^w cross within Region A if and only if $n > 3$.

For Region C, $p_c^s \geq p_c^w$ if and only if $v \geq 1 \equiv \overline{v}_c$. Notice that the upper bound for Region C is always larger than 1. The lower bound is larger than 1 if either $n > 4$ or $n < 4$ and $N > \frac{4n}{(4-n)}$.

For Region B, p_b^s is steeper than p_b^w if and only if $N < \frac{n(n^2+n-4)}{2(n-2)}$. If $N = \frac{n(n^2+n-4)}{2(n-2)}$, then the two functions have the same slope: in that case, when $n = 3$ (hence, $N = 12$), the two functions overlap, while for any other value of n, the two are parallel. Whenever $N \neq \frac{n(n^2+n-4)}{2(n-2)}$, $p_b^s = p_b^w$ if $v = \frac{n(N(n-2)-2n(n-1))}{N(n-2)-2n(n^2+n-4)} \equiv \overline{v}_b$.

Putting all the above information together, it is possible to conclude that the following scenarios may occur:

- if $n \in (2, 3]$ and $N > \frac{4n}{4-n}$, then p^s crosses p^w only once, from below, in Region C, at $\hat{v}(n, N) = \overline{v}_c$.
- if $n \in (2, 3]$ and $N < \frac{4n}{4-n}$, then p^s crosses p^w only once, from below, in Region B, at $\hat{v}(n, N) = \overline{v}_b$. In the degenerate case of $n = 3$ and $N = \frac{4n}{4-n}$, then $p_b^s = p_b^w$ for all values in Region B.
- if $n \in (3, 4)$ and $N < \frac{4n}{4-n}$ or $n > 4$, then p^s crosses p^w only once, from below, in Region A, at $\hat{v}(n, N) = \overline{v}_a$.
- if $n \in (3, 4)$ and $N > \frac{4n}{4-n}$, then p^s crosses p^w three times. From below, in Region A, at $\hat{v}(n, N) = \overline{v}_a$; from above in Region B, at $\hat{v}(n, N) = \overline{v}_b$; from below, in Region C, at $\hat{v}(n, N) = \overline{v}_c$.

□

Proof of Proposition 3. First notice that:

- the domain with the platform is $v \in \left[\frac{1}{2}, \frac{3N-2n}{2(N-n)}\right)$
- without the platform, the equilibrium price is $p^t = \frac{v}{2n}$ if
  - either $N \geq 2n$ and $v < N$
  - or $N < 2n$ and $v < \frac{N+N\sqrt{\frac{n}{N-n}}}{2}$
- the upper bound with the platform $v = \frac{3N-2n}{2(N-n)}$ is
  - smaller than N when $N \geq 2n$
  - smaller than $\frac{N+N\sqrt{\frac{n}{N-n}}}{2}$ when $N < 2n$.

Therefore, the relevant price without the platform is always $p^t = \frac{v}{2n}$. This is actually the same price as p_a^w, that is the price for walkers in Region A.

Hence, we immediately conclude, based on previous results, that:

- in Region A, $p^w = p^t$, in region B and C $p^w > p^t$.

- if $n \geq 3$, then $p^s \geq p^t$ if and only if $v \geq \overline{v}_a$, with $p^s = p^t$ when $v = \overline{v}_a$.

When $n < 3$, one should compare p^s_b and p^s_c with p^t. The crossing $p^s_b = p^t$ occurs at $v = \frac{n\left(N(n-2)^2+2n\left(2n^2-n-2\right)\right)}{2(n-1)(N(n-2)^2+2n(n^2+2n-2))}$, which belongs to Region B if either of the two following conditions holds:

- $n \in \left[\frac{5+\sqrt{13}}{3}, 3\right]$
- $n \in \left(2, \frac{5+\sqrt{13}}{3}\right]$ and $N < \frac{2n(5n-2)}{10n-3n^2-4}$.

The crossing $p^s_b = p^t$ occurs at $v = \frac{n(N-2n)}{2(n-1)(N-n)}$, which belongs to Region C if and only if $n \in \left(2, \frac{5+\sqrt{13}}{3}\right]$ and $N \geq \frac{2n(5n-2)}{10n-3n^2-4}$.

□

Proof of Lemma 3 and Proposition 4. This proof begins by showing that Lemma 3 holds. For this, it is important to keep in mind the following aspects. Obviously, when a single agent maximises an objective function, it must be the case that the function is increasing at the left of the maximum and decreasing at its right. However, in the case of entry, the new entrant is not choosing n to maximise profits. Similarly to the textbook case of the problem of the commons, a new entrant is only considering whether profit, conditional on their entry, will be enough to recover any fixed cost.

As a consequence, suppose that $\pi^x > \pi^y$ and that, for a given n^y, condition $\pi^y = F$ holds. Then, it must be that $\pi^x > F$, which implies that new firms will enter and that $n^x > n^y$.

In order to prove Proposition 4, profit is analysed region by region, always comparing the case with the platform (denoted π_k, with $k = \{a, b, c\}$) and without it (denoted by π_t).

Region A The difference in profits $\pi_a - \pi_t$ is:

$$\frac{4v^2(N-n)(n-2) + Nn(N(n-2)+2n)(4v^2-4v+1)}{8N^3(n-2)n} \tag{28}$$

which is always positive for $v \geq \frac{1}{2}$.

Region B The difference in profits $\pi_b - \pi_t$ is:

$$\frac{4v^2\left(N^2(n-2)\alpha + 2\alpha + 2n(N-n) - n^3\right) - 4v\alpha N\left(\alpha - 2n^2 - 3n + 4\right)\big) + \alpha N(\alpha - 8n(n-1))\big)}{8N^3\left(\alpha(n-2)+n^3\right)} \tag{29}$$

It is a matter of algebra to show that, as long as $v \geq \frac{n(3n-4)}{2(n^2+n-2)}$ (which is the lower bound to be in Region B), Eq. (29) is increasing in v and is positive at $v = \frac{n(3n-4)}{2(n^2+n-2)}$.

Region C The difference in profits $\pi_c - \pi_t$ is:

$$\frac{4v^2(N-n)(N^2-nN-1) - 4vN(N-2n)(N-n) + N(N-2n)^2}{8N^3(N-n)} \tag{30}$$

from which it follows that profit in Region C is larger as long as the numerator is positive, that is

$$v > \frac{N(N-2n)(N-n) + (N-2n)\sqrt{N(N-n)}}{2(N-n)(N^2-nN-1)} \tag{31}$$

Since the condition on v is weaker than the condition defining the lower bound of Region C, it follows that it is always verified.

Assuming that firms face some fixed cost (this could be, for example, a licence or settlement cost), potential competitors will enter if, at any point in time, profit exceeds those costs (this is true, irrespective of whether profit is increasing or decreasing in n). Hence, if gross profit is larger with the platform, potential entrants will keep joining. □

Proof of Lemma 4 and Proposition 5. First, I show that the equilibrium with a platform is weakly Pareto superior for all agents that are inactive without the platform (Lemma 4). I then proceed with the proof of Proposition 5.

If an agent is inactive without the platform, they can choose to be inactive with the platform too, in which case they would achieve the same level of utility. Hence, the scenario with a platform must be weakly preferred. If any previously inactive agent starts consuming under the platform equilibrium, then by revealed preferences they must be better off (strictly, for all agents but the marginal consumer).

The proof of Proposition 5 is organised by region. In region A, the walker price is the same as without the platform: $p^t = p^w$. Hence, at first sight everyone could replicate the equilibrium without the platform and get at least the same utility.

It is important to look at this in more detail. First of all, notice that the platform allows every potential consumer to figure out which are the n varieties for sale. Conversely, without the platform some agents decided to buy while ignoring whether the variety that they are looking for is even produced. This has two consequences: some agents that were buying without the platform will realise that their preferred variety is not produced. Their expected utility was positive, but ex-post they were necessarily suffering a loss, as the quality of the match was deemed unsatisfactory. These agents will stop consuming, moving from an ex-post negative utility to a zero utility, hence their welfare increases.

The second consequence concerns walkers. They will keep buying offline and they pay the same price. However, their ex-ante expected utility increases because their probability of a high quality match increases from $\frac{1}{N}$ to $\frac{1}{n}$.

Finally, if an agent was buying without the platform and becomes a surfer with the platform, then again by revealed preferences they must be better off. The argument is simple. Those agents would have been able to *walk* (i.e. to buy offline) at the same price as before and with a larger probability of a good match. If they decide to *surf* (i.e. to buy online), it must be that this option is even more profitable for them.

In Region B, $p^t < p^w$, walkers hence pay more than before, but their probability of a good match is larger. Thus, the overall effect is ambiguous. Comparing the utility of agents without and with the platform doesn't lead to a definitive result. It is possible, however, to compute the utility of the marginal agent without the platform (i.e. $\hat{x}_o^t = \frac{v}{2N}$), as well as to show that $max\{EU^s, EU^w\} \geq EU^t$, that is, under all possible combinations of parameter values, the expected utility of the marginal agent is always larger with the platform. The marginal agent is therefore always strictly better off with the platform, and hence there also exists a neighbourhood around $\hat{x}_o^t$ where this is true.

At the other extreme, when $x_i = 0$, there is no simple expression to define when the platform scenario is preferred. There are specific combinations of parameters for which the platform scenario is preferred, while other combinations imply that only a subset of agents is better off with the platform.

In Region C, one can look directly at the case of $x_i = 0$, which is the location where the condition for the platform scenario to be preferred is most stringent. In this region, everyone buys online at a greater price than that without the platform. Yet, the better quality of matches may justify the extra cost.

Computing the difference in utility between buyers without the platform and surfers, it appears that the scenario with a platform is (weakly) Pareto superior whenever

$$v \geq \frac{N(N(3n-4) - 2(n-2)n)}{2(N-n)(Nn+n-2)}. \tag{32}$$

Comparing this threshold with the lower bound for Region C, it is possible to conclude that the platform scenario is Pareto superior if and only if the (non-trivial) quadratic inequality $N^2(4-n)(n-2) + N(n-2)(4-8n) + (n-2)\left(2n^2 - 4n\right) > 0$ is satisfied. Having $n > 4.4$ is a sufficient condition for the inequality to be satisfied, in which case the platform scenario Pareto dominates the scenario without a platform, in Region C. When $2 < n < 4.4$, there are several combinations of n, N and v such that the platform scenario Pareto dominates. However, there are several other combinations of parameters for which the benefits of the platform are unevenly distributed, with some agents that benefit and others that lose from the presence of the platform. □

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