Exclusionary Pricing in Two-Sided Markets*

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Abstract

This paper studies the incentives to engage in exclusionary pricing in the context of two-sided markets. Platforms are horizontally differentiated, and seek to attract users of two groups who single-home and enjoy indirect network externalities from the size of the opposite user group active on the same platform. The entrant incurs a fixed cost of entry, and the incumbent can commit to its prices before the entry decision is taken. The incumbent has thus the option to either accommodate entry, or to exclude entry and enjoy monopolistic profits, albeit under the constraint that its price must be low enough to not leave any room for an entrant to cover its fixed cost of entry. We find that, in the spirit of the literature on limit pricing, under certain circumstances even platforms find it profitable to exclude entrants if the fixed entry cost lies above a certain threshold. By studying the properties of the threshold, we show that the stronger the network externality, the lower the thresholds for which incumbent platforms find it profitable to exclude. We also find that entry deterrence is more likely to harm consumers the weaker are network externalities, and the more differentiated are the two platforms.

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1. INTRODUCTION

Two-sided markets are an area of considerable research in the field of Industrial Organisation. Based on the initial work of Caillaud and Jullien (2003), Rochet and Tirole (2003) and Armstrong (2005), the literature has studied, among other problems, the role of the price structure in solving coordination problems. Caillaud and Jullien (2003) and Armstrong (2006) show that platforms may set "negative prices" on one side in order to enhance participation. This paper builds on this work on two-sided markets, merging it in particular with the literature dealing with exclusionary pricing.

Two-sided platforms generally refer to situations where (at least) two distinct user groups (i.e. two demands) interact with each other through a common platform and the participation of at least one of these groups affects the value of participation for the other group(s). Following Evans (2003), "a platform constitutes the set of the institutional arrangements necessary to realize a transaction between two users groups".

Two-sided platforms are very common and are present in many markets including: stock exchanges, internet portals, payment card systems, newspapers, television broadcasters, directories, smartphones, mobile and fixed telecommunication networks and estate agents. These examples cover very diverse industries affecting many different aspects of consumers' lives. It is therefore essential to have a thorough understanding of these platforms not only from an academic perspective but also from a more practical perspective, for instance in order to properly enforce antitrust scrutiny.

Often, in the scientific domain as well as in the public debate, it is advocated that multi-sided platforms deserve a special (typically, more relaxed) scrutiny by antitrust authorities (see Evans and Schmalensee (2007)). The aim of this paper is to examine whether the presence of (indirect) network externalities makes platforms indeed less prone to exclusionary conduct, as is often maintained, or whether instead the opposite is the case.

We answer this question in a setting where we apply the concept of entry deterrence in a sequential move game à la Dixit (1980) to a canonical two-sided market that we borrow from Armstrong (2006). Users (final consumers) on one side derive a positive externality from participation on the other side. We study both the monopoly and the duopoly equilibria of this model, where duopoly arises as the result of an entry game in which an incumbent platform can set its prices to the two user groups (and commit to these prices) before a potential entrant gets to make its entry and pricing decisions. Thus the incumbent has the ability to deter entry in our setting, and possibly also the incentives if it is profitable to do so. We study when this indeed arises, and its welfare properties.

The debate on platforms and the role of competition policy is very much at the forefront of the current policy discussion. There is a widespread climate of reflection around the world, as evidenced by many reports and hearings, notably the FTC hearings in the US, the European Commission special advisors report (European Union, 2019), the French and German reports (AC-BKartA, 2016), the Furman report (HM Treasury, 2019) and the House of Lords report (House of Lords, 2016) in the UK, the JFTC report on data in Japan (JFTC, 2017), and the recent final report from the Australian Competition Authority (ACCC, 2019). All these reports and hearings explore how competition authorities should meet the challenges arising from analysing competition between platforms and show a high degree of convergence when it comes to identifying these challenges. Among the most important ones, it is worth recalling (i) the reflection on how competition authorities should define relevant markets with multi-sided platforms, (ii) understanding the role of data, (iii) the need to scrutinise acquisitions of innovative start-ups by the digital incumbents, (iv) analysing the source of platforms' market power, and (v) last but not least (and crucially for our paper) how platforms compete in markets where network externalities and returns to scale are strong, especially in the absence of multi-homing, or protocol and data interoperability. Eventually they all seem to advocate for a closer and more thorough scrutiny of platforms recognising their ability and incentive to hamper competition.

This paper is very much inspired by the current debate, and its aim is to provide some guidance to competition authorities on the likelihood of anticompetitive foreclosure in a context where indirect network externalities are strong and the platforms are differentiated. The paper reaches the conclusion that under certain circumstances the presence of network externalities does not make platforms less prone to embracing exclusionary conduct.[1] The paper also provides two extensions that preliminarily study, on the one hand, the restriction on the platforms to set non-negative prices and, on the other hand, the introduction of the option for customer to multi-home on one side of the platform, i.e. so called competitive bottlenecks.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature. Section 3 builds the benchmark model. Section 4 characterises the equilibria. Section 5 studies the welfare implications. Section 6 presents a discussion on non-negative prices, and on competitive bottlenecks. Section 7 concludes.

2. LITERATURE REVIEW

A natural approach when starting to model exclusionary pricing in a multi-sided framework is to turn to the literature on exclusionary pricing in standard one-sided markets, to see how they can be adapted to fit the two-sided framework, and to what extent the results obtained for one-sided markets carry over to the multi-sided framework. There are many different avenues that one could take, and this article focuses on one specific but standard setting.

This paper is based on the strand of literature regarding exclusionary strategies which are not driven by asymmetric information, and which, among other papers, are also associated with the work of Dixit (1980). Dixit (1980) belongs to an earlier literature on entry deterrence through limit pricing, where an incumbent can discourage entry by setting a price just low enough (or producing an output just high enough) to render prospective entry unprofitable. The limit pricing literature relies on the presence of scale economies to achieve foreclosure. In this field of the literature, the incumbent has a first-mover advantage in making its price (or output) choices in a way that leaves no room for entrants to establish their business alongside the incumbent in the market.

Our paper is cast in terms of price competition, and incorporates the concept of limit pricing into the framework of duopolistic platform competition as developed by Armstrong (2006). It is also remotely related to the "divide-and-conquer" stream of literature (see for instance Segal (2000)), whereby one group of buyers is locked in by the incumbent with very favorable offers, so as to prevent a potential entrant from reaching critical scale, thus allowing the incumbent to then monopolise the rest of the market.

A key assumption of this paper is thus that all relevant parameters and actions are fully observable to all

[1] Such potential for exclusionary conduct in two-sided markets was also found in the context of anticompetitive tying by Choi and Jeon (2020).

players, notably to consumers and to the entrant. Thus, our paper does not speak to the rich literature on exclusionary conduct which builds on asymmetric information between incumbent and entrant, and explains the rationality of predation through signalling or reputation building on the side of the better informed incumbent. These models tend to focus on the informational asymmetry among the two suppliers, while treating the competitive interaction in a rather reduced-form way. This is why these models do not lend themselves easily to an adaptation to a two-sided context, where the exact nature of competition on either side of the market is arguably an important feature if one wants to gain further insight beyond what is known about one-sided markets.

The first contribution of our paper is thus to relate the incentives of a two-sided platform to engage in limit pricing to the features of the market, notably the intensity of network externalities and the level of differentiation across platforms. The second contribution lies in its analysis of consumer welfare. Previous models of exclusionary conduct in network industries struggled to find instances where exclusion, beyond being individually rational for the incumbent firm engaging in such conduct, would also be harmful to consumers.

In the model studied by Vasconcelos (2015), the incumbency advantage consists in having locked-in an installed base. While the incumbent is less efficient at providing the network good (it has a higher marginal cost of serving both the 'old' and the 'new' consumers), it generates larger network externalities for all consumers because of the presence of the installed base. The arrival of a second platform in the market leads to a fragmentation of the customer base, which severely reduces the consumption benefits provided by either of the two platforms.

In our model, the introduction of a second platform into the market involves a similar trade-off between the benefits of reducing transportation costs (which is akin to the difference in marginal costs of production in Vasconcelos (2015)) and the welfare losses from the reduction in network externalities when the consumer base is split into two smaller consumer groups.

The main differences between our model and that of Vasconcelos (2015) are that (i) in our model, price setting is sequential (the incumbency advantage being that the incumbent can set its prices first, and commit to them), and (ii) there is a fixed cost of entry to be paid by the entrant (which further reduces the welfare gains from entry). By contrast, in Vasconcelos (2015), the two platforms set their prices simultaneously (competing only over the 'new' consumers, not the entire consumer base, as in our model), and the entrant does not face any entry costs. The features of our model allow us to distinguish between an accommodating strategy and an exclusionary strategy for the incumbent, which cannot arise in the model of Vasconcelos (2015).

When it comes to policy considerations, we find that there is a non-empty space where exclusion arises but reduces consumer surplus - which is the standard metric adopted by enforcers in antitrust - compared to the duopoly equilibrium. This is in contrast to Vasconcelos (2015). To see why this can happen in our model, consider a situation where, at the accommodating equilibrium, the entrant (who always charges a lower price than the incumbent in the duopoly equilibrium) just barely breaks even. In this situation, the incumbent will need to lower its prices just by an epsilon to achieve exclusion. To fix ideas, also suppose that network externalities are close to zero, so that the extra benefit from avoiding fragmentation of the consumer base is almost zero as well. Then, the surplus of those consumers who always engage with the incumbent platform (even under duopoly) will be almost unchanged by exclusion. However, those consumers who engage with the entrant platform when available will certainly be worse off under exclusion, because they have to pay the (higher) prices of the incumbent platform, and incur the additional transportation costs, without experiencing any (appreciable) increase in network benefits.

Our paper also speaks to the recent literature on the determinants of platform market structure. Karle et al. (2020) study platforms providing intermediation services, i.e. enabling transactions between buyers and sellers. They find that when sellers compete intensely among each other, this tends to give rise to multiple platforms relaxing competition among the sellers, while industries with soft product market competition tend to display platform agglomeration where all users locate on a single platform.

Markovich and Yehezkel (2019) analyse a setup where two platforms compete for a user population composed of many small users and one compact user group. One of the two platforms offers higher quality than the other, but needs to attract a minimum number of users to be viable. Because of miscoordination among the buyers, the industry may be stuck in an inefficient equilibrium where all users locate on the low-quality platform. The paper studies under what conditions the presence of the user group can take the industry to the efficient equilibrium, and how the benefits are distributed among the different user types and the winning platform.

One of the main ingredients of our analysis is the canonical model of Armstrong (2006), where both sides can decide which platform to patronise, but, once this decision is made, each side "single-homes". This modelling choice is dictated by several factors.

First, we think it is natural to start from a seminal model that has made considerable inroads in the literature. Second, it does actually apply in real-life circumstances. Belleflamme and Peitz (2015, page 667) discuss at some length single-homing environments in the real world. These can be motivated by indivisibilities (including time and attention) and limited resources. Cases with single homing on both sides of a two-sided platform apply to marketplaces where buyers and sellers can physically locate in only one of them. Obvious examples could be some physical markets but instances extend beyond these. According to Clements and Ohashi (2005), only 17% of video-game publishers in their sample were available on multiple platforms, at least for early generations of game platforms. Kaiser and Wright (2006) similarly report single-homing both for readers and advertisers for specialised magazines.

Third, it is often challenging to reach a definitive conclusion on the extent of single-homing versus multi-homing in a given market, which speaks in favour of analysing the two options. For instance, the CMA in his market study on Digital Comparison Tools[2] faced significant difficulty in properly estimating the extent of single-homing versus multi-homing and concluded that there was mixed evidence.

Fourth, and importantly for the policy angle that ultimately motivates our approach, single-homing is often the result of contractual restrictions. Belleflamme and Peitz (2015) mention German taxi companies that sign exclusive contracts with call centers. Shopping malls regularly impose the so-called 'radius clause', whereby they prevent retail chains from opening another outlet in an adjacent competing shopping mall. Ride hailing companies Uber and Lyft have designed their application to make it difficult for drivers to multihome.

[2] See Digital comparison tools market study, Final report, Paper E: Competitive landscape and effectiveness of competition, https://assets.publishing.service.gov.uk/media/59e093f5e5274a11ac1c4970/paper-e-competitive-landscape.pdf. It is also worth noting that when discussing the empirical evidence, the CMA also pointed to the fact that apps and voice devices might play a role in the future in increasing the extent of single-homing.

Many media markets also have the feature that content is exclusive. Such contractual restrictions may be anti-competitive practices enacted by some dominant companies.

Entry deterrence and exclusionary practices that limit multi-homing should then be seen in the same context. For instance, the EC Google AdSense case[3] was about online search advertising intermediation (between advertisers and website owners, including newspapers), a key entry point for search ads. According to the European Commission, Google imposed clauses (such as exclusivity prohibiting placing search ads from competitors on their search results page, then replaced by premium placement clauses, in practice preventing competitors from placing their ads on the most visible parts of the website's search results pages) that made it difficult, if not impossible, for websites to use or even begin testing with other search providers – in practice there was no significant multi-homing among websites, the side of the market that would generally be expected to do so. At national level, the Swedish competition authority has also very recently issued an interim decision against a platform fitness aggregator (matching consumers and training facility owners) for imposing exclusivity agreements on the training facility owners.[4] Also in the US, the FTC sued in 2019 the health information company Surescripts[5] for monopolising two 'e-prescribing' markets, i.e. routing and eligibility services. By means of illegal vertical and horizontal restraints, Surescripts set out to keep e-prescription routing and eligibility customers on both sides of each market from using additional platforms (i.e. preventing customers to multi-homing) using anticompetitive exclusivity agreements, threats, and other exclusionary tactics.

Notwithstanding these remarks, we think our analysis and findings should be extended in other directions too, especially when one is seeking to derive broader policy implications. In particular, we believe it is important to analyse exclusionary behavior in a context of "competitive bottlenecks", where one side single-homes and the other side multi-homes. A preliminary discussion in that direction is done in Section 6.2 below.

3. THE BENCHMARK MODEL

We start by recalling the basic features of the canonical model developed in Armstrong (2006). Let there be two groups of agents, 1 and 2, each of mass 1, and two platforms, A and B, on which the two groups can interact. An agent in one group cares about the number of the other group who use the same platform, i.e. network externalities are of the indirect type in our model. If both platforms are active on the market, agents are assumed to single-home, i.e. they can join either of the two platforms, but not both.

When joining platform $i = A, B$, agents of group 1 and 2 obtain net utilities u_1^i and u_2^i, respectively. These net utilities are assumed to depend (i) on the number of agents of the *opposite* group present on the *same* platform, (ii) on the fixed benefit the agent obtains from using that platform, and (iii) on the uniform membership fee charged by platform i to that agent. Denote by n_1^i and n_2^i the number of agents of group 1 and 2, respectively, who joined platform i. Net utilities $\left\{u_1^i, u_2^i\right\}$ are expressed as follows:

$$u_1^i = \alpha_1 n_2^i + v - t_1 D\left(i, x\right) - p_1^i \text{ and } u_2^i = \alpha_2 n_1^i + v - t_2 D\left(i, x\right) - p_2^i. \tag{1}$$

[3]Case AT.40411, Decision of 20 March 2019 fining Google EUR 1.49 billion for infringing Art. 102 TFEU. The decision is currently under appeal at the EU General Court.

[4]See http://www.konkurrensverket.se/globalassets/konkurrens/beslut/19-0572.pdf

[5]Complaint of 24 April 2019, see https://www.ftc.gov/enforcement/cases-proceedings/141-0210/surescripts-llc

The parameter $\alpha_1 > 0$ measures the benefit that a group-1 agent enjoys from interacting with each group-2 agent, and similarly for $\alpha_2 > 0$. We thus follow Armstrong (2006) in assuming that the intensity of cross-group externalities, $\{\alpha_1, \alpha_2\}$, does not depend on the identity of the platform i, but only on which side of the market the agent is on (1 or 2).[6]

The term v is a fixed benefit from using a platform which is independent of agent group, group size, and platform identity. The individual transportation cost incurred by an agent from group 1(2) in reaching supplier $i = A, B$ is denoted by $t_{1(2)}D(i, x)$, and corresponds to the standard product differentiation term in the Hotelling model. Agents in a group are assumed to be uniformly distributed over the unit interval, with the two platforms located at the two endpoints. The transportation cost for a consumer from group 1(2) located in $x \in [0, 1]$ is then obtained as the product of $t_1(t_2) > 0$ and the distance of the consumer from platform i, which is given by $D(A, x) = x$ and $D(B, x) = 1 - x$, respectively. This specification allows us to study situations where agents in one group consider the two platforms as highly substitutable, while agents on the other side consider them as very differentiated, independently of how strong the network externalities are across the two groups.

Finally, the term p_1^i (p_2^i) denotes the flat membership fee (in the following simply called "price") charged uniformly to all agents of group 1 (group 2) by platform $i = A, B$. Agents are thus charged a flat price for joining the platform (like a subscription fee), not a per-transaction fee, so that the agent's payment is independent of the number of agents (and hence transactions) on the other side of the platform. In practice, this price structure can often be found in media and telecoms outlets, but does not apply, for instance, to the credit card industry.

We will follow Armstrong (2006) in assuming that network effects are not too strong, in order to avoid equilibria where a single platform attracts all users and concentrate instead on those cases where competition happens. The necessary and sufficient condition for a market-sharing equilibrium to exist is:

$$4t_1t_2 > (\alpha_1 + \alpha_2)^2 . \tag{2}$$

3.1. Monopoly Pricing

We first solve for a monopolist's optimal pricing, assuming that each platform faces the same constant per-agent cost f_1 for serving group 1 and f_2 for serving group 2. Given that the incumbent platform A is located at endpoint 0, the solution to the monopolist's problems is either an interior solution or a corner solution. For analytical convenience, we concentrate on the corner solution such that the monopolist optimally serves the entire market, i.e. $n_1^A = n_2^A = 1$. In this case, the platform will extract the full consumer surplus from each of the two agents located at endpoint 1 (the consumers with the highest transportation cost on the unit line), which determines the price charged to all other consumers of the same group.

In the Appendix, we characterise both the monopoly corner solution and the interior solution where the monopolist serves only part of the market. Intuitively, we rule out this possibility with a condition such that the stand-alone value v from joining the platform is "high enough" (see the Appendix for details). This implies that each agent's participation constraint will always be satisfied under all possible monopoly and duopoly prices, i.e. no agent will prefer to stay out of the market rather than joining her preferred platform.

[6] These assumptions thus depart from the setup in Rochet and Tirole (2003), where the intensity of cross group-externalities varies with the agent's identity and with the platform they join.

In our model we will always have full market coverage for both groups, so that all agents of a group join exactly one platform: $n_i^A + n_i^B = 1$.

Our model thus represents a mature network market where a given platform can only grow at the expense of its rival, but not through market expansion into areas on the unit line not yet covered by any supplier. This means that entry, where it occurs, will have a tangible impact on the incumbent's market share and profits, which in turn is a necessary condition for entry deterring conduct to be rational in the first place. When and how such entry deterrence will arise is then the focus of our equilibrium analysis.

3.2. Duopoly Pricing

We start by characterising demand as a function of the prices charged by the different firms in the market. An agent of group 1 residing at location $x_1 \in [0,1]$ on the unit line weakly prefers Platform A over B if $u_1^A \geq u_1^B$, where u_1^A and u_1^B are presented in eq. (1). The indifferent consumer is thus located at $\tilde{x}_1$ at which $u_1^A = u_1^B$, which can be rewritten as:

$$\tilde{x}_1 = \frac{1}{2} + \frac{\alpha_1\left(n_2^A - n_2^B\right) - \left(p_1^A - p_1^B\right)}{2t_1}.$$

All consumers of group 1 to the left of $\tilde{x}_1$ strictly prefer to join Platform A, while all consumers to the right of $\tilde{x}_1$ strictly prefer Platform B. The number of group 1 agents attracted to Platform A is thus $n_1^A = \tilde{x}_1$, while the number of group 1 agents joining Platform B is $n_1^B = 1 - \tilde{x}_1$. The share of group 2 agents who join Platform A, $\tilde{x}_2$, can be found analogously to $\tilde{x}_1$.

We see that the market shares that arise on one side of the market, say group 1, depend on the market shares the two platforms hold in group 2, and vice versa. Using the full market coverage assumption, $n_1^i = 1 - n_1^j$, we can rewrite the market shares for the two groups of agents as follows:

$$n_1^i = \frac{1}{2} + \frac{\alpha_1\left(2n_2^i - 1\right) - \left(p_1^i - p_1^j\right)}{2t_1} \text{ and} \tag{3}$$

$$n_2^i = \frac{1}{2} + \frac{\alpha_2\left(2n_1^i - 1\right) - \left(p_2^i - p_2^j\right)}{2t_2}. \tag{4}$$

Inspecting these two expressions, we see that platform differentiation mitigates the network externalities exerted between the two groups: ceteris paribus, an additional agent of group 2 on platform i will attract another α_1/t_1 agents from group 1 to the same platform.

Denote the price vector by $\mathbf{p} = \left(p_1^i, p_1^j, p_2^i, p_2^j\right)$. We can then express the demand system as functions of the price vector by solving the simultaneous equations of (3) and (4) to obtain:

$$n_1^i(\mathbf{p}) = \frac{1}{2} + \frac{1}{2}\frac{\alpha_1\left(p_2^j - p_2^i\right) + t_2\left(p_1^j - p_1^i\right)}{t_1 t_2 - \alpha_1\alpha_2} \text{ and} \tag{5}$$

$$n_2^i(\mathbf{p}) = \frac{1}{2} + \frac{1}{2}\frac{\alpha_2\left(p_1^j - p_1^i\right) + t_1\left(p_2^j - p_2^i\right)}{t_1 t_2 - \alpha_1\alpha_2}. \tag{6}$$

Platform i's profits in the single-homing duopoly as a function of the price vector are thus given by:

$$\pi^i(\mathbf{p}) = \left(p_1^i - f_1\right) n_1^i(\mathbf{p}) + \left(p_2^i - f_2\right) n_2^i(\mathbf{p}). \tag{7}$$

Armstrong (2006) shows in his Proposition 2 that, if the two platforms choose prices simultaneously, and Condition (2) holds, this model has a unique equilibrium that is symmetric, and equilibrium prices for group 1 and group 2 are given, respectively, by

$$p_1 = f_1 + t_1 - \alpha_2 \text{ and } p_2 = f_2 + t_2 - \alpha_1. \tag{8}$$

The resulting equilibrium (gross) profits under duopoly can therefore be characterised as:

$$\begin{aligned} \pi^i(\mathbf{p}) &= \left(p_1^i - f_1\right) n_1^i(\mathbf{p}) + \left(p_2^i - f_2\right) n_2^i(\mathbf{p}) \\ &= \frac{1}{2}\left(t_1 + t_2 - (\alpha_1 + \alpha_2)\right). \end{aligned}$$

where $n_1^i(\mathbf{p}) = n_2^i(\mathbf{p}) = \frac{1}{2}$ for $i = A, B$ follows from the symmetry of the equilibrium.

We depart from Armstrong (2006) in considering a *sequential* move game instead of a simultaneous move game. This is because our main focus below in Section 4 is on exclusionary strategies based on a standard model of limit pricing, where the incumbent moves first, followed by an entrant. We thus think it is more appropriate to keep the timing unchanged when comparing equilibria with and without exclusion.

In particular, we assume that the incumbent platform, say Platform A, sets its prices $\left(p_1^A, p_2^A\right)$ before the entrant platform, here Platform B, can do so, and that Platform A cannot modify its prices later upon observing B's prices $\left(p_1^B, p_2^B\right)$. For instance, such commitment to particular prices will arise in practice whenever the incumbent engages in legally binding long-term contracts with the users of its platform, where the contract term covers the time window of entry, and the price stipulated in these contracts cannot be unilaterally raised by the incumbent.[7] More generally, there can also be other reasons why platforms can commit to prices like reputational reasons or menu costs.

We provide the closed-form solution to the sequential price-setting game in the Appendix. As becomes apparent from inspecting the expressions of this solution, the fixed per-agent costs f_i do not play a relevant role. From now onwards, we therefore set them to zero without loss of generality, and prices can be interpreted as margins above such costs.

4. EXCLUSIONARY PRICING

In what follows, we will apply the concept of "limit pricing", sometimes referred to as the BSM (or Bain–Sylos Labini–Modigliani) model,[8] to study the incentives of an incumbent platform to deter entry by a second platform in the setup of Armstrong (2006).

The starting point of the BSM model is that an entrant's decision to enter an industry depends on the entrant's expectations about the profits it will make post-entry: If these expected profits are not sufficient to cover the entry costs, the entrant prefers to stay out of the industry. The incumbent may then take some actions prior to entry which will reduce the entrant's profits below the break-even, thus discouraging the entrant from entering the industry. Such pre-entry actions may consist in either reducing price below the

[7] If instead the model is cast in terms of quantity competition, then the incumbent may be able to make pre-entry investment in capacity levels which lower the incumbent's marginal cost of production in the post-entry period accordingly, so that an aggressive output reaction to the entrant's entry becomes credible (see Dixit, 1980).

[8] See Bain (1956), Sylos Labini (1962), and Modigliani (1958).

monopoly level (the latter is referred to as "limit pricing") or expanding output (or capacity) above the monopoly level, such that an entrant, even when behaving optimally given this limit price (or limit output), cannot recover its fixed cost of entry.

For such a strategy of entry deterrence to be adopted by a rational incumbent, two conditions must hold: (1) the incumbent's actions must have commitment value, meaning that the incumbent cannot revise its price (or quantity) level later on if entry should occur nonetheless; otherwise, such actions would not have any deterrence effect, because the entrant anticipates that it would be in the incumbent's interest to accommodate entry (i.e. lower the output, or raise the price) once entry occurs; (2) the profits earned by the incumbent under limit pricing must exceed the profits it could earn under entry accommodation. The latter correspond to the profits derived for the sequential duopoly equilibrium derived above (for the full expression, see eq. (31) in the Appendix).

For the remainder of this analysis, we will take for granted that the incumbent can precommit to a price, and will focus on the question under which circumstances it will be profitable for the incumbent to commit to a price that differs from its accommodating price. To do so, we will first characterise the incumbent's profits when setting the limit price, and then compare these profits to the profits when the entrant is instead accommodated.

The game unfolds in the following three stages:

Stage 1: The incumbent platform A sets prices to the two groups of agents: p_1^A and p_2^A;

Stage 2: The entrant decides whether to enter or to stay out; if entry occurs, entrant platform B incurs an entry cost of K and sets prices to the two groups of agents: p_1^B and p_2^B. We assume that entry is viable if the entrant is accommodated by the incumbent. E.g., it is $K \leq \pi_{acc}^B$, where the expression for π_{acc}^B is given by (32) in the Appendix.

Stage 3: Agents observe all available platforms and prices and choose which platform to join.

We will solve this game by backward induction.

Stage 3. Suppose that Platform B entered in stage 2, so that users can choose between the two platforms. Then, utility maximisation by the agents of both groups gives rise to the demand system as given in eq.s (5) and (6) above. If instead only Platform A is available, we will maintain the assumption of full market coverage, so that all users will turn to Platform A (recall that each group has mass 1), so that Platform A's profits are given by

$$\pi_{ED}^A = p_1^A + p_2^A,$$

(where the subscript ED stands for "entry deterrence").

Stage 2. If Platform B enters, then it takes Platform A's prices as given (recall that we assumed that the latter cannot be revised after Stage 1), and chooses its own prices optimally by solving the following problem:

$$\max_{p_1^B, p_2^B} \pi^B(\mathbf{p}) = p_1^B n_1^B(\mathbf{p}) + p_2^B n_2^B(\mathbf{p}) - K. \tag{9}$$

Platform B enters if it can at least cover the fixed cost of entry, K. Otherwise, B stays out of the market.

Stage 1. At stage 1, Platform A has to decide whether to accommodate Platform B or to deter B's entry.

4.1. A Special Case: Symmetry

To set the scene, we start with a simplified version of our model, in which we assume the following symmetric parameters:

$$t_1 = t_2 = 1, \text{and } \alpha_1 = \alpha_2 = a.$$

Under this parametrisation, the expressions for the corner solution of the monopoly problem can be written as:

$$p_1^M = p_2^M = a + v - 1, \quad n_1^M = n_2^M = 1, \tag{10}$$

while the equilibrium prices and outputs in the duopoly equilibrium simplify to:

$$p_1^L = p_2^L = \frac{3}{2}(1-a), \quad n_1^L = n_2^L = \frac{3}{8}, \tag{11}$$

$$p_1^F = p_2^F = \frac{5}{4}(1-a), \quad n_1^F = n_2^F = \frac{5}{8}. \tag{12}$$

This equilibrium is guaranteed to exist if condition (2) is met, which under the present parametrisation simplifies to $a \in [0,1)$.

The resulting equilibrium profits (gross of any fixed costs of entry) are thus given by:

$$\text{Monopoly profits} \quad : \quad \pi^M = 2(a + v - 1),$$

$$\text{Duopoly leader profits:} \quad \pi_{acc}^A = \frac{9}{8}(1-a), \tag{13}$$

$$\text{Duopoly follower gross profits:} \quad \pi_{acc}^B = \frac{25}{16}(1-a). \tag{14}$$

We see that at the duopoly equilibrium, more intense network externalities (i.e. higher values of a) intensify competition between the two platforms, and lead to lower prices and profits in equilibrium. This feature of the duopoly equilibrium will be important to understand how the presence of network externalities affects the incumbent platform's incentives to engage in entry deterrence.

Note that in a sequential price setting game, being the second mover actually confers an advantage over the first mover: The leader commits itself to a given price, and cannot adjust this price in reaction to the follower's price. If the goods are (almost) perfect substitutes, then the follower will simply undercut the leader and take the whole market. This intuition carries over to the case where the goods are differentiated (as in the Hotelling specification studied here): The follower undercuts the leader, thus securing a larger market share, and a higher profit, compared to the first mover. This feature of our model is interesting when we consider exclusionary pricing, as our setting is one which is inherently favorable to entry.[9]

Turning to exclusionary pricing, the entrant platform's best-response prices solving problem (9) in stage 3 are found as:

$$p_1^B\left(p_1^A, p_2^A\right) = \frac{1}{2}\left(1 - a + p_1^A\right),$$

$$p_2^B\left(p_1^A, p_2^A\right) = \frac{1}{2}\left(1 - a + p_2^A\right).$$

[9] If the choice variable is output instead of price, the familiar first-mover-advantage of the Stackelberg leader is again present: By committing to a large output before the follower can choose its own output level, the leader can flood the market with its own supply, thus reducing the follower's market share and profits.

Inserting these prices into Platform B's profit function, net of entry costs, we obtain:

$$\begin{aligned}\pi^B\left(p_1^A,p_2^A\right) &= p_1^B\left(p_1^A,p_2^A\right)n_1^B(\mathbf{p})+p_2^B\left(p_1^A,p_2^A\right)n_2^B(\mathbf{p})-K\\ &= \frac{1}{4}\left((1-a)+p_1^A+p_2^A\right)+\frac{1}{4\left(1-a^2\right)}\left(\frac{1}{2}\left(p_1^A\right)^2+\frac{1}{2}\left(p_2^A\right)^2+ap_1^Ap_2^A\right)-K.\end{aligned}$$

To successfully deter entry, the incumbent platform has to push the entrant's profits below the break-even level. In other words, Platform A will set its prices $\left(p_1^A,p_2^A\right)$ such that $\pi^B\left(p_1^A,p_2^A\right)=0$. In the standard one-sided setup, where the incumbent only has one price to set, the zero-profit condition for the entrant pins down the unique limit price as the upper bound on all incumbent prices which achieve entry deterrence.

In our model of two-sided markets, the incumbent has two price instruments to achieve this goal,[10] so that there is a wide combination of price pairs at which the entrant's profits would be exactly zero. Solving $\pi^B\left(p_1^A,p_2^A\right)=0$ for p_1^A, the constraint on p_1^A implied by entry deterrence can be expressed as a function of p_2^A:

$$p_1^A\left(p_2^A\right)=a^2-1-ap_2^A+\sqrt{\left(1-a^2\right)\left(8K+2a\left(1+p_2^A\right)-a^2-\left(1+p_2^A\right)^2\right)}. \tag{15}$$

Among all price pairs which satisfy condition (15), the incumbent will choose the one that maximises its profits when entry deterrence is successful, leading to a scenario where Platform A is the only available platform to consumers. As we assumed full market coverage under monopoly prices, the same holds under limit prices as well, i.e. $n_1^A\left(p_1^A,p_2^A\right)=n_2^A\left(p_1^A,p_2^A\right)=1$, since limit prices are necessarily lower than monopoly prices. Platform A's optimisation problem in the entry deterrence scenario is thus given by:

$$\begin{aligned}\max_{p_1^A,p_2^A}\pi_{ED}^A &= p_1^A+p_2^A\\ \text{s.t. } p_1^A &\leq p_1^A\left(p_2^A\right)\end{aligned} \tag{16}$$

Given our assumption on the upper bound on $K\leq\pi_{acc}^B$, the constraint is binding at the optimum. Thus, Platform A's profit function π_{ED}^A is a single-peaked function in p_2^A, and the following prices solve Problem (16):

$$p_{1,ED}^A=p_{2,ED}^A=a-1+2\sqrt{K\left(1-a\right)}. \tag{17}$$

The resulting profit under *entry deterrence* is thus given by the sum of the two prices:

$$\pi_{ED}^A=2\left(a-1+2\sqrt{K\left(1-a\right)}\right). \tag{18}$$

The incumbent platform will engage in entry deterrence if and only if this conduct is more profitable than accommodating the entrant, in which case the incumbent makes the duopoly leader profits:

$$\pi_{ED}^A\geq\pi_{acc}^A=\frac{9}{8}\left(1-a\right).$$

We see that, in our model, entry deterrence is driven by two parameters, namely (i) the level of entry costs, K, and (ii) the intensity of network externalities, a. Clearly, for high levels of K, entry deterrence can be achieved even with rather moderate price cuts, and so the incumbent will be more likely to prefer entry

[10] Note that in a setting *à la* Dixit (1980), the limit price (or quantity) set by the incumbent is exactly determined by the zero profit condition for the entrant. In a multi-sided setting instead, there is an additional degree of freedom that the incumbent can exploit to its advantage.

deterrence over accommodation. The threshold level of K above which entry deterrence will arise can be found by solving $\pi^A_{ED} = \pi^A_{acc}$ for K, which yields:

$$\tilde{K} = \frac{625}{1024}(1-a). \tag{19}$$

Proposition 1 *(entry deterrence - symmetric case)*

Under the symmetric parametrisation $\alpha_1 = \alpha_2 = a \in [0,1)$ and $t_1 = t_2 = 1$, the set of subgame-perfect Nash equilibria is given as follows:

(i) For $K \in \left[0, \tilde{K}\right)$, the entrant will be accommodated, and the resulting asymmetric duopoly profits are given by

$$\pi^A_{acc} = \frac{9}{8}(1-a), \pi^B_{acc} = \frac{25}{16}(1-a) - K.$$

(ii) For $K \in \left[\tilde{K}, \frac{25}{16}(1-a)\right]$, the incumbent platform A will set limit prices and deter entry by Platform B. The resulting profits are given by

$$\begin{aligned} \pi^A_{ED} &= 2\left(2\sqrt{K(1-a)} - (1-a)\right), \\ \pi^B_{ED} &= 0. \end{aligned}$$

As a increases, both $\tilde{K}$ and π^B_{acc} fall, so that entry deterrence equilibria arise for ever lower values of K.

Proof: Follows from above, noting that $\partial\tilde{K}/\partial a = -\frac{625}{1024} < 0$, and $\partial\pi^B_{acc}/\partial a = -\frac{25}{16} < 0$.

Figure 1 illustrates the parameter spaces identified in Proposition 1 for the symmetric case.

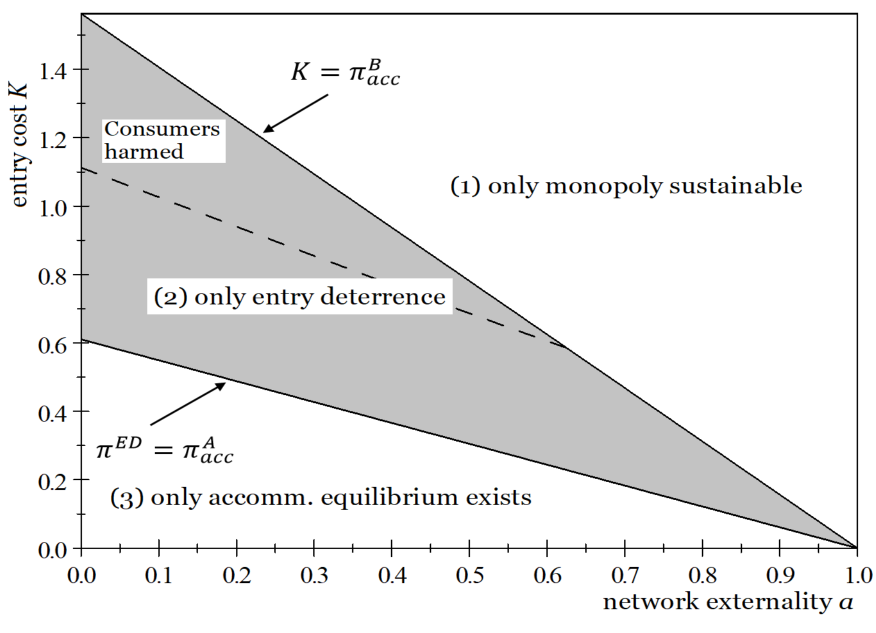

Figure 1: Symmetric case: Entry deterrence is the unique equilibrium inside the shaded cone

The parameter space is divided into three areas. In the top right corner (Region (1) in Figure 1), the fixed entry costs are so high that only monopoly equilibria are sustainable. Given our restriction $K \leq \pi^B_{acc}$ we do not consider this area any further. In the bottom left corner (Region (3) in Figure 1), the fixed entry costs are so low that the incumbent prefers accommodation over entry deterrence, so that only accommodating duopoly equilibria exist in this part of the parameter space.

In the grey-shaded area of Figure 1 (Region (2)), the fixed entry costs are in an intermediate range where they are high enough to make entry deterrence preferable over accommodation, but still low enough so that the entrant would enter if accommodated (but not if confronted with limit pricing). In this region of the parameter space, entry deterrence will arise as the unique equilibrium of the game.[11]

Note that entry deterrence equilibria exist for *all* values of the network externality a, i.e. there is no "safe haven" value for a beyond which entry deterrence would become impossible. This is the area of immediate interest in our analysis, as this is where a strategy of entry deterrence is rational and will succeed.

We can observe immediately that, the stronger this network externality a:

(i) the less likely it is that a duopoly will arise in equilibrium (in the sense that the range of values of entry cost K compatible with a duopoly equilibrium shrinks as a increases);

(ii) the less likely entry deterrence equilibria become over all; and

(iii) the lower the entry cost levels at which entry deterrence equilibria become feasible (in the sense that the range of values of entry cost K compatible with entry deterrence equilibria shrinks as a increases, and shifts down all the way to (almost) zero).

In other words, entry becomes generally more difficult as network externalities grow stronger, and entrants become ever more vulnerable to entry deterrence, even at low levels of entry costs. As network externalities become stronger, competitive pressure in the duopoly increases, and the leader's profits in the duopoly drop faster than in the corresponding limit pricing scenario, so that, all else equal, the incumbent platform has more and more incentives to engage in entry deterrence. At the same time, the duopoly equilibrium becomes more and more difficult to sustain, because the follower's profits fall as well as a increases, so that the industry moves to a situation where only a monopoly would be sustainable.

Intuitively, the reason why duopoly profits drop faster in a than limit pricing profits is that under entry deterrence, the leader's profit is affected by a through two opposite channels. While the negative impact of network effects on market power is still present even under entry deterrence, the incumbent platform also benefits from the fact that it becomes a monopolist, so that the fragmentation of the two user groups across two competing platforms is avoided. As a result, Platform A can maximise network benefits on both sides of the platform, which makes its profits increase in a.

We also analysed, for completeness, the case of "blockaded" entry. This happens when the entrant cannot find it profitable to enter, even when the incumbent behaves as an unconstrained monopolist, that is, it sets prices given by (10). The solution comes by analysing the best response of firm B against these prices, and computing the limiting value of the entry cost that still makes its profits equal to zero. Simple computations show that this happens when $K = K_{block} = \frac{v^2}{4(1-a)}$.[12] Since the condition for a covered market equilibrium under monopoly is $v > 2(1-a)$, it follows that $K_{block} > 1 - a$, while $\tilde{K} < 1 - a$. Hence there always exists a non-empty set of parameters where the entry-deterrence equilibrium characterised by Proposition 1 exists. It clearly is also possible to choose a value of v sufficiently high such that $K_{block} > \pi^B_{acc}$ holds, and therefore

[11] The dashed line in Region (2) refers to consumer welfare that we analyze further below in Section 5.

[12] Note that, as $K \to K_{block}$, then $p^A_{1,ED} = p^A_{2,ED}$ as given by (17) indeed converge to (10).

"blockaded" entry does not affect the pricing strategy in the grey-shaded cone in Figure 1. In the remainder, we concentrate our analysis on this area which is the most interesting one for policy considerations.

4.2. General Case

We now turn to the general setup where the two groups do not necessarily experience the same intensity of network effects or transportation costs, thus allowing for $\alpha_1 \neq \alpha_2$ and $t_1 \neq t_2$. The situation with $\alpha_1 \neq \alpha_2$ will often arise, for instance, in the market for advertisement in media outlets, where the size of an outlet's readership typically matters a lot to advertisers, while readers may be indifferent about the number of advertisers on the platform. The case $t_1 \neq t_2$ instead can capture differences in the intensity of competition and brand differentiation on the two different sides. Again in the market for advertisement in media outlets, this could arise where readers may perceive the various outlets as strongly differentiated in terms of content while advertisers may not care much about these dimensions of differentiation.

The analytical steps taken to derive the entry deterrence equilibrium are exactly analogous to those of the case of symmetric network effects. The details are omitted here for the sake of brevity. We directly report the limit prices which the incumbent platform A will set in the entry deterrence scenario (see the Proof of Proposition 2 in the Appendix for the full derivation):

$$p_{i,ED}^{A} = \alpha_i - t_i - \frac{\sqrt{2K}\,(\alpha_1 + \alpha_2 - 2t_i)}{\sqrt{t_1 + t_2 - \alpha_1 - \alpha_2}}. \tag{20}$$

The difference between the two prices, letting $t_1 = t_2$, can thus be expressed as:

$$\triangle p_{ED} = p_{1,ED}^{A} - p_{2,ED}^{A} = \alpha_1 - \alpha_2. \tag{21}$$

We find that $\triangle p_{ED} > 0 \Longleftrightarrow \alpha_1 - \alpha_2 > 0$. In other words, we find that the group generating larger network benefits is charged the lower price, in the spirit of a divide-and-conquer strategy. A similar pattern is also present under entry accommodation, where the difference in prices reduces to $\frac{\alpha_1 - \alpha_2}{2}$ (see eq. (29) and (30) in the Annex). However, the incentive to engage in divide-and-conquer appears to be stronger under entry deterrence, because the difference in the alpha terms is fully reflected in the price difference in that case, whereas the same difference in the alpha terms would only lead to half this difference in prices under accommodation.

When network externalities become very asymmetric across groups, i.e. $|\alpha_1 - \alpha_2|$ becomes very large, we may even arrive at a situation where, say, the limit price for group 1 is *below* the accommodating price (as in any standard limit pricing model), while the limit price for group 2 *exceeds* the corresponding accommodating price. Figure 2 illustrates such a case for parameter values $\alpha_1 = 0, t_1 = t_2 = 1, K = 1$, so that all prices are functions of α_2. Dashed lines show the accommodating prices, while solid lines are the limit prices. We see that, for values of $\alpha_2 > 0.55$, the limit price for group 2 is consistently above the accommodating price for the same group. This concomitance of an "exclusionary" and an "exploitative" price is unique to exclusionary pricing in two-sided markets, because there, the incumbent has two price instruments at its disposal to implement the exclusionary strategy. By contrast, in the more familiar one-sided setting, the incumbent only has one price instrument, so that limit pricing is always characterised by a price that is "too low".

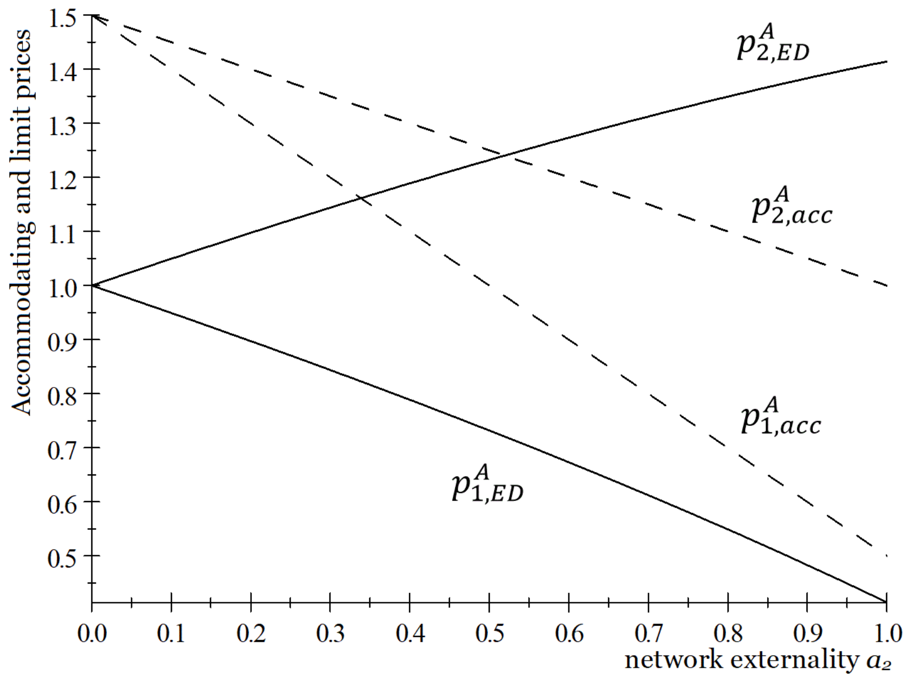

Figure 2: Numerical example setting $\alpha_1 = 0, t_1 = 1, t_2 = 1, K = 1$. Prices as function of α_2. Dashed lines are accommodating prices, solid lines are limit prices.

Comparing the entry deterrence profits under the above prices to the accommodation profits for Platform A in (31) yields the following threshold level of K above which entry deterrence will arise, namely

$$\tilde{K} = \frac{t_1 + t_2 - \alpha_1 - \alpha_2}{128} \left(\frac{6\alpha_1^2 + 6\alpha_2^2 + 13\alpha_1\alpha_2 - 25t_1t_2}{4t_1t_2 - (\alpha_1 + \alpha_2)^2} \right)^2 . \tag{22}$$

Expression $\tilde{K}$ thus generalises to the general case the analogous lower bound on K found for symmetric network externalities (namely $\tilde{K}$, see eq. (19)). The other important threshold is π^B_{acc} which determines the maximum level of K such that a shared duopoly equilibrium is sustainable. It will be convenient to rewrite this upper bound on K as:

$$\pi^B_{acc} = \frac{t_1 + t_2 - \alpha_1 - \alpha_2}{8} \frac{6\alpha_1^2 + 6\alpha_2^2 + 13\alpha_1\alpha_2 - 25t_1t_2}{4t_1t_2 - (\alpha_1 + \alpha_2)^2}. \tag{23}$$

Proposition 2 *(entry deterrence - general case)*

Let both network externalities and transportation costs differ in strength across the two agent groups, i.e. $\alpha_1 \neq \alpha_2$ *and* $t_1 \neq t_2$. *The set of subgame-perfect Nash equilibria of the sequential price setting game are given as follows:*

(i) For $K \in [0, \tilde{K})$, *the entrant will be accommodated.*

(ii) For $K \in \left[\tilde{K}, \pi^B_{acc}\right]$, *the incumbent platform A will set limit prices and deter entry by Platform B.*

The resulting profits are given by

$$\pi^A_{ED} = 2\sqrt{2K}\sqrt{t_1 + t_2 - \alpha_1 - \alpha_2} - (t_1 + t_2 - \alpha_1 - \alpha_2),$$
$$\pi^B_{ED} = 0.$$

Proof: See Appendix.

The findings of Proposition 2 generalise those of Proposition 1, with the added value that one can now consider comparative statics in richer directions. This is done below by way of a series of plots that illustrate our findings in a very intuitive way.

Figure 3 shows a case where we fix symmetric transportation costs, $t_1 = t_2 = 1$, and let network externalities vary, while still ensuring that condition (2) is satisfied.[13] We see that the cone where deterrence happens in equilibrium is wider when either network externality parameter, unilaterally, decreases. At the same time, the threshold for deterrence decreases with higher externalities.

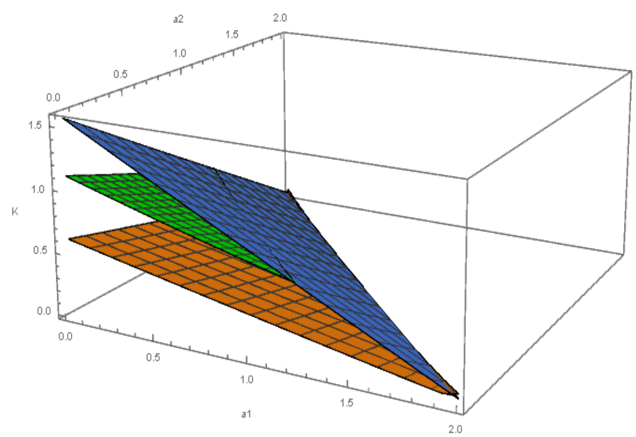

Figure 3: Asymmetric network externalities: Entry deterrence arises in the space between the orange and blue plane; consumers are hurt by entry deterrence above the green and below the blue plane

Figure 4, still with symmetric transport costs, fixes the *total* level of externality to d, where $d \equiv \alpha_1 + \alpha_2$, and studies the thresholds when d varies. Interestingly, for a given d, it does not particularly matter which side, whether 1 or 2, bears most of the externality for entry deterrence to happen.

Note that while Figure 4 was constructed assuming $t_1 = t_2 = 1$, this finding carries over to the general case where transportation costs can take any value. Once we substitute $d \equiv \alpha_1 + \alpha_2$, and $\alpha_2 = d - \alpha_1$, into eq.s (22) and (23) above, we see that they are almost entirely driven by the aggregate network externality term d, while the distribution of a given level of d across the two groups affects the threshold terms only minimally.

$$\tilde{K} = \frac{t_1 + t_2 - d}{128}\left(\frac{6d^2 + \alpha_1(d - \alpha_1) - 25t_1t_2}{4t_1t_2 - d^2}\right)^2$$
$$\pi^B_{acc} = \frac{t_1 + t_2 - d}{8}\frac{6d^2 + \alpha_1(d - \alpha_1) - 25t_1t_2}{4t_1t_2 - d^2}.$$

[13]In this case, condition (2) simplifies to $\alpha_1 + \alpha_2 < 2$.

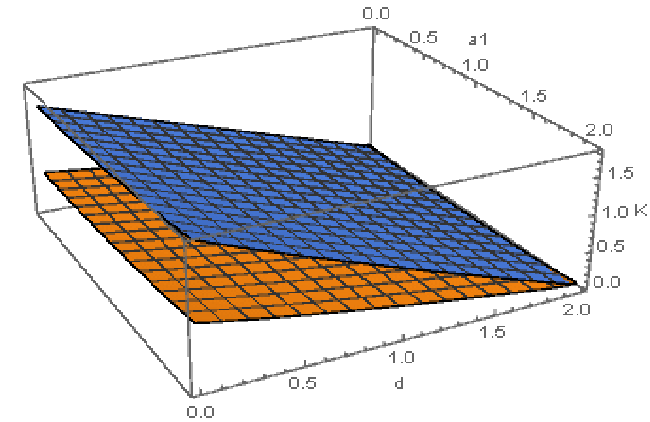

Figure 4: Asymmetric network externalities, fixing total externality $d = \alpha_1 + \alpha_2$: Entry deterrence arises in the space between the orange and the blue plane

Simplifying our model to symmetric network externalities, $\alpha_1 = \alpha_2$, would thus imply only a very limited loss of generality of results. In this context, it is worth noting that the incumbent platform's profits under entry deterrence (see Proposition 2) only depend on the sum $\alpha_1 + \alpha_2$, but not on any individual level of α_i.

Figure 5 illustrates the other opposite, where we fix symmetric externalities $\alpha_1 = \alpha_2 = 1/2$ and let transportation costs vary.[14] We see that as either t_i increases, the scope for accommodating equilibria

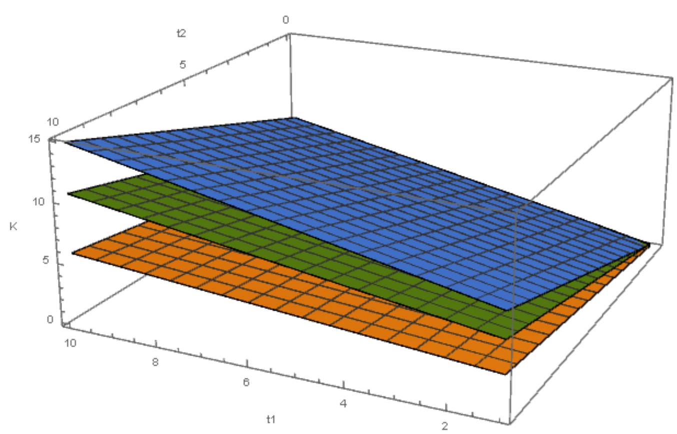

Figure 5: Asymmetric transportation costs: Entry deterrence arises in the space between the orange and the blue plane; consumers are hurt by entry deterrence above the green and below the blue plane

broadens, because the two platforms are perceived to be more and more differentiated (at least by one of the two consumer groups); this in turn allows both firms to charge higher prices, and make higher duopoly profits, which facilitates entry even at high levels of entry costs. At the same time, we also see that increasing transportation costs make entry deterrence by the incumbent more and more likely to arise (that is reflected in the wider "cone" representing the region of entry deterrence). Again, the effect works through the duopoly prices and profits, which increase in the transportation costs, also in the entry deterrence scenario. The latter

[14] In this case, condition (2) simplifies to $t_1 t_2 > 1/4$.

therefore becomes more profitable as well, and is increasingly employed in regions where the high entry cost in itself is no longer sufficient to keep entrants out of the market.

5. WELFARE ANALYSIS

The analysis of equilibrium market structure in Section 4 showed that there is indeed scope for exclusionary conduct in an industry characterised by significant network externalities. Clearly such conduct is harmful to the potential entrant who will be prevented from gaining a foothold in the market. Whether or not such conduct is also harmful to consumers and society at large is a different question, to which we will turn now.

Note that our assumption on full market coverage in all scenarios (monopoly and duopoly) implies that entry cannot lead to any market expansion, in the sense that consumers who would not consume the network good under monopoly will now gain access to the good. We are therefore conservative, in that, should we find that entry is deterred and bad for consumers, then this should be particularly worrying from a policy perspective as we shut down another channel (market expansion) that typically benefits consumers via the competitive process. In our model, any benefits to consumers arising from entry must work through either a reduction in transportation costs (because the entrant's product is a better match for at least some of the consumers' preferences), or by having access to the incumbent's good but at a lower price. Since the prices charged by the incumbent when engaging in entry deterrence are already quite low, and possibly lower than the prices which would prevail under an accommodating duopoly, the price effect is less likely to drive our results on the consumer welfare effects of entry deterrence.

We also conduct our welfare assessment in those regions where deterrence can happen in equilibrium, by comparing it with a counterfactual where instead the platform is not allowed to engage in this exclusionary practice. This methodology is supported by the fact that competition authorities can resort to their standard tools to discipline platforms. By means of reasoned decisions, competition authorities have the power to force platforms to cease and desist a certain conduct, thus imposing an end to the anticompetitive conducts. This also has the positive effect of establishing a precedent that allows platforms to self-asses and thus refrain from embracing similar behaviors.

As in Section 4, we consider first the simpler symmetric case, followed by the more general treatment.

5.1. Symmetric Case

We first fix $\alpha_1 = \alpha_2 = a$ and $t_1 = t_2 = 1$. We showed in Proposition 1 that for $K \in \left[\tilde{K}, \pi^B_{acc}\right]$, a duopoly market structure would be viable, but will not arise in equilibrium, since the incumbent will find it profitable to engage in entry deterrence. If instead accommodation could be enforced, then the corresponding equilibrium prices and volumes would be given by (11) and (12), as derived in Section 4.

We start the analysis by considering the impact of entry deterrence on consumer surplus, as this is the most important metric taken into account by enforcers when considering abusive practices. Inserting these expressions into the consumer utilities given in (1), and integrating over the respective consumer mass, we obtain the following expressions for consumer surplus under accommodation:

$$CS^A_{acc} = \int_0^{n_1^A} \left(an_2^A + v - x - p_1^A\right) dx + \int_0^{n_2^A} \left(an_1^A + v - x - p_2^A\right) dx = \tag{24}$$
$$= 2\left(\frac{3}{8}\left(a\frac{3}{8} + v - \frac{3}{2}(1-a)\right) - \frac{1}{2}\left(\frac{3}{8}\right)^2\right),$$
$$CS^B_{acc} = \int_{n_1^A}^{1} \left(an_2^B + v - (1-x) - p_1^B\right) dx + \int_{n_2^A}^{1} \left(an_1^B + v - (1-x) - p_2^B\right) dx = \tag{25}$$
$$= 2\left(\frac{5}{8}\left(a\frac{5}{8} + v - \frac{5}{4}(1-a)\right) - \frac{1}{2}\left(\frac{5}{8}\right)^2\right),$$
$$CS_{acc} = CS^A_{acc} + CS^B_{acc} = 2v - \frac{103}{32} + \frac{15a}{4}.$$

If instead the entrant is deterred, then the incumbent platform would serve the entire market, $n_1^A = n_2^A = 1$, at the limit prices given by (17). The consumer surplus generated under entry deterrence is thus:

$$CS^A_{ED} = 2\left(a + v - p^A_{1,ED} - \frac{1}{2}\right) = 2v + 1 - 4\sqrt{K(1-a)}. \tag{26}$$

Note that in defining total consumer surplus as the sum of consumer surplus generated for each group, we implicitly assume that losses of consumer surplus in one group can be compensated by simultaneous gains on the other side of the platform. While not particularly controversial from an economic standpoint, this is a non-trivial assumption and in many jurisdictions, notably in Europe, this aggregation is not always justified.[15]

A comparison of eq.s (24) and (25) to (26) illustrates the various forces at play: Under duopoly, the customer base is fragmented, so that consumers enjoy a total of $a\left[\left(\frac{3}{8}\right)^2 + \left(\frac{5}{8}\right)^2\right]$ of network benefits per group, which is less than the full benefits of $a \cdot 1$ per group which are generated when all consumers are served by the same platform. At the same time, the addition of a second platform at the opposite end of the linear city allows consumers located close to Platform B to save on transportation costs. The average transportation cost in the market thus drops from $\frac{1}{2}$ (the monopoly value) to $\frac{1}{2}\left[\left(\frac{3}{8}\right)^2 + \left(\frac{5}{8}\right)^2\right]$. Whether or not consumers will actually be harmed by entry deterrence thus crucially depends on the prices they will pay in this case, which depend in turn on the level of entry costs K.

We can state our first result on consumer welfare as follows:

Proposition 3 *(consumer welfare - symmetric case)*

[15] The Guidelines on Article 101(3) state that the aggregation of efficiencies in different markets is acceptable as long as (i) these two sets of markets are related and (ii) the groups of consumers affected by the restriction of competition and benefiting from these efficiencies are substantially the same. Up to now this has been accepted only in the Star Alliance case (AT.39595), and it does not seem that typical settings where the two-sided platforms operate meet these requirements. According to the recent Mastercard judgement (C-382/12 P, Judgment ECLI:EU:C:2014:2201, 11/09/2014, MasterCard and Others v Commission), that up to now disciplines the assessment of two-sided platforms in Europe, the two sides of the platforms should be considered two separate relevant markets which implies that consumers are likely to be different. By summing the consumer welfare of the two sides we are possibly more conservative by reducing the likelihood of finding anticompetitive foreclosure.

Under the symmetric parametrisation, entry deterrence which reduces consumer surplus compared to entry accommodation will arise for $a \leq 5/8$ and $K \in \left[\left(\frac{135}{128} - \frac{15}{16}a\right)^2 \frac{1}{1-a}, \frac{25}{16}(1-a)\right]$.

Proof: See Appendix.

We comment Proposition 3 by referring back to Figure 1. In the grey-shaded cone where deterrence is the equilibrium outcome when unchallenged by competition authorities (Region (2)), consumers are worse off above the dashed area, compared to a counterfactual where limit pricing is not allowed so that the incumbent has to play the entry-accommodating prices. Intuitively, this happens when the value of the externality is low enough (so that fragmentation induced by entry does not carry a big loss), and when K is high enough (so that the limit entry-deterrence price is also rather high and consumers benefit little from it). It is also interesting to observe that, when $a \leq 5/8$, increasing a while keeping constant K determines a shift from a situation where consumers benefit from entry deterrence to a situation where consumers are harmed. This essentially supports the idea that under certain circumstances and for the same entry costs, an increase of the network externalities can lead to situations where consumers are harmed. This is essentially due to the fact that network externalities enhance the degree of competition (i.e. duopoly equilibrium prices decrease in a at a faster rate than the exclusionary prices) and thus consumers suffer when by limit pricing the incumber excludes the entrant. We can thus provisionally conclude that, at least in the case of symmetric network externalities, consumer harm induced by entry deterrence can indeed occur. While a blank restriction on limit pricing strategies does not make sense (as consumers often benefit from it), there is a non-negligible area where an antitrust intervention would be appropriate. It is also true, however, that this type of intervention is less justifiable the higher the level of (symmetric) network externalities.

Note that the particular parameter restrictions used to derive the various threshold levels identified in Propositions 1 and 3 for the symmetric case crucially depend on the assumption that transportation costs are $t_1 = t_2 = 1$. If one lets transportation costs increase, it is easy to show that the parameter space where entry deterrence occurs, and where it harms consumers, will shift upward and extend towards the right in Figure 1, implying that entry deterrence will arise for ever higher values of entry cost K and network externality a.

Let us turn to the question how entry deterrence affects total welfare in our model. Our assumption of full market coverage under all scenarios implies that, for any given market structure, prices are simply transfers of utility between consumers and platform(s), so that they do not affect the overall level of welfare generated by the platform(s). Thus, if only the incumbent platform is active in the market, the total welfare is given by

$$W_{ED}^{A} = 2v + (\alpha_1 + \alpha_2) - \frac{1}{2}(t_1 + t_2). \tag{27}$$

If instead entry occurs, this affects total welfare in three different ways: (1) the entry cost K is incurred; (2) aggregate network benefits drop because the customer base is now split across the two platforms, and network benefits are only enjoyed between agents who joined the same platform; and (3) transportation costs are saved because consumers can now choose between two platforms located at the opposite ends of the linear city. Clearly, (1) and (2) reduce total welfare, while (3) increases welfare.

We now analyse under which conditions the welfare gains implied by entry (namely the savings on transportation costs) dominate the welfare losses due to the entry cost and the fragmentation of the customer base, again in the "cone" where entry deterrence would be the equilibrium if unchallenged by the authorities.

It turns out that our symmetric model generates excess entry, in the sense that the accommodating equilibria generate lower total welfare than if the network good had been provided by the incumbent platform alone.

Proposition 4 *(total welfare - symmetric case)*

Under the symmetric parametrisation, entry deterrence generates a higher total welfare than accommodating entry, in the entry-deterrence region.

Proof: See Appendix

Intuitively, when transportation costs are fixed (as in Proposition 4), entry deterrence should harm welfare most when network externalities a are small (so that little consumer surplus is gained from having all consumers on one monopoly platform rather than split across two platforms), and when entry costs K are low (so that establishing a second platform is not very costly to society). While indeed it is always possible to find a sufficiently low value of K such that welfare is higher with entry, this cannot be the end of the analysis. One also needs to check the incumbent's incentives to engage in limit pricing. When K is low, such incentives are minimal: Deterring entry would be very costly for the incumbent (low K implies low limit prices), while accommodating entry still yields relatively high duopoly profits when a is low, so that competitive pressure between the two platforms is moderate.

5.2. General Case

In this section we analyse the impact of entry deterrence on consumer surplus and total welfare in the general setup where the two groups do not necessarily experience the same intensity of network effects or transportation costs, thus allowing for $\alpha_1 \neq \alpha_2$ and $t_1 \neq t_2$.

Again, we will start by analysing consumer surplus. In the general case, the prices charged under accommodation are given by (29) and (30) in the Appendix, and the resulting consumer surplus can again be expressed as the sum of consumer surplus generated by each platform for each of the two groups:

$$
\begin{aligned}
CS^A_{acc} &= \int_0^{n_1^A} \left(\alpha_1 n_2^A + v - t_1 x - p_1^A\right) dx + \int_0^{n_2^A} \left(\alpha_2 n_1^A + v - t_2 x - p_2^A\right) dx, \\
CS^B_{acc} &= \int_{n_1^A}^{1} \left(\alpha_1 n_2^B + v - t_1 (1-x) - p_1^B\right) dx + \int_{n_2^A}^{1} \left(\alpha_2 n_1^B + v - t_2 (1-x) - p_2^B\right) dx, \\
CS_{acc} &= CS^A_{acc} + CS^B_{acc}.
\end{aligned}
$$

When the incumbent engages in entry deterrence instead, the resulting prices are given by (20), as derived in Section 4.2, at which the incumbent will serve the entire market, $n^A_{1,ED} = n^A_{2,ED} = 1$. Using these expressions we obtain the following consumer surplus under entry deterrence:

$$
\begin{aligned}
CS^A_{ED} &= \int_0^1 \left(\alpha_1 + v - t_1 x - p^A_{1,ED}\right) dx + \int_0^1 \left(\alpha_2 + v - t_2 x - p^A_{2,ED}\right) dx \\
&= 2v + \frac{1}{2}\left(t_1 + t_2\right) - 2\sqrt{2K}\sqrt{\left(t_1 + t_2 - \alpha_1 - \alpha_2\right)}.
\end{aligned}
$$

Again, we can identify the threshold value for K at which entry deterrence yields exactly the same consumer surplus as accommodation:

$$CS^A_{ED} = CS_{acc}.$$

We can now state our main result on consumer welfare under generalised transportation costs:

Proposition 5 *(consumer welfare - general case)*

Under general transportation costs t_1, t_2 and network externalities α_1, α_2, there exists a threshold value of K above which entry deterrence which reduces consumer surplus compared to entry accommodation will arise.

Proof: See Appendix.

The figures in Section 4.2. illustrate the findings of Proposition 5 for different special cases. First, for symmetric transportation costs $t_1 = t_2 = 1$, Figure 3 shows how the scope for consumer-harming entry deterrence evolves when allowing for asymmetric network externalities. We see that consumer harm is most likely to arise from entry deterrence when both α_1 and α_2 are small, and K is sufficiently large (see the space between the orange and blue plane in the figure). The range of values for K compatible with consumer-harming entry deterrence shrinks as network externalities intensify for either of the two consumer groups.

Figure 5 considers asymmetric transportation costs, while fixing network externalities at $\alpha_1 = \alpha_2 = \frac{1}{2}$. We see that such consumer harm arises in a non-negligible part of the parameter space, and that product differentiation drives the impact of entry deterrence on consumers (again, see the space between the orange and blue plane in the figure). Overall, we can conclude so far that entry deterrence is more likely to harm consumers the weaker are network externalities, and the more differentiated are the two platforms.

Turning to the analysis of total welfare, we can now state our welfare result for the case of general network externalities and transportation costs:

Proposition 6 *(total welfare - general case)*

Under general transportation costs t_1, t_2 and network externalities α_1, α_2, total welfare under entry deterrence is always higher than under entry accommodation.

Proof: See Appendix

Excluding the entrant is efficient, from a total welfare perspective, when entry costs are high enough. But entry costs also determine the limit pricing of the incumbent when engaging in an exclusionary strategy. In particular, low entry costs are associated to low limit prices. This is why, in our model, we find that, when an entrant is excluded, it is efficient to do so. The converse is not true: there are ranges where the incumbent would still need deep discounts to exclude a fairly inefficient rival, so that it prefers to accommodate entry. The discounts that would need to be given to existing customers do not compensate for the more limited gains from getting the rival market share.

6. EXTENSIONS

6.1. Non-negative Prices

In our analysis, up to now, we have not considered the potential presence of constraints to set non-negative prices by platforms.[16] This restriction can play an important role in certain markets where prices can be substantially skewed, with prices on one side of the market being significantly lower than on the other side, and even below zero. This possibility can be exacerbated in the presence of limit pricing (see our observations on this point in Section 4.2., discussing eq. (21)). In this section we offer an initial reflection on this scenario by discussing some limiting cases.[17]

First, consider the *symmetric* case that we covered in Section 4.1. Such a case actually does not pose any problem of non-negativity. This can be seen by simple inspection of the prices and profits of the leader, given by eq. (17) and (18) respectively, which are always positive: The limit prices in eq. (17) are non-negative whenever $K \geq 0.25\,(1-a)$, while entry deterrence will arise whenever $K \geq \tilde{K} \simeq 0.61\,(1-a)$. Moreover, any time (symmetric) limit prices are positive, entry-deterrence profits will be positive too, as profits are simply twice such (symmetric) prices. We can thus conclude that, whenever limit prices will actually be deployed by the incumbent platform, they will be strictly positive. This is quite intuitive, but relies on symmetry too.

Hence we take another simplified case which instead amplifies the *asymmetry*, namely we consider $\alpha_1 = 0, \alpha_2 > 0$ which describes a situation where one side does not care about the other side (i.e., consumers do not care about the number of advertisers) while the other side does (e.g., advertisers do care about eyeballs). In order to simplify expressions, we also posit $t_1 = t_2 = t$. The restriction for the existence of a market sharing equilibrium becomes $t > \alpha_2/2$.

If entry is *accommodated*, we get for the leader:

$$\begin{aligned} p_1^A &= \frac{3}{2}t - \alpha_2, \\ p_2^A &= \frac{3}{2}t - \frac{1}{2}\alpha_2. \end{aligned}$$

For the follower:

$$\begin{aligned} p_1^B &= \frac{5t^2 - 2\alpha_2 t - 2\alpha_2^2}{2(\alpha_2 + 2t)}, \\ p_2^B &= \frac{t(2\alpha_2 + 5t)}{2(\alpha_2 + 2t)}. \end{aligned}$$

Looking at all these four prices, the most stringent condition in order for them to be positive comes from p_1^B, and in particular it is $t > \frac{1+\sqrt{11}}{5}\alpha_2 \simeq 0.87\alpha_2$. This condition is more stringent than the condition above for a shared equilibrium. We first assume that it is satisfied. In other words, we consider that, in case entry is accommodated, all prices would be positive, and we discuss if, looking at the incentives to deter entry, prices might instead become negative *because* of a limit pricing strategy.

[16] This part builds on the economic literature that has studied the effects of imposing a non-negativity constraint on the pricing strategy of platforms. See for instance Amelio and Jullien (2012), Karlinger and Motta (2012).

[17] We should remind the reader that, so far, we have normalised to zero the per-agent platform costs f_i as they did not play any particular role in the analysis, and interpreted prices as margins. When it comes to negative prices, such costs obviously matter. In this section, we literally interpret prices in their absolute value, concentrating on the 'toughest' case $f_i = 0$.

If entry is *deterred*, we know from Proposition 2 that for $K \in \left[\tilde{K}, \pi^B_{acc}\right]$, the incumbent platform A will set the limit price and deter entry by Platform B where the threshold values simplify to:

$$\tilde{K} = \frac{1}{128}\frac{(25t^2 - 6\alpha_2^2)^2}{(2t+\alpha_2)^2(2t-\alpha_2)},$$

$$\pi^B_{acc} = \frac{1}{8}\frac{25t^2 - 6\alpha_2^2}{2t+\alpha_2}.$$

It is a matter of simple computations to show that firm A's limit prices are given by:

$$\begin{aligned} p^A_{1,ED} &= -t + \sqrt{2K(2t-\alpha_2)} \\ p^A_{2,ED} &= -(t-\alpha_2) + \sqrt{2K(2t-\alpha_2)}. \end{aligned}$$

It is immediate to see that indeed it is always $p^A_{1,ED} < p^A_{2,ED}$, which is intuitive. Prices are also increasing in K, the lowest possible price will thus be at $\tilde{K}$ and it amounts to:

$$p^A_{1,ED}(\tilde{K}) = \frac{9t^2 - 8t\alpha_2 - 6\alpha_2^2}{8(2t+\alpha_2)}.$$

Looking at the last expression, the limit price *can* be negative, but only when $t < \frac{4+\sqrt{70}}{9}\alpha_2 \simeq 1.37\alpha_2$. Hence it is sufficient that t is large enough for $p^A_{1,ED}$ to be always positive, for any value of α_2. In fact, recalling that prices under accommodated entry are positive when $t > \frac{1+\sqrt{11}}{5}\alpha_2 \simeq 0.87\alpha_2$, the area where prices would be negative *because* of a limit pricing strategy is extremely small.

Working in exactly the same way at the upper bound of the deterrence area, we find

$$p^A_{1,ED}(\pi^B_{acc}) = -t + \frac{1}{2}\sqrt{\frac{25t^2 - 6\alpha_2^2}{2t+\alpha_2}(2t-\alpha_2)}.$$

This expression is positive when $t > 0.83\alpha_2$. Hence an equilibrium with positive limit prices is *always* a non-empty set, in the relevant range.

Finally, let us briefly discuss what happens in the limiting case, when externalities are so asymmetric that prices on one side of the market are already hitting the zero-price constraint under accommodated entry. Is entry deterrence still possible in this case? We thus still consider the simple setting with $\alpha_1 = 0, \alpha_2 > 0$, and further *impose* that $p^A_1 = p^B_1 = 0$, while allowing for general transportation costs $t_1 \neq t_2$.[18] Applying these parameters to the general demand system (see eq. (5) and (6)), one immediately notices a striking fact: demand is now independent of externalities on the remaining side of the market. This is because either externalities are directly zero (side 1 of the market), or there is no potential for price differentials that would be amplified by externalities on the other side of the market (side 2 of the market). Hence competition boils down to a standard Hotelling setting (on side 2 of the market). We omit for brevity calculations as they are straightforward. Under *accommodated entry*, we get for the leader and for the follower, respectively

$$\begin{aligned} p^A_2 &= \frac{3}{2}t, \\ p^B_2 &= \frac{5}{4}t, \end{aligned}$$

[18]Under these parameters, only t_2 (but not t_1) will affect equilibrium prices and profits, which is why we simplified the following notation to t.

with associated profits $\pi_{acc}^{B} = \frac{9}{16}t$ and $\pi_{acc}^{B} = \frac{25}{32}t$. If entry is *deterred*, firm A must set a limit price given by:

$$p_{2,ED}^{A} = -t + 2\sqrt{2Kt},$$

which is positive for $K > \frac{t}{8}$. This strategy generates a profit $\pi_{ED}^{A} = -t + 2\sqrt{2Kt}$ which is better than π_{acc}^{B} when

$$K \geq \tilde{K} = \frac{625t}{2048}, \text{ with } \tilde{K} < \pi_{acc}^{B}.$$

Since $\tilde{K} > \frac{t}{8}$, we have just shown that, when entry deterrence is profitable, it always involves positive prices on the remaining side of the market.[19]

While more work is needed to tackle the general case, we have shown that there are specific circumstances in which the presence of the non-negativity constraint does not alter the results of our main analysis.

6.2. Competitive Bottlenecks (Multi-homing)

Our model is restrictive since we have concentrated the analysis on markets where there is single-homing on both sides of the market. We argued in Section 2 that there are realistic situations where that would possibly hold true, especially in the context of antitrust cases where some practices are alleged to make multi-homing difficult. Still, we believe that further research is needed to analyse other instances where multi-homing is feasible. In particular, another setting that has become a workhorse model in the IO literature is one of "competitive bottlenecks", whereby group 1 agents continue to join at most one platform (i.e. group 1 single-home), while group 2 agents can join both platforms instead (i.e. group 2 multi-home).

In Appendix B we make a first step in that direction, considering a model where $\alpha_1 = 0$ (e.g. readers of a newspaper are indifferent about the number of advertisers placing ads on this newspaper), while $\alpha_2 > 0$ (e.g. advertisers want to meet as many eyeballs as possible, and may place their ads on more than one newspaper). In line with the single-homing model of the previous part, we still consider a Hotelling line where all agents on side 1 connect to one of the platforms in equilibrium, while all agents on side 2 connect to both platforms in equilibrium (full market coverage, which happens when the stand-alone value v is high enough). We obtain the following result.

Proposition 7 *(entry deterrence - competitive bottlenecks)*

When $\alpha_1 = 0$ and $\alpha_2 > 0$, and group-2 agents can multi-home, entry deterrence will arise in equilibrium whenever

$$K \in \left[\tilde{K}_{MH}, \pi_{acc}^{B}\right].$$

Hence we obtain a result which is, in spirit, identical to our main Proposition 2. The main difference, and an important one compared to the case of single-homing on both sides, is that neither the threshold π_{acc}^{B} nor $\tilde{K}_{MH}$ depend on the level of the externalities. This is so because, both under accommodation and under entry deterrence, the network premium earned on group 2 (i.e. α_2) is fully passed on to group 1 to attract them to the platform, so that it does not have any impact on the incumbent platform's profits under either scenario. In this special case of competitive bottlenecks, network externalities thus do not affect the

[19] It is also straightforward to verify that there exists a non-empty space where such entry deterrence harms consumers. Specifically, the relevant threshold for such consumer-detrimental exclusion to arise is $K \geq \frac{(119t+32\alpha_2)^2}{128^2 2t}$. Notice that externalities do matter for assessing the impact on consumers.

occurrence of limit pricing in either direction. This neutrality result is most likely an artefact of the Hotelling framework with full market coverage. Further research would be particularly welcome to understand whether this feature also carries over to more general models where prices also affect total market size, rather than just the distribution of users across platforms.

Finally, suppose that the non-negativity constraint on prices is binding for the prices charged to group 1 even in the accommodation equilibrium. Then, there is no room for limit pricing under multi-homing, since such a limit price would necessarily be below zero as well. Thus, the only feasible equilibrium under such a non-negativity constraint would be the duopoly equilibrium: As long as α_2 is large enough, both the incumbent and the entrant will charge a price of zero on side 1, because consumers generate large externalities to advertisers on side 2. Hence, each platform obtains an equal consumer market share of one-half. But multi-homing with $\alpha_1 = 0$ implies that there is no competition on the advertiser side: Thus, each platform can extract the full surplus generated to advertisers on the other side. Whenever this surplus is sufficient for the entrant to cover its entry cost K, entry cannot be prevented by the incumbent. This result is, however, driven by the special features of our Hotelling framework, in particular by the fact that multi-homing implies that there is no competition among the two platforms for advertisers any longer. Thus, this feature may make the Hotelling model not the most suitable setting to study multi-homing in the context of entry deterrence.

7. CONCLUSION

The paper extends one strand of the literature about exclusionary pricing to the framework of indirect network externalities and platform competition. We have conducted this exercise by embedding a canonical model of two-sided markets (borrowed from Armstrong, 2006) into another canonical model of entry deterrence (borrowed from Dixit, 1980). Our results show that traditional exclusionary practices can carry over to platform competition and, under some circumstances, indirect network externalities accentuate the incentive to foreclosure by incumbents. We show that if the two platforms are sufficiently differentiated, such foreclosure turns out to harm consumers. More specifically, the usual result found for exclusionary pricing in the context of platform competition, namely that low prices and the avoidance of network fragmentation turn out to benefit consumers, does not materialise under certain parameter conditions. On the contrary, there are circumstances in which consumers are harmed because they are not sufficiently compensated for the loss of an alternative platform which is a better fit for at least some of the consumers in the market.

The paper has thus a direct policy implication. It suggests that the typical tools and the economic intuitions used and developed in the analysis of single-sided markets need not be abandoned but need to be adapted. In their assessment, competition authorities would need to be vigilant and in particular try to establish, at least qualitatively, the extent of single-homing versus multi-homing of agents, the ability to freely set prices (e.g., absence of non-negativity constraint), the cost of entry, the strength of network externalities, and the degree of platform differentiation.

Subject to the maintained assumptions, single-homing in particular, we considered a model which is flexible enough to accommodate differences in competition and externalities on the different sides, as this can play an important role in practical cases. Yet, we found that most economic insights could also be obtained without particular loss of generality in a simpler, symmetric model. When it comes to externalities, we also found that what seems to matter is their total level, not how they are distributed between the two sides.

Overall, we consider our model useful and calling for further research in this field. In particular, at this current stage, we observe two potential avenues for future research. First, given that this paper treats the parameters of differentiation and the degree of indirect network externalities as exogenous, future research could extend our settings by studying the fact that platforms can decide on the design of their services and thus directly influence the degree of differentiation and the strength of network externalities experienced by their users. Such design choices would then also affect the pricing strategies and thus the market structure that will arise in equilibrium. Second, this paper deals only preliminarily with the issues of non-negativity of prices and incentives to multi-home. Further research would be needed in order to study these settings in a more comprehensive way.

Appendix A: Proofs

Characterisation of the monopoly solution.

At the corner solution, we have (superscript M denotes the monopoly solution):

$$\begin{aligned} p_1^M &= \alpha_1 + v - t_1, \;\; p_2^M = \alpha_2 + v - t_2, \\ \pi^M &= (\alpha_1 + v - t_1 - f_1) + (\alpha_2 + v - t_2 - f_2). \end{aligned} \tag{28}$$

Let us now characterise the interior solution. Imagine the monopolist serves only a part of the market. For any given price pair $\left(p_1^A, p_2^A\right)$, all consumers with non-negative utility will buy the product:

$$\begin{aligned} u_1^A &= \alpha_1 n_2^A + v - t_1 x_1 - p_1^A \geq 0, \\ u_2^A &= \alpha_2 n_1^A + v - t_2 x_2 - p_1^A \geq 0. \end{aligned}$$

These two inequalities allow us to identify the location of the respective consumers of either group 1 or 2 who are indifferent between joining the monopoly platform and not consuming the network good at all:

$$\begin{aligned} \tilde{x}_1 &= \frac{1}{t_1}\left(\alpha_1 n_2^A + v - p_1^A\right), \\ \tilde{x}_2 &= \frac{1}{t_2}\left(\alpha_2 n_1^A + v - p_2^A\right). \end{aligned}$$

Since consumers are distributed uniformly over the unit interval, the mass of consumers who derive non-negative utility from consuming the network good, and who will therefore join the platform, is given by: $n_1^A = \tilde{x}_1$ and $n_2^A = \tilde{x}_2$. The resulting demand system can thus be solved to obtain:

$$\begin{aligned} n_1^A\left(p_1^A, p_2^A\right) &= \frac{v\left(\alpha_1 + t_2\right) - p_1^A t_2 - \alpha_1 p_2^A}{t_1 t_2 - \alpha_1 \alpha_2}, \\ n_2^A\left(p_1^A, p_2^A\right) &= \frac{v\left(\alpha_2 + t_1\right) - p_1^A \alpha_2 - t_1 p_2^A}{t_1 t_2 - \alpha_1 \alpha_2}. \end{aligned}$$

The monopoly platform's problem is thus similar to the one of a monopolist selling two complementary goods: The demand from group-1 consumers is affected not only by the price charged to these consumers, but also - indirectly - by the price charged to group-2 consumers, because the latter determines how many group-2 consumers will join the platform, and hence how much utility the network good can generate for group-1 consumers.

The monopoly platform solves the following problem:

$$\max_{p_1^A, p_2^A} \pi^A\left(p_1^A, p_2^A\right) = \left(p_1^A - f_1\right) n_1^A\left(p_1^A, p_2^A\right) + \left(p_2^A - f_2\right) n_2^A\left(p_1^A, p_2^A\right).$$

If condition (2) holds, the following interior solution to the above problem arises:

$$\begin{aligned} p_1^{M(int)} &= \frac{v\left(2t_1t_2 - \alpha_2^2 - \alpha_1\alpha_2 + \alpha_1 t_1 - \alpha_2 t_1\right) - \alpha_1^2 f_1 - \alpha_1\alpha_2 f_1 - \alpha_1 f_2 t_1 + \alpha_2 f_2 t_1 + 2 f_1 t_1 t_2}{4t_1t_2 - \left(\alpha_1 + \alpha_2\right)^2}, \\ p_2^{M(int)} &= \frac{v\left(2t_1t_2 - \alpha_1^2 - \alpha_1\alpha_2 - \alpha_1 t_2 + \alpha_2 t_2\right) - \alpha_2^2 f_2 - \alpha_1\alpha_2 f_2 + \alpha_1 f_1 t_2 - \alpha_2 f_1 t_2 + 2 f_2 t_1 t_2}{4t_1t_2 - \left(\alpha_1 + \alpha_2\right)^2}. \end{aligned}$$

In our analysis, we assume that the interior solution is never feasible, so that the corner solution characterised in (28) always applies. We therefore need to make sure that the standalone value v is high enough so that the demand generated by the monopoly prices at the interior solution would *exceed* unity (i.e. the size of the entire market). More precisely we assume that

$$v \in \left\{ v : \min \left(n_1^A \left(p_1^{M(int)}, p_2^{M(int)} \right), n_2^A \left(p_1^{M(int)}, p_2^{M(int)} \right) \right) \geq 1 \right\}.$$

which can be rewritten as

$$\begin{aligned} v \quad \geq \quad & \max \left\{ \frac{1}{\alpha_1 + \alpha_2 + 2t_2} \left(f_2 (\alpha_1 + \alpha_2) + 2f_1 t_2 + 4t_1 t_2 - (\alpha_1 + \alpha_2)^2 \right), \right. \\ & \left. \frac{1}{\alpha_1 + \alpha_2 + 2t_1} \left(f_1 (\alpha_1 + \alpha_2) + 2f_2 t_1 + 4t_1 t_2 - (\alpha_1 + \alpha_2)^2 \right) \right\} \end{aligned}$$

Under the simplified parametrisation $f_1 = f_2 = 0, t_1 = t_2 = 1, \alpha_1 = \alpha_2 = a$, the corresponding lower bound on the standalone value v reduces to:

$$v \geq 2(1-a).$$

Characterisation of the duopoly solution under sequential price setting

We solve this game by backward induction, starting with the second stage of the game, where Platform B sets its prices $\left(p_1^B, p_2^B\right)$ given Platform A's choice of $\left(p_1^A, p_2^A\right)$ made at the first stage of the game. Based on Platform B's best response function, Platform A will set its own prices to maximise own profits.

This problem has a closed form solution. For the leader, we obtain the still rather simple expressions for price as follows:

$$\begin{aligned} p_1^A &= f_1 + \frac{3}{2}(t_1 - \alpha_1) + \alpha_1 - \alpha_2, \\ p_2^A &= f_2 + \frac{3}{2}(t_2 - \alpha_2) + \alpha_2 - \alpha_1. \end{aligned} \tag{29}$$

For the follower, expressions are slightly more complex than the simple ones found by Armstrong (2006):

$$\begin{aligned} p_1^B &= f_1 + \frac{5}{4}(t_1 - \alpha_1) + (\alpha_1 - \alpha_2) \left\{ \frac{5\alpha_1 + 4\alpha_2 + 9t_1}{4(\alpha_1 + \alpha_2 + 2t_1)} + \frac{(\alpha_1 - \alpha_2)t_1(t_2 - t_1)}{2(\alpha_1 + \alpha_2 + 2t_1)\left[(\alpha_1 + \alpha_2)^2 - 4t_1 t_2\right]} \right\}, \\ p_2^B &= f_2 + \frac{5}{4}(t_2 - \alpha_2) + (\alpha_2 - \alpha_1) \left\{ \frac{5\alpha_2 + 4\alpha_1 + 9t_2}{4(\alpha_1 + \alpha_2 + 2t_2)} + \frac{(\alpha_2 - \alpha_1)t_2(t_1 - t_2)}{2(\alpha_1 + \alpha_2 + 2t_2)\left[(\alpha_1 + \alpha_2)^2 - 4t_1 t_2\right]} \right\}. \end{aligned} \tag{30}$$

The equilibrium profits in the duopoly equilibrium under sequential price setting, under *accommodated entry*, are found as:

$$\pi_{acc}^A = \frac{9}{16}(t_1 + t_2 - 2\alpha_1) + (\alpha_1 - \alpha_2) \frac{10\alpha_1^2 + 8\alpha_2^2 + \alpha_1(18\alpha_2 - t_1 - t_2) - 36t_1 t_2 + \alpha_2 (t_1 + t_2)}{16\left[(\alpha_1 + \alpha_2)^2 - 4t_1 t_2\right]}, \tag{31}$$

$$\pi_{acc}^B = \frac{25}{32}(t_1 + t_2 - 2\alpha_1) + (\alpha_1 - \alpha_2) \frac{26\alpha_1^2 + 24\alpha_2^2 + \alpha_1(50\alpha_2 - t_1 - t_2) - 100t_1 t_2 + \alpha_2 (t_1 + t_2)}{32\left[(\alpha_1 + \alpha_2)^2 - 4t_1 t_2\right]}. \tag{32}$$

Proof of Proposition 2 *(entry deterrence - general case)*

Eq.s (29) and (30) identify the equilibrium prices that arise in the duopoly equilibrium with sequential price choice, while eq.s (31) and (32) show the corresponding leader and follower profits for the general case.

We will now derive the incumbent platform's prices and profits under limit pricing, and compare these to the accommodation profits to identify the entry cost threshold $\tilde{K}$ at which entry deterrence becomes the incumbent's preferred strategy.

A's limit prices are obtained by backward induction as follows: Solving the follower's problem of maximising its profits as given in eq. (7), where the demand functions are given by (5) and (6), yields the following best-response functions:

$$\begin{aligned} p_1^B\left(p_1^A,p_2^A\right) &= \frac{1}{(\alpha_1+\alpha_2)^2-4t_1t_2}(-\alpha_1^2\alpha_2+\alpha_2^2p_1^A-2t_1(p_1^A+t_1)t_2+ \\ &\quad +\alpha_2t_1(p_2^A+t_2)+\alpha_1(-\alpha_2^2+\alpha_2(p_1^A+2t_1)+t_1(-p_2^A+t_2))) \\ p_2^B\left(p_1^A,p_2^A\right) &= \frac{1}{(\alpha_1+\alpha_2)^2-4t_1t_2}(\alpha_1^2\left(-\alpha_2+p_2^A\right)-t_2\left(\alpha_2(p_1^A-t_1)+2t_1(p_2^A+t_2)\right)+ \\ &\quad +\alpha_1(-\alpha_2^2+(p_1^A+t_1)t_2+\alpha_2(p_2^A+2t_2))) \end{aligned} \tag{33}$$

Inserting these best response functions into Platform B's profit function, eq. (7), and solving for the price p_1^A which sets Platform B's profits, evaluated at B's best response prices (33), equal to zero, yields Platform A's limit price on group 1 as a function of p_2^A. (Of the two roots which solve this problem, only the positive one is relevant here). Inserting this limit price into A's profit function and maximising A's profits with respect to p_2^A, yields the second part of A's limit prices, which are given by:

$$p_{i,ED}^A=\alpha_i-t_i-\frac{\sqrt{2K}\left(\alpha_1+\alpha_2-2t_i\right)}{\sqrt{t_1+t_2-\alpha_1-\alpha_2}}.$$

Since the incumbent will serve the entire market in the exclusionary scenario, we have that $n_1^A=n_2^A=1$, and so A's profits under limit pricing are given by

$$\begin{aligned} \pi_{ED}^A &= p_{1,ED}^A+p_{2,ED}^A \\ &= 2\sqrt{2K}\sqrt{t_1+t_2-\alpha_1-\alpha_2}-(t_1+t_2-\alpha_1-\alpha_2)\,. \end{aligned} \tag{34}$$

By construction, B's profits will be zero when A engages in limit pricing, i.e. $\pi_{ED}^A=0$.

A's profits under limit pricing, (34), are continuously increasing in entry cost K, while A's profits under accommodation, (31), are not a function of K. We also have that, at $K=0$, $\pi_{ED}^A<0$, while the accommodation profits (31) are strictly positive. By the Intermediate Value Theorem, we can infer that there exists a positive value K such that $\pi_{ED}^A=\pi_{acc}^A$; solving this equality yields $\tilde{K}$ as given in (22).

Part (i) of Proposition 2: For any $K<\tilde{K}$, we have that $\pi_{ED}^A<\pi_{acc}^A$, and so Platform A will prefer to accommodate the entrant platform B. By assumption, we have that $K>0$, so that the interval $\left[0,\tilde{K}\right)$ on which accommodation arises is non-empty.

Part (ii) of Proposition 2: For any $K\geq\tilde{K}$, we have that $\pi_{ED}^A\geq\pi_{acc}^A$, and so Platform A will prefer to deter entry of Platform B. It is straightforward to show that $\tilde{K}<\pi_{acc}^B$ simplifies to $39t_1t_2>10\alpha_1^2+19\alpha_1\alpha_2+10\alpha_2^2$, which can be re-written as $4t_1t_2>(\alpha_1+\alpha_2)^2+\frac{t_1t_2-\alpha_1\alpha_2}{10}$. Hence, by slightly strengthening condition (2) to satisfy this inequality, we can guarantee that the interval $\left[\tilde{K},\pi_{acc}^B\right]$ on which entry deterrence arises is non-empty.

As a final step, the threshold value of K above which entry is blockaded is derived as follows: Inserting A's monopoly prices, eq. (28), into the solution of B's profit maximisation problem (9), we obtain the following threshold value for K:

$$K_{block} > \frac{(t_1 + t_2 + \alpha_1 + \alpha_2)\, v^2}{2\left(4t_1t_2 - (\alpha_1 + \alpha_2)^2\right)}.$$

Thus, we can always obtain $K_{block} > \pi^B_{acc}$ by setting v sufficiently high.

This completes the proof of Proposition 2. □

Proof of Proposition 3 *(consumer welfare - symmetric case):*

To identify the cut-off value for K such that total consumer surplus under entry deterrence (eq. (26)) is exactly equal to total consumer surplus under entry accommodation, i.e. the sum of (24) and (25), solve the following equation for K:

$$CS_{acc} = CS^A_{acc} + CS^B_{acc}.$$

The resulting cut-off value $\tilde{K}_2$, is given by

$$\tilde{K}_2 = \left(\frac{135}{128} - \frac{15}{16}a\right)^2 \frac{1}{1-a}.$$

which is well defined for all $a \in [0, 1)$, the latter constraint reflecting condition (2). Since CS^A_{ED} is monotonically decreasing in K, and $CS^A_{acc} + CS^B_{acc}$ does not depend on K, we have that $CS^A_{ED} \leq CS_{acc}$ whenever $K \geq \tilde{K}_2$ and vice versa.

We know from Proposition 1 that entry deterrence is the unique subgame perfect equilibrium for $K \in \left[\tilde{K}, \pi^B_{acc}\right]$. It is easily verified that $\tilde{K}_2 > \tilde{K}$ for all $a \in [0, 1]$. Thus, the interval of K in which consumer-detrimental entry deterrence can possibly arise is $K \in \left[\tilde{K}_2, \pi^B_{acc}\right]$, if this is non-empty. Simple algebra then shows that $\pi^B_{acc} - \tilde{K}_2 = \frac{25(59-56a)(5-8a)}{16384(1-a)}$. Thus, if $a > 5/8$, then $\pi^B_{acc} < \tilde{K}_2$, and hence consumers are always better off with limit pricing, even if it deters entry, compared to an accommodated equilibrium. If instead $a < 5/8$, then $\left[\tilde{K}_2, \pi^B_{acc}\right]$ is non-empty, so that there exists a set of parameters where entry deterrence arises as the incumbent's preferred strategy and at the same time harms consumers. See also Figure 1 in the main text. □

Proposition 4 *(total welfare - symmetric case)*

When $\alpha_1 = \alpha_2 = a \in [0, 1)$ and $t_1 = t_2 = 1$, we can compute the total welfare under accommodation in this case as the sum of consumer surplus (eq.s (24) and (25)) and aggregate net profits (eq.s (13) and (14)) to obtain

$$W_{acc} = 2v + \frac{17}{16}a - \frac{17}{32} - K.$$

The total welfare under monopoly supply by Platform A simplifies to

$$W^A_{ED} = 2v + 2a - 1.$$

We have that $W_{acc} \leq W^A_{ED}$ whenever $K \geq \frac{15}{32}(1-2a) \equiv \tilde{K}_3$. It follows immediately that $\tilde{K}_3 < \tilde{K} = \frac{625}{1024}(1-a)$. Hence, in the entry-deterrence cone, it is always $W^A_{ED} > W_{acc}$. □

Proposition 5 *(consumer welfare - general case)*

The structure of this proof is identical to the one of Proposition 3. Again, we have that CS_{ED}^A is continuously decreasing in $K > 0$, while CS_{acc} does not depend on K, so that there exists a threshold level for K above which $CS_{ED}^A \leq CS_{acc}$, and below which $CS_{ED}^A \geq CS_{acc}$. This threshold level can be expressed as

$$\begin{aligned}\tilde{K}_4 &= \frac{1}{2048\left(t_1+t_2-\alpha_1-\alpha_2\right)\left(4t_1t_2-\left(\alpha_1+\alpha_2\right)^2\right)^4}((\alpha_1+\alpha_2)^2\left(-4\left(\alpha_1+\alpha_2\right)\cdot\right.\\ &\quad\cdot\left(7\alpha_1^2+16\alpha_1\alpha_2+7\alpha_2^2\right)+\left(32\alpha_1^2+72\alpha_1\alpha_2+31\alpha_2^2\right)t_1+\left(31\alpha_1^2+72\alpha_1\alpha_2+32\alpha_2^2\right)t_2)+\\ &\quad+6\left(\alpha_1+\alpha_2\right)\left(39\alpha_1^2+82\alpha_1\alpha_2+39\alpha_2^2\right)t_1t_2-\left(265\alpha_1^2+554\alpha_1\alpha_2+261\alpha_2^2\right)t_1^2t_2-\\ &\quad-\left(261\alpha_1^2+554\alpha_1\alpha_2+265\alpha_2^2+480\left(\alpha_1+\alpha_2\right)t_1-540t_1^2\right)t_1t_2^2+540t_1^2t_2^3)^2.\end{aligned}$$

Intersecting the condition for existence of entry deterrence equilibria from Proposition 3, $\tilde{K}$ as given in (22), we find that $\tilde{K}_4 > \tilde{K}$ whenever $\alpha_1 > 0, \alpha_2 > 0, 2t_2 > \alpha_1 + \alpha_2$, and t_1 large enough.

Moreover, we showed in Part (ii) of Proposition 2 that the interval $\left[\tilde{K}, \pi_{acc}^B\right]$ on which entry deterrence arises is non-empty. Since there exist values of $(\alpha_1, \alpha_2, t_1, t_2)$ such that $\tilde{K}_4$ is arbitrarily close to $\tilde{K}$, there must therefore also be a non-empty interval $\left[\tilde{K}_4, \pi_{acc}^B\right]$ where entry deterrence does arise and is harmful to consumers, as claimed in the Proposition. $\square$

Proposition 6 *(total welfare) - general case*

The result is obtained by comparing the total welfare under monopoly supply,

$$W_{ED}^A = 2v + (\alpha_1+\alpha_2) - \frac{1}{2}\left(t_1+t_2\right),$$

as defined in eq. (27) to the corresponding welfare under duopoly. To find the latter, we have to calculate the aggregate gross consumer surplus across all consumer groups and platforms, and subtract the entry cost.

$$\begin{aligned}GCS_{acc}^A &= \int_0^{n_1^A}\left(\alpha_1 n_2^A + v - t_1 x\right)dx + \int_0^{n_2^A}\left(\alpha_2 n_1^A + v - t_2 x\right)dx\\ GCS_{acc}^B &= \int_{n_1^A}^{1}\left(\alpha_1 n_2^B + v - t_1\left(1-x\right)\right)dx + \int_{n_2^A}^{1}\left(\alpha_2 n_1^B + v - t_2\left(1-x\right)\right)dx\\ W_{acc} &= GCS_{acc}^A + GCS_{acc}^B - K.\end{aligned}$$

We can then identify the threshold value of K such that $W^{acc} \leq W_{ED}^A$ as follows:

$$K \geq GCS_{acc}^A + GCS_{acc}^B - \left(2v + (\alpha_1+\alpha_2) - \frac{1}{2}\left(t_1+t_2\right)\right).$$

Inserting the corresponding expressions for duopoly prices (see (29) and (30)) and the resulting quantities into the expressions for GCS_{acc}^A and GCS_{acc}^B, and simplifying, yields the following threshold value for K:

$$\begin{aligned}\tilde{K}_5 &= \frac{1}{16\left(4t_1t_2-\left(\alpha_1+\alpha_2\right)^2\right)}((\alpha_1+\alpha_2)^2\left(-2\left(\alpha_1+\alpha_2\right)\cdot\right.\\ &\quad\cdot\left(4\alpha_1^2+7\alpha_1\alpha_2+4\alpha_2^2\right)+\left(4\alpha_1^2+6\alpha_1\alpha_2+5\alpha_2^2\right)t_1+\left(5\alpha_1^2+6\alpha_1\alpha_2+4\alpha_2^2\right)t_2)+\\ &\quad+60\left(\alpha_1+\alpha_2\right)^3t_1t_2-\left(29\alpha_1^2+58\alpha_1\alpha_2+33\alpha_2^2\right)t_1^2t_2-\\ &\quad-\left(33\alpha_1^2+58\alpha_1\alpha_2+29\alpha_2^2+120\left(\alpha_1+\alpha_2\right)t_1-60t_1^2\right)t_1t_2^2+60t_1^2t_2^3).\end{aligned}$$

All else equal, the welfare loss from entry deterrence is minimised when $\alpha_1, \alpha_2 \to 0$, so that splitting the consumer mass across two platforms does not carry a large welfare cost. In this case, we have that

$$\lim_{\alpha_1,\alpha_2\to 0} \tilde{K}_5 = \frac{15\,(t_1+t_2)}{64}, \lim_{\alpha_1,\alpha_2\to 0} \tilde{K} = \frac{625\,(t_1+t_2)}{2048}.$$

It is easy to verify that $\lim_{\alpha_1,\alpha_2\to 0} \tilde{K}_5 < \lim_{\alpha_1,\alpha_2\to 0} \tilde{K}$, where the latter represents the threshold above which entry deterrence arises in equilibrium. We can thus conclude that where entry deterrence arises, it always generates higher total welfare than the corresponding duopoly. □

Appendix B: Competitive Bottlenecks (Multi-homing)

In this appendix, we relax the assumption of single-homing on both sides, and instead assume that group 1 agents continue to join at most one platform (i.e. group 1 single-home), while group 2 agents can join both platforms instead (i.e. group 2 multi-home). We sketch a simple model where we set $\alpha_1 = 0$, while $\alpha_2 > 0$.

Net utilities for group-1 agents from eq. (1) thus simplify to the standard Hotelling-type utilities:

$$u_1^A = v - t_1 x - p_1^A \text{ and } u_1^B = v - t_1(1-x) - p_1^B,$$

while the net utilities for group-2 agents remain the same as in eq. (1).

The demand functions for group-1 agents can be derived from the indifference condition as follows:

$$n_1^A = \frac{1}{2} + \frac{p_1^B - p_1^A}{2t_1} \text{ and } n_1^B = \frac{1}{2} + \frac{p_1^A - p_1^B}{2t_1}. \tag{35}$$

When group 2 agents can multi-home, they can join both platforms and hence will join any platform that offers them non-negative utility. Because we have concentrated on full market coverage, platforms will then extract all surplus from the marginal group-2 agent, which is the one further away on the Hotelling line. All group-2 agents will join both platforms, i.e. $n_2^A = n_2^B = 1$, and assuming that v is always high enough to make the corner solution the relevant one,[20] the resulting prices paid by group-2 agents are thus given by:

$$p_2^i = \alpha_2 n_1^i + v - t_2, \tag{36}$$

where n_1^i is given in eq. (35).

Inserting these expressions into the platforms' profit functions yields

$$\pi^A\left(p_1^A, p_1^B\right) = \left(p_1^A + \alpha_2\right)\left(\frac{1}{2} + \frac{p_1^B - p_1^A}{2t_1}\right) + v - t_2 \tag{37}$$

$$\pi^B\left(p_1^A, p_1^B\right) = \left(p_1^B + \alpha_2\right)\left(\frac{1}{2} + \frac{p_1^A - p_1^B}{2t_1}\right) + v - t_2 - K. \tag{38}$$

Accommodation

Again, proceeding by backward induction, we first solve Platform B's price-setting problem after it decided to enter. Note that, under multi-homing, Platform B's profits are entirely determined by its group-1 price (and Platform A's group-1 price).

Maximising eq. (38) with respect to p_1^B, and inserting this solution into eq. (36), yields the following best-response prices for Platform B:

$$\begin{aligned} p_1^B\left(p_1^A\right) &= \frac{1}{2}\left(t_1 - \alpha_2 + p_1^A\right) \\ p_2^B\left(p_1^A\right) &= \frac{\alpha_2}{4t_1}\left(t_1 + \alpha_2 + p_1^A\right) + v - t_2. \end{aligned} \tag{39}$$

If the incumbent Platform A takes B's entry for granted, it will maximise its own profits subject to B's best-response prices in eq. (39). Inserting these prices into A's profit function in eq. (37), and solving for

[20] The relevant constraint can be expressed as $v > 2t$.

the p_1^A that maximises π^A, we obtain the following solutions for prices in the duopoly equilibrium:

$$\begin{aligned} p_{1,acc}^A &= \frac{3t_1}{2} - \alpha_2, p_{2,acc}^A = \frac{3\alpha_2}{8} - t_2 + v \\ p_{1,acc}^B &= \frac{5t_1}{4} - \alpha_2, p_{2,acc}^B = \frac{5\alpha_2}{8} - t_2 + v, \end{aligned} \quad (40)$$

and duopoly profits can thus be derived as:

$$\begin{aligned} \pi_{acc}^A &= \frac{9t_1}{16} - t_2 + v \\ \pi_{acc}^B &= \frac{25t_1}{32} - t_2 + v - K. \end{aligned} \quad (41)$$

We thus see that the duopoly equilibrium under multi-homing will be sustainable whenever:

$$K \leq \pi_{acc}^B = \frac{25t_1}{32} - t_2 + v.$$

Whenever v is large enough so that, under monopoly, the corner solution applies on both sides, these duopoly prices and profits are well defined.

Entry Deterrence

If instead Platform A wants to deter entry by Platform B, it has to set its prices so as to drive Platform B's profits net of entry costs K down to zero. Inserting B's best-response prices of eq. (39) into B's profit function of eq. (38),[21] we can solve for the limit price p_1^A:

$$p_{1,ED}^A = 2\sqrt{2t_1\left(t_2 - v + K\right)} - \alpha_2 - t_1. \quad (42)$$

Given this price to group-1 consumers, Platform A will achieve entry deterrence, implying that it will serve the entire group 1, i.e. $n_1^A = 1$.[22] From (36), the price for group-2 under limit pricing is therefore:

$$p_{2,ED}^A = \alpha_2 + v - t_2.$$

Platform A's profits under entry deterrence are given by the sum of the two limit prices (since Platform A will serve the entire market):

$$\pi_{ED}^A = v - (t_1 + t_2) + 2\sqrt{2}\sqrt{t_1\left(t_2 - v + K\right)}. \quad (43)$$

Platform A will thus want to engage in entry deterrence whenever $\pi_{ED}^A \geq \pi_{acc}^A$. Inserting from eq. (41) and (43), we can solve for the threshold level of K above which entry deterrence will arise as

$$K \geq \tilde{K}_{MH} = \frac{625t_1}{2048} - t_2 + v, \text{ with } \tilde{K}_{MH} < \pi_{acc}^B. \quad (44)$$

Proposition 7 *(entry deterrence - competitive bottlenecks)*

[21] It is natural to assume here that, if $n_1^B = 0$, then entry would not be viable for Platform B, even though it could in principle still sell to some group-2 customers. This is true when serving only group-2 customers is not enough to cover fixed costs on a stand-alone basis, that is, $v - t_2 < K$. We assume this to be satisfied as it is the only non-trivial case to study entry deterrence.

[22] In analogy to the single-homing case, we concentrate on those instances when, under monopoly price, it is optimal to set a price $p_{1,M}^A$ that reaches the corner solution $n_1^A = 1$. A fortiori, the corner solution also applies under the limit price $p_{1,ED}^A < p_{1,M}^A$.

When $\alpha_1 = 0$ and $\alpha_2 > 0$, and group-2 agents can multi-home, entry deterrence will arise in equilibrium whenever

$$K \in \left[\tilde{K}_{MH}, \pi^B_{acc}\right].$$

Finally, let us also comment on the possible non-negativity constraints on the limit prices set by the incumbent platform. In the case of multi-homing, it turns out that such a constraint will never be binding for those values of K for which entry deterrence can actually arise. To see this, note that $p^A_{1,ED}$ given in eq. (42) is increasing in K, and therefore reaches its minimum value for $K = \tilde{K}_{MH}$. Inserting $\tilde{K}_{MH}$ from eq. (44) into $p^A_{1,ED}$, we find that $p^A_{1,ED} > 0$ reduces to $\alpha_2 < \frac{9t_1}{16}$, which is always satisfied whenever the accommodation prices in eq. (40) are strictly positive.

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