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Interoperability between Ad-Financed Platforms with Endogenous Multi-Homing

Abstract

Platform interoperability is considered a powerful tool to promote competition in digital markets when network effects are at play. We study the effect of interoperability on competition between two ad-financed platforms, allowing for endogenous multi-homing of consumers. When the platforms are symmetric and decide non-cooperatively on their level of interoperability, interoperability emerges in equilibrium if the value of multi-homers relative to single-homers is sufficiently low for advertisers. From a welfare perspective, the equilibrium level of interoperability can be either too low or too high. When one (“large”) platform has an installed base of customers, its incentive to make its services interoperable is lower than for the other, smaller platform. However, mandating interoperability between the asymmetric platforms is not always socially optimal.

JEL-Codes: L130, L860, L150.

Keywords: interoperability, platform competition, multi-homing, advertising.

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“The Internet was made in universities and it was designed to interoperate. And as we’ve commercialized it, we’ve added more of an island-like approach to it, which I think is a somewhat a shame for users.” Larry Page, Google cofounder, December 11, 2012.¹

1 Introduction

The Internet was originally designed as an interoperable network between open systems. For example, email services are based on an open and interoperable protocol for online communication, regardless of a person’s email service or the type of device used to send emails. In contrast, today’s most widely used instant messaging services rely on proprietary protocols, and users cannot send messages from one messaging service to another (e.g., from WhatsApp to WeChat or Snapchat). Thus, consumers have no choice but to join the same platform as the users they want to communicate with. As a result, network effects play a key role in the competition between messaging service providers.

However, strong network effects can make it difficult for new entrants to compete with incumbent platforms. Users are often reluctant to switch to a new platform, even if it offers better services, because they would have to coordinate their move and may face individual switching costs, such as rebuilding their profile or providing data again. While platform differentiation and multi-homing (being present on different platforms at the same time) may allow multiple platforms to coexist in the market, a platform with a large locked-in customer base will still be more attractive to consumers than a smaller one.

Recently, policymakers and academics (see, for example, Gans (2018), Borgogno and Colangelo (2019), Chao and Schulman (2020), Nadler and Cicilline (2020), Cyphers and Doctorow (2021), Graves (2021), Riley (2020), Santesteban and Longpre (2021), Scott Morton et al. (2021), Stella (2021)) have been advocating for greater interoperability between digital platforms. In September 2022, the European Commission (EC) introduced the Digital Market Act (DMA),² a regulatory framework aimed at promoting fairness and contestability in digital markets. In particular, the new law mandates large dominant platforms (the so-called “gatekeepers”) offering messaging services to provide interoperability with smaller messaging platforms upon request and free of charge. The EC will assess the extension of this interoperability provision to social media in the future. Similar legislation, the ACCESS Act, is currently under consideration in

¹Fortune, *Larry Page on Google*, December 11, 2012.

²Regulation (EU) 2022/1925 of the European Parliament and of the Council of 14 September 2022 on contestable and fair markets in the digital sector, <http://data.europa.eu/eli/reg/2022/1925/oj>.

the U.S. Congress.³

In this paper, we study the effect of interoperability on competition between ad-financed platforms when consumers can multi-home.

We develop a model in which two platforms provide communication services to consumers. Consistent with the business model adopted by messaging service providers and social media, we assume that the platforms are free to users and derive their revenue solely from advertising. Consumers can decide to single-home on a given platform or to multi-home, taking into account the size of each network and the nuisance they expect from advertising on each platform. In this framework, we study the platforms' unilateral incentives to make their services interoperable and how the equilibrium level of interoperability compares to the social optimum.

We first consider a benchmark case where the two platforms are symmetric. We show that interoperability reduces multi-homing on the consumer side, decreasing the total demand addressed to each platform. The composition of demand is also affected, with an increase in single-homing and a decrease in multi-homing for each platform.

Since multi-homers are less valuable to advertisers than single-homers (the “incremental pricing principle”⁴), this shift in demand has two opposite effects on platforms' profits. First, the shift in the composition of demand towards more single-homing increases the market power of the platforms vis-à-vis advertisers (*market power* effect). Second, the decline in total demand reduces the audience that platforms can offer to advertisers (*total viewership* effect). The platforms' incentives to make their services interoperable then depend on the relative value of multi-homers versus single-homers in the advertising market. If advertisers discount a second exposure to their ads at a high rate, the market power effect dominates, and platforms make their services fully interoperable. Otherwise, the total viewership effect dominates, and the platforms keep their services non-interoperable.

We also show that the platforms may set the level of interoperability too low or too high compared to what would be socially optimal. This is because, first, the platforms do not internalize the consumer gains from higher levels of interoperability that result from higher quality interactions, leading platforms to choose too low a level of interoperability. Second, platforms do not fully internalize the surplus created by advertising in the multi-homing segment. This leads them to choose too high a level of interoperability.

³See <https://www.congress.gov/bill/117th-congress/house-bill/3849/text>.

⁴On the “incremental pricing principle,” see, e.g., Anderson and Jullien (2015).

In a second step, we extend our framework by considering that one platform (the “large” platform) has a locked-in customer base. Due to network effects, this installed base advantage allows the large platform to attract more unattached users than the other, “small”, platform in the competitive consumer segment. We then study the unilateral incentives of the large and the small platforms to make their services interoperable, and how the asymmetry between them affects these incentives.

If the installed base is large enough, we show that the large platform is less willing to interoperate, and the small platform is more willing to interoperate compared to the benchmark case with symmetric platforms. This is because the shift toward single-homing induced by a higher level of interoperability is more pronounced for the small platform than for the large platform. Therefore, the small platform faces a larger market power effect and a smaller total viewership effect than in the symmetric benchmark, which increases its incentive to interoperate. Conversely, the large platform faces a smaller market power effect and a higher total viewership effect, so its incentives to interoperate are lower. As a result, if the installed base advantage is large enough, interoperability does not arise in equilibrium.

However, we show that requiring asymmetric platforms to be interoperable is not always socially optimal. First, interoperability reduces multihoming and instead pushes consumers toward single-homing. To the extent that interoperability is imperfect, this leads to a loss of consumer surplus due to lower quality interactions with single-homers who were previously multi-homers. Second, the reduction in multihoming harms advertisers because it reduces the likelihood that consumers will become aware of their products.

Our results have important policy implications. They highlight the importance of considering the multi-sided business model of platforms. We show that implementing interoperability on the consumer side can negatively affect the welfare of market participants on other sides. In particular, the surplus of advertisers drops due to the reduced possibility of reaching the same consumer twice across platforms. Moreover, even in contexts where a large platform dominates the market, (imperfect) interoperability can reduce consumer welfare.

Related literature

This paper contributes to two streams of literature.

The first stream of literature analyzes the incentives of firms to make their networks compatible (interoperable) when network effects are present (see, e.g., Katz and Shapiro (1985) and

Farrell and Klemperer (2007)). Whether or not compatibility arises in equilibrium depends on the balance between a demand expansion effect and a leveling effect. First, compatibility enhances the value of firms' products by increasing network benefits. Since they can attract more users to the market, firms have a mutual interest in making their products compatible. Second, when firms have different installed bases (see, e.g., Crémer, Rey and Tirole (2000), Maluog and Schwartz (2006); Chen, Doraszelski and Harrington (2009)), the larger firm loses its competitive advantage with compatibility. In contrast, the smaller firm always prefers products to be compatible because it can catch up with the larger firm.

Our contribution to this literature is twofold. First, the literature either ignores multi-homing or models it exogenously,⁵ whereas we fully endogenize the multi-homing decisions of consumers. Second, the literature focuses on subscription-based business models, while we consider advertising-based business models (i.e., the type of business model used by messaging service providers or social media). We show that this leads to two new effects that have been ignored in the literature, the *market power* and *total viewership* effects. They arise because interoperability affects multi-homing, and multi-homers are less valuable to advertisers than single-homers. They then have implications for whether interoperability can occur in equilibrium.

Our paper is also closely related to Bourreau and Krämer (2022). As in the present paper, they show that interoperability reduces multi-homing and that this can have important implications for competition between digital platforms. However, their focus is different; they examine the impact of interoperability on market contestability, i.e., the possibility for a more efficient entrant to displace an incumbent platform. In contrast, we consider a setting where two platforms can both be active in the market. Furthermore, these authors assume that platforms earn a fixed revenue per user and do not consider the impact of interoperability on the profit-making (advertiser) side of the platforms.

Second, we relate to the literature on ad-financed media markets in the presence of shared viewership (see, e.g., Ambrus and Reisinger (2006), Ambrus, Calvano and Reisinger (2016), Gabszewicz, Laussel and Sonnac (2001) and Anderson, Foros and Kind (2018)). This literature emphasizes the importance of demand composition as opposed to total demand, given that firms

⁵Doganoglu and Wright (2006) study the incentives of firms to make their networks compatible in a setting where multi-homing can occur but is mostly exogenous. Crémer, Rey and Tirole (2000) consider endogenous multi-homing in an extension of their main setting but only in the extreme case where networks are incompatible (no connectivity).

compete on the advertiser side only for multi-homing users while acting as gatekeepers for single-homers. In particular, Anderson, Foros and Kind (2018) show that the *incremental pricing principle*, according to which multi-homing consumers are less valuable than single-homing consumers, has implications for firms' revenues and their incentives to differentiate. The idea is that if firms earn more profit from their single-homing users, they will avoid differentiation in order to minimize multi-homing.

Our contribution to this literature is to study the implications of the variation in the demand composition for ad-financed platforms with endogenous network size as a source of differentiation.

Organization of the paper

The rest of the paper is organized as follows. In the next section, we present the model. In Section 3, we solve for the equilibrium level of interoperability between two symmetric platforms and compare it to the social optimum. In Section 4, we extend our framework to consider interoperability between a small and a large platform. We conclude in Section 5.

2 Model set-up

We study a model in which two communication platforms (e.g., messaging or social media platforms) compete for consumers and advertisers and decide non-cooperatively on their level of interoperability. In the following, we introduce the three types of agents and their decisions.

Platforms Two platforms, A and B , offer a communication service to consumers that allows them to interact with each other. The platforms are ad-supported, so each platform $i \in \{A, B\}$ charges advertisers a price per ad p_i , but consumers can join and use the platforms for free. We assume that the cost of providing the service to consumers and advertisers is zero.

The two platforms offer a mass one of communication features, such as sending and receiving text or video messages or sharing location. Each platform i chooses unilaterally the subset of features $[0, \theta_i]$ that it wants to make interoperable with the other platform, with $\theta_i \leq 1$. Communication is only effective if the sending and receiving parties use the same features. So, the resulting level of interoperability θ between the two platforms corresponds to the set of common features, that is, $\theta = \min\{\theta_A, \theta_B\}$.⁶ Implementing interoperability is costless for the platforms.

⁶Cr  mer, Rey and Tirole (2000) make the same assumption.

Consumers The two platforms are horizontally differentiated *à la Hotelling*, with platform A located at $x = 0$ on the unit interval and platform B at $x = 1$. There is a unit mass of potential consumers uniformly distributed on the unit interval. Each consumer can decide to single-home or multi-home, that is, to join both platforms. As Anderson, Foros and Kind (2018), we assume that consumers do not observe the ad prices or the resulting ad levels but rationally anticipate them. We denote by r_i^e the level of advertising that consumers expect on platform i . Furthermore, consumers form rational expectations about the number of consumers who will join each platform. They expect x_A^e users on platform A and $1 - x_B^e$ users on platform B .

Thus, a consumer located at x receives the following expected net utility from single-homing on platform A :

$$u_A = v + \alpha [x_A^e + \theta(1 - x_A^e)] - tx - \gamma r_A^e,$$

where v represents a stand-alone utility, α the strength of network effects, t the transportation cost and $\gamma > 0$ the marginal disutility of advertising. By joining platform A , the consumer can interact with x_A^e users on that platform. In addition, she can interact *via* interoperability with the $1 - x_A^e$ users of the other platform, but with a degraded quality of interaction $\theta \leq 1$.

Similarly, a consumer located at x derives the following expected net utility from single-homing on platform B :

$$u_B = v + \alpha [1 - x_B^e + \theta x_B^e] - t(1 - x) - \gamma r_B^e.$$

Finally, a multi-homing consumer obtains the following expected net utility:

$$u_{AB} = 2v + \alpha - t - \gamma(r_A^e + r_B^e). \tag{1}$$

We make the following assumptions about the utility of multi-homing. First, the standalone benefits of each platform add up; there is no overlap between the services that generate these benefits. Second, there is no double-counting of network benefits; a multi-homer can interact with other multi-homers twice, but only one interaction has value.

Advertisers A unit mass of homogeneous advertisers wants to inform consumers about their products. To do so, they can buy ad space from each platform. We assume that each advertiser places at most one ad per platform. If an advertiser chooses to single-home on a platform, it reaches all the consumers on that platform, each valued at σ . If, instead, the advertiser

chooses to multi-home, it can reach all potential consumers at least once, and twice for multi-homing consumers. Advertisers value reaching a consumer twice, but the second impression is discounted by $\beta < 1$. Thus, an advertiser's willingness to pay to reach a multi-homer on two different platforms is $\sigma + \beta\sigma$.

For example, suppose that for each advertised product, there is a fraction μ of consumers with a reservation value ω for the product, and the remaining fraction $1 - \mu$ with a reservation value of zero. Each advertiser charges the price ω for his product because he is a monopolist in his market. Furthermore, assume that there is a probability ε that a user will not pay attention to an ad impression. Then, the expected value per user of advertising on one platform is $(1 - \varepsilon)\mu\omega \equiv \sigma$, while advertising on both platforms yields an expected value per multi-homer of $(1 - \varepsilon)\mu\omega + \varepsilon(1 - \varepsilon)\mu\omega$, with $\beta \equiv \varepsilon$.⁷

In this framework, the surplus that consumers can derive from being aware of a product is extracted by the advertisers, so advertising is just a nuisance to them. As for advertisers, consumer inattention leads them to advertise on both platforms to increase the likelihood that a multi-homing consumer will learn about their product.

Timing First, platforms non-cooperatively choose their level of interoperability θ_i . The resulting level of interoperability $\theta = \min\{\theta_A, \theta_B\}$ is made public. Second, platforms simultaneously choose their price per ad p_i ; advertisers observe the ad prices and decide on which platform(s) to buy advertising space. Third, consumers decide which platform(s) to join. They do not observe the ad prices or the ad levels, but rationally anticipate them.

We look for the (fulfilled-expectations) Perfect Nash Equilibrium of this game. Since consumers do not observe the ad prices or the ad levels, they do not react to the actual ad levels on each platform when deciding which platform(s) to join. Consequently, consumers have (passive) fulfilled expectations about network sizes (see Hurkens and López (2014)).

In the next section, we solve for the equilibrium of the game when the platforms are symmetric. In Section 4, we introduce platform asymmetry by considering that one platform initially has a larger locked-in customer base than its rival.

⁷As Anderson, Foros and Kind (2018), we assume that there is no "information congestion" in advertising, so that the probability of not paying attention to an ad ε is not due to the attention paid to other ads, but to other exogenous factors. As a result, advertisers' valuations are independent of the number of ads displayed on the platforms.

3 Symmetric platforms

As usual, we solve the game by backward induction. First, we study the homing decisions of consumers. Second, we solve for the equilibrium in the advertising market. Third, we analyze the choice of interoperability levels by the platforms. Finally, we analyze the impact of interoperability on consumers and producers and compare the equilibrium level with the level of interoperability that a welfare-maximizing regulator would choose.

3.1 Consumer homing decisions

At Stage 3, consumers decide which platform(s) to join. First, note that a consumer has a positive net utility from single-homing on platform A if and only if

$$x \leq \bar{x}_A \equiv \frac{v + \alpha [x_A^e + \theta(1 - x_A^e)] - \gamma r_A^e}{t}.$$

Furthermore, a consumer located at x derives the following incremental utility from joining platform A in addition to platform B :

$$u_{AB} - u_B = v + \alpha(1 - \theta)x_B^e - \gamma r_A^e - tx.$$

Second-homing on platform A brings an additional standalone utility, v , and the ability to interact with the x_B^e single-homing users of platform A with a higher quality of interaction, using the $(1 - \theta)$ non-interoperable features. The decision to multi-home is made by weighing these benefits against the costs of multi-homing, which consist of the transportation cost to the second platform and the expected nuisance from advertising on that platform. Therefore, consumers of type $x \leq \hat{x}_A$ join A in addition to B , with

$$\hat{x}_A = \frac{v + \alpha(1 - \theta)x_B^e - \gamma r_A^e}{t}. \quad (2)$$

Assuming that consumers' expectations about network sizes imply some multi-homing (i.e., $x_A^e > x_B^e$), we have $\hat{x}_A < \bar{x}_A$. Therefore, consumers of type $x \leq \hat{x}_A$ join platform A either as single-homers or as multi-homers.

Similarly, consumers of type $x \geq \hat{x}_B$ join platform B either as single-homers or as multi-homers, with

$$\hat{x}_B = 1 - \frac{v + \alpha(1 - \theta)(1 - x_A^e) - \gamma r_B^e}{t}. \quad (3)$$

We have $\partial \hat{x}_A / \partial x_B^e = \alpha(1 - \theta)/t$ and $\partial \hat{x}_B / \partial x_A^e = \alpha(1 - \theta)/t$. To ensure the existence of a stable equilibrium where both platforms are active, we must assume that $t > \alpha(1 - \theta)$ for all interoperability levels $\theta \in [0, 1]$, which is true with the following assumption:

Assumption 1 (*Market sharing*). $t > \alpha$

In the fulfilled expectations equilibrium, we have $x_i^e = \hat{x}_i$. Solving for the system of equations defined by (2) and (3), we find that the marginal consumers indifferent between single-homing and multi-homing are located at \hat{x}_A and \hat{x}_B , with

$$\hat{x}_A = 1 - \frac{t - v}{t + \alpha(1 - \theta)} - \gamma \frac{tr_A^e - \alpha(1 - \theta)r_B^e}{t^2 - \alpha^2(1 - \theta)^2} \quad \text{and} \quad \hat{x}_B = \frac{t - v}{t + \alpha(1 - \theta)} + \gamma \frac{tr_B^e - \alpha(1 - \theta)r_A^e}{t^2 - \alpha^2(1 - \theta)^2}.$$

Denoting SH_i the mass of single-homing consumers on platform i who are exclusive to that platform, and MH the mass of multi-homing consumers who are shared by A and B , we have:

$$SH_A \equiv \hat{x}_B, \quad MH \equiv \hat{x}_A - \hat{x}_B \quad \text{and} \quad SH_B \equiv 1 - \hat{x}_A.$$

3.2 Advertising decisions

At Stage 2, the platforms set their advertising price p_i and then, advertisers decide on which platform(s) to buy advertising space. The following lemma characterizes the equilibrium in the advertising market.

Lemma 1 (*Incremental pricing*). *There exists a unique equilibrium where each platform i sets the price per ad $p_i = \sigma SH_i + \beta \sigma MH$, with*

$$SH_i = \frac{\gamma + t - v}{t + \alpha(1 - \theta)} \quad \text{and} \quad MH = 1 - \frac{2(\gamma + t - v)}{t + \alpha(1 - \theta)}.$$

Each advertiser places an ad on each platform. The resulting advertising level on each platform is $r_i = 1$.

Proof. The proof follows that of Proposition 1 in Anderson, Foros and Kind (2018). Given consumer expectations about ad levels, r_A^e and r_B^e , there is a unique equilibrium in which each platform sets the price per ad $p_i = \sigma SH_i(r_A^e, r_B^e) + \beta \sigma MH(r_A^e, r_B^e)$, which is known as the *incremental pricing principle*. It is an equilibrium, because if firm j prices as such, it is a best response for firm i to do so as well. Any higher price would lead to zero demand from advertisers. Conversely, any lower price would not attract more advertisers. The equilibrium

is also unique: since all platforms must be active in any equilibrium, there is no undercutting, and all advertisers must be on both platforms. If they are all on each platform, then platform i must be pricing at the *incremental value*. Since all advertisers are on all platforms, the realized number of ads on each platform is equal to 1. Therefore, consumers should rationally expect that $r_i = 1$. \square

We are interested in market structures with both single-homers and multi-homers, that is where $0 < \hat{x}_B < \hat{x}_A < 1$ in equilibrium for all $\theta \in [0, 1]$. This is true if:

Assumption 2 (*Partial multi-homing equilibrium*).

$$\gamma + t/2 < v < \gamma + t.$$

Figure 1 shows the demand structure in the equilibrium with partial multi-homing. Consumers located at $x < \hat{x}_B$ single-home on platform A , while consumers of type $x > \hat{x}_A$ single-home on platform B . Consumers located between \hat{x}_B and \hat{x}_A multi-home.

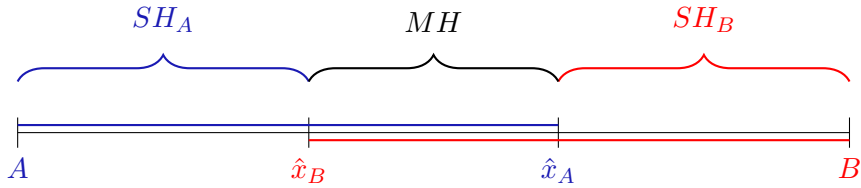


Figure 1: Demand structure with partial multi-homing.

3.3 Platforms' interoperability decisions

At Stage 1, platforms decide non-cooperatively on their level of interoperability. We begin by studying the impact of interoperability on consumer demand for each platform.

The following lemma characterizes how the demand structure is affected by an increase in the level of interoperability θ .

Lemma 2 (*Interoperability and multi-homing*). *An increase in the level of interoperability reduces consumer multi-homing.*

Proof. Under Assumption 2, we have $dMH/d\theta < 0$. \square

To understand how interoperability affects the consumer's choice between single-homing and multi-homing, consider equation (2), which gives the location \hat{x}_A of the marginal consumer

indifferent between single-homing on platform B and multi-homing. Differentiating (2) with respect to the level of interoperability θ , we obtain

$$\frac{d\hat{x}_A}{d\theta} = \frac{\alpha}{t} \left[-\hat{x}_B + (1 - \theta) \frac{d\hat{x}_B}{d\theta} \right]. \quad (4)$$

Equation (4) shows that increasing the level of interoperability has two effects on the location of the marginal consumer. A first effect is that for a given \hat{x}_B , which represents the single-homing demand of platform A , a higher level of interoperability reduces the incentives to multi-home and pushes to single-home on B . Indeed, for a user of platform B , a higher level of interoperability improves the quality of interactions with the exclusive users of A *via* interoperability, making multi-homing less attractive. A second effect is that a higher level of interoperability increases the single-homing demand of platform A (as $d\hat{x}_B/d\theta \geq 0$ under Assumption 1), making multi-homing more attractive for a given level of interoperability. Overall, we find that the first effect always dominates the second. Thus, we have the following:

Corollary 1 (*Interoperability and consumer demand*). *An increase in the level of interoperability leads to an increase in the single-homing demand of each platform and a decrease in their total demand.*

We now consider the (non-cooperative) interoperability decisions of the platforms. Since in the equilibrium of Stage 2, all advertisers multi-home, platform i 's profit is given by:

$$\Pi_i(\theta_i, \theta_j) = \sigma SH_i(\theta) + \beta \sigma MH(\theta), \quad \text{with } \theta = \min\{\theta_i, \theta_j\}.$$

We find that:

Proposition 1 (*Platforms' interoperability decisions*). *In equilibrium, the platforms set the maximum level of interoperability $\theta_i^* = 1$ if $\beta \leq 1/2$ and the minimum level of interoperability $\theta_i^* = 0$ if $\beta > 1/2$.*

Proof. Let $\tilde{\Pi}_i(\theta) = \sigma SH_i(\theta) + \beta \sigma MH(\theta)$, with

$$SH_i(\theta) = \frac{\gamma + t - v}{t + \alpha(1 - \theta)} \quad \text{and} \quad MH(\theta) = 1 - \frac{2(\gamma + t - v)}{t + \alpha(1 - \theta)}.$$

Platform i 's profit is then given by:

$$\Pi_i(\theta_i, \theta_j) = \begin{cases} \tilde{\Pi}_i(\theta_i) & \text{if } \theta_i \leq \theta_j \\ \tilde{\Pi}_i(\theta_j) & \text{if } \theta_i > \theta_j \end{cases}$$

We find that $\tilde{\Pi}_i(\theta)$ is strictly increasing in θ if $\beta < 1/2$ and strictly decreasing if $\beta > 1/2$. Therefore, if $\beta < 1/2$, there is a unique equilibrium where both platforms set their interoperability level at the maximum ($\theta_i^* = 1$). Conversely, if $\beta > 1/2$, there is a unique equilibrium where both platforms set their interoperability level at the minimum ($\theta_i^* = 0$). If $\beta = 1/2$, $\tilde{\Pi}_i(\theta)$ is constant. In this case, we adopt the convention that the platforms set their interoperability level at the maximum. \square

When deciding on its level of interoperability, a platform balances two opposite effects: a *market power* effect and a *total viewership* effect. Without loss of generality, consider the effect of a higher level of interoperability on platform A 's profit:

$$\frac{d\Pi_A}{d\theta} = \sigma(1 - \beta)\frac{d\hat{x}_B}{d\theta} + \beta\sigma\frac{d\hat{x}_A}{d\theta}. \quad (5)$$

The first effect (*market power*) corresponds to the first term in equation (5) and is due to the shift in the composition of demand. As the marginal consumer \hat{x}_B shifts to the right following an increase in the level of interoperability ($d\hat{x}_B/d\theta \geq 0$), some multi-homers become exclusive users of platform A . Therefore, for these consumers, the platform can now charge advertisers the monopoly price σ instead of the *incremental value* resulting from competition between platforms in the multi-homing segment, $\beta\sigma$. The net gain from this change in demand composition is $\sigma(1 - \beta)d\hat{x}_B/d\theta$.

The second effect (*total viewership*) is given by the last term in equation (5). It corresponds to the decrease in total viewership, \hat{x}_A , that platform A can offer to advertisers. Indeed, the marginal consumer \hat{x}_A shifts to the left ($d\hat{x}_A/d\theta \leq 0$) after an increase in θ . Since marginal viewers are multi-homers, platform A 's profit is reduced by an amount $\beta\sigma d\hat{x}_A/d\theta$.

In the symmetric case, the effect of a change in the level of interoperability on the location of the marginal consumer is symmetric for the two platforms ($d\hat{x}_B/d\theta = -d\hat{x}_A/d\theta$). Therefore, the net effect of an increase in the level of interoperability is equal to $\sigma(1 - 2\beta)d\hat{x}_B/d\theta$. It is positive if advertisers discount a second ad exposure at $\beta < 1/2$, in which case both platforms

choose a maximum level of interoperability ($\theta_i = 1$). Otherwise, if $\beta > 1/2$, the net effect is negative and both platforms choose a minimum level of interoperability ($\theta_i = 0$). Finally, note that in this symmetric case, if the platforms were to coordinate their decisions, they would choose the same level of interoperability.

Therefore, even though interoperability is costless and platforms are symmetric, platforms may choose not to be interoperable. This contrasts with the standard literature on interoperability. For example, Crémer, Rey and Tirole (2000) find that symmetric networks always benefit from being interoperable because it expands their demands without having any other adverse effect. In our framework, multi-homing is endogenous, and platforms are ad-financed, which leads to two new effects. First, interoperability decreases total demand by reducing multi-homing (*total viewership* effect). Second, it increases the market power of platforms over advertisers (*market power* effect). When the first effect dominates (which happens if $\beta > 1/2$), interoperability does not emerge in equilibrium.

3.4 Welfare analysis

Finally, we examine the effect of interoperability on the surplus of market participants and study the optimal choice of interoperability by a welfare-maximizing regulator. We define welfare as the sum of consumer surplus and producer surplus.

Consumer surplus is given by

$$CS(\theta) = \int_0^{\hat{x}_B(\theta)} u_A(\theta, x) dx + \int_{\hat{x}_B(\theta)}^{\hat{x}_A(\theta)} u_{AB} dx + \int_{\hat{x}_A(\theta)}^1 u_B(\theta, x) dx. \quad (6)$$

We find that:

Lemma 3 (*Consumer surplus*). *Consumer surplus increases in the level of interoperability.*

To understand this result, consider the differentiation of (6) with respect to the level of interoperability θ :

$$\begin{aligned} \frac{dCS}{d\theta} &= \int_0^{\hat{x}_B(\theta)} \frac{\partial u_A}{\partial \theta}(\theta, x) dx + \underbrace{\int_{\hat{x}_B(\theta)}^{\hat{x}_A(\theta)} \frac{\partial u_{AB}}{\partial \theta} dx}_{=0} + \int_{\hat{x}_A(\theta)}^1 \frac{\partial u_B}{\partial \theta}(\theta, x) dx \\ &\quad + \frac{d\hat{x}_B}{d\theta} \underbrace{[u_A(\theta, \hat{x}_B) - u_{AB}]}_{=0} - \frac{d\hat{x}_A}{d\theta} \underbrace{[u_B(\theta, \hat{x}_A) - u_{AB}]}_{=0} \\ &= 2\alpha (\hat{x}_B)^2 - 2\alpha \hat{x}_B(1 - \theta) \frac{d\hat{x}_B}{d\theta}. \end{aligned} \quad (7)$$

The first term in equation (7) represents a direct effect of increasing the level of interoperability for a given demand structure. A higher level of interoperability increases the quality of the interactions between single-homers, in volume $2(\hat{x}_B)^2$. The second term in (7) represents an indirect effect of a change in the level of interoperability. As the level of interoperability increases, the mass of single-homers on each platform increases. This represents a loss of utility from interactions for the single-homers on both platforms, since single-homers can only be reached by other single-homers through interoperability. Overall, we find that the first effect always dominates the second:

$$\frac{dCS}{d\theta} = \frac{2\alpha t(\hat{x}_B)^2}{t + \alpha(1 - \theta)} > 0.$$

Producer surplus is defined as the sum of advertiser surplus and platforms' profits:

$$PS = AS + \Pi_A + \Pi_B = \sigma + \beta\sigma MH,$$

$$\text{with } AS = \sigma(1 - \beta)MH.$$

The producer surplus is equal to the gross surplus of advertisers, which is partially extracted by the platforms. Through multi-homing, advertisers are able to reach all consumers at least once, which is worth σ . They receive an additional gross surplus of $\beta\sigma$ by reaching multi-homers a second time. While their surplus from reaching single-homers is always fully extracted by the platforms, they derive utility $\sigma + \beta\sigma$ from reaching a multi-homer twice and pay the price $\beta\sigma$ to each platform. As a result, their net surplus from reaching a multi-homer twice is $\sigma(1 - \beta)$.

The following result shows that the producer surplus is maximized with a minimum level of interoperability ($\theta = 0$).

Lemma 4 (*Producer surplus*). *Producer surplus and advertiser surplus are decreasing in the level of interoperability.*

Proof. We have $dPS/d\theta = \sigma\beta dMH/d\theta < 0$ and $dAS/d\theta = \sigma(1 - \beta)dMH/d\theta < 0$. □

The industry benefits from multi-homing because it increases consumer awareness of products. Since interoperability reduces multi-homing, a minimum level of interoperability is preferable from an industry perspective.

The previous analysis shows that while consumers benefit from interoperability, the industry is harmed. Therefore, a regulator who would mandate a certain level of interoperability would

face a trade-off. The following proposition describes the optimal choice of a welfare-maximizing regulator.

Proposition 2 (*Regulator's interoperability choice*). *A welfare-maximizing regulator sets the maximum level of interoperability $\theta^W = 1$ if $\beta \leq \beta^W$ and the minimum level of interoperability $\theta^W = 0$ if $\beta > \beta^W$, with*

$$\beta^W = \frac{(\gamma + t - v)(\alpha + 2t)}{2\sigma(\alpha + t)}.$$

Proof. See appendix. □

We find that the welfare function W is convex in the level of interoperability. For low levels of θ , the loss in producer surplus tends to outweigh the gain in consumer surplus. For higher levels of interoperability, however, improving interoperability increases total welfare. Therefore, the regulator sets the level of interoperability either at its minimum ($\theta = 0$) or at its maximum ($\theta = 1$). More precisely, the regulator sets full interoperability if $\beta < \beta^W$ and no interoperability otherwise.

The following proposition compares the equilibrium level of interoperability to the social optimum.

Proposition 3 (*Platforms' and regulator misalignment*). *Compared to the social optimum, platforms set*

- *too low a level of interoperability if $\beta \in [1/2, \beta^W]$, which can happen if $\beta^W > 1/2$,*
- *too high a level of interoperability if $\beta \in [\beta^W, 1/2]$, which can happen if $\beta^W < 1/2$.*

We have $\beta^W < 1/2$ if and only if $\sigma > (2t + \alpha)\hat{x}_B(0)$.

Proof. We have $\beta^W = (1/2)\hat{x}_B(0)(\alpha + 2t)/\sigma$, with $\hat{x}_B(0) = \hat{x}_B|_{\theta=0}$. Therefore, $\beta^W < 1/2$ if and only if $\sigma > (2t + \alpha)\hat{x}_B(0)$. □

There are two sources of market failure. First, platforms do not internalize the consumer gains from higher levels of interoperability that result from higher quality interactions. In particular, this is due to our assumption that platforms do not charge consumers subscription or usage fees. However, this is a relevant assumption in the context of messaging applications or social media. This leads platforms to choose too low a level of interoperability. Second, platforms

do not fully internalize the surplus created by advertising in the multi-homing segment. This leads them to choose too high a level of interoperability, which reduces multi-homing. Overall, the equilibrium level of interoperability may thus be too low or too high.

4 Platform asymmetry

In this section, we extend the baseline model by introducing an asymmetry between the platforms. We want to study the incentives of a large and a small platform to interoperate, and how the asymmetry between them affects these incentives.

Specifically, we assume that one platform (platform A , without loss of generality) has an (exogenous) installed base δ of locked-in users, while the other platform (platform B) has none. Therefore, platform A represents the large platform, and platform B the small platform.

The locked-in users of platform A do not consider joining the rival platform. Therefore, we focus on the homing decision of consumers in the competitive Hotelling segment of mass 1. In this segment, a consumer located at x receives the following utility from single-homing on A , single-homing on B , and multi-homing:

$$\begin{aligned} u_A &= v + \alpha [x_A + \delta + \theta(1 - x_A)] - tx - \gamma r_A^e, \\ u_B &= v + \alpha [1 - x_B + \theta(x_B + \delta)] - t(1 - x) - \gamma r_B^e, \\ u_{AB} &= 2v + \alpha(1 + \delta) - t - \gamma(r_A^e + r_B^e). \end{aligned}$$

By single-homing on platform A , a consumer can interact with the locked-in users of that platform with the complete set of features. However, consumers single-homing on platform B can only interact with the locked-in users through interoperability, so with a degraded quality of interaction. Multi-homing allows full interaction with the entire population of users.

4.1 Consumer homing and advertising decisions

To determine consumers' homing decisions at Stage 3, we use similar reasoning as in the baseline model. A consumer located at x joins platform A in addition to platform B if and only if $u_{AB} - u_B \geq 0$, that is, if $x \leq \hat{x}_A$ where

$$\hat{x}_A = \frac{v + \alpha(1 - \theta)(x_B^e + \delta) - \gamma r_A^e}{t}. \quad (8)$$

Similarly, a consumer located at x joins B in addition to A if and only if $u_{AB} - u_A \geq 0$, that is, if $x \geq \hat{x}_B$ where

$$\hat{x}_B = 1 - \frac{v + \alpha(1 - \theta)(1 - x_A^e) - \gamma r_B^e}{t}. \quad (9)$$

In the fulfilled expectations demand equilibrium, we must have $x_i^e = \hat{x}_i$. Replacing x_i^e for \hat{x}_i , we solve the system of equations given by (8) and (9) for \hat{x}_A and \hat{x}_B . We obtain:

$$\begin{aligned} \hat{x}_A &= 1 - \frac{t - v}{t + \alpha(1 - \theta)} - \frac{\gamma(tr_A^e - \alpha(1 - \theta)r_B^e) - \delta\alpha t(1 - \theta)}{t^2 - \alpha^2(1 - \theta)^2} \\ \hat{x}_B &= \frac{t - v}{t + \alpha(1 - \theta)} + \frac{\gamma(tr_B^e - \alpha(1 - \theta)r_A^e) + \delta\alpha^2(1 - \theta)^2}{t^2 - \alpha^2(1 - \theta)^2}. \end{aligned}$$

At Stage 2, platforms set their price per ad and advertisers decide on which platform(s) to buy ad space. The following lemma characterizes the fulfilled-expectation equilibrium at this stage of the game.

Lemma 5 (*Equilibrium with platform asymmetry*). *There exists a unique equilibrium where platforms set the price per ad $p_i = \sigma SH_i + \beta \sigma MH$, with*

$$\begin{aligned} SH_A &= \frac{\gamma + t - v}{t + \alpha(1 - \theta)} + \delta \frac{\alpha^2(1 - \theta)^2}{t^2 - \alpha^2(1 - \theta)^2}, \quad SH_B = \frac{\gamma + t - v}{t + \alpha(1 - \theta)} - \delta \frac{t\alpha(1 - \theta)}{t^2 - \alpha^2(1 - \theta)^2} \\ \text{and } MH &= 1 - \frac{2(\gamma + t - v) - \delta\alpha(1 - \theta)}{t + \alpha(1 - \theta)}. \end{aligned}$$

Each advertiser places one ad on each platform, resulting on a level of advertising $r_A = r_B = 1$.

Proof. Using similar reasoning as in Lemma 1, we find that in the equilibrium of Stage 2, platforms charge the price per ad $p_i = \sigma SH_i + \beta \sigma MH$ and each advertiser places one ad on each platform, resulting in a level of advertising $r_i = 1$. Replacing for $r_i = 1$ into $SH_A = \hat{x}_B$, $SH_B = 1 - \hat{x}_A$, and $MH = \hat{x}_A - \hat{x}_B$, gives the equilibrium number of single-homers and multi-homers. \square

We are interested in market structures with both single-homers and multi-homers, that is, where in equilibrium, $SH_i > 0$ for $i = A, B$ and $MH > 0$, for all $\theta \in [0, 1]$. This is true if:

Assumption 3 (*Partial multi-homing equilibrium with platform asymmetry*).

$$\gamma + \frac{t}{2} < v < \gamma + t - \frac{\delta\alpha t}{t - \alpha}.$$

There is a range of values of v satisfying these conditions if δ is not too large:

$$\delta < \frac{t - \alpha}{2\alpha} \equiv \delta^{\max}.$$

The following lemma characterizes how the installed base advantage of platform A affects the demand of each platform and the composition of demand in the competitive segment.

Lemma 6 (*Effect of installed base on consumer demand*). *A larger installed base δ leads to an increase in the demand of platform A and a decrease in the demand of platform B . Single-homing on A increases, while single-homing on B decreases. Multi-homing increases.*

Proof. The total demand of platform A on the competitive segment is equal to \hat{x}_A and the demand of platform B is equal to $1 - \hat{x}_B$. We have $d\hat{x}_A/d\delta > 0$ and $d\hat{x}_B/d\delta > 0$. Besides, we have $dSH_A/d\delta > 0$, $dSH_B/d\delta < 0$ and $dMH/d\delta > 0$. \square

Intuitively, the installed base advantage of platform A allows the large platform to attract more demand than the small platform in the competitive segment due to network effects.

The installed base also affects the composition of demand. Consider the variations in the location of the marginal multi-homers given by differentiating equations (8) and (9) with respect to δ :

$$\begin{aligned} \frac{d\hat{x}_A}{d\delta} &= \frac{\alpha(1 - \theta)}{t} \left[1 + \frac{d\hat{x}_B}{d\delta} \right] \\ \frac{d\hat{x}_B}{d\delta} &= \frac{\alpha(1 - \theta)}{t} \frac{d\hat{x}_A}{d\delta}. \end{aligned}$$

First, an increase in δ makes second-homing on platform A more attractive in order to interact with the locked-in users of that platform. Thus, the marginal consumer indifferent between multi-homing and single-homing on B , located at \hat{x}_A , shifts to the right, reducing the exclusive user base of platform B . This in turn reduces the incentive to second-home on platform B . Therefore, the marginal consumer indifferent between multi-homing and single-homing on A , located at \hat{x}_B , also shifts to the right, though less so than for \hat{x}_B (see Figure 2 for an illustration). Since this increases the size of platform A 's exclusive user base, it further increases the incentives to second-home on that platform, and so on. Assumption 1 ensures that the market does not tip and that both platforms remain active in equilibrium. Overall, a larger installed base increases the single-homing demand of the large platform and decreases that of the small platform.

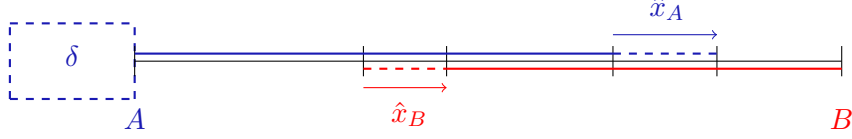


Figure 2: Asymmetric shift in the composition of demand induced by an increase in δ .

4.2 Platforms' interoperability decisions

At Stage 1, platforms decide non-cooperatively on their level of interoperability. We begin by characterizing the impact of interoperability on the consumer demand for each platform in the competitive segment.

Lemma 7 (*Interoperability and consumer demand with platform asymmetry*). *An increase in the level of interoperability:*

- reduces consumer multi-homing;
- decreases the single-homing demand of platform A if $\theta < \hat{\theta}$ and increases it if $\theta > \hat{\theta}$, where $\hat{\theta} \in [0, 1)$ and $\hat{\theta} > 0$ if δ is high enough;
- increases the single-homing demand of platform B.

Proof. See appendix. □

Similar to the symmetric case, interoperability reduces multi-homing. However, the marginal multi-homers \hat{x}_A and \hat{x}_B , and thus the demand composition of the two platforms, are affected differently. While the single-homing demand of the small platform always increases with the level of interoperability, the single-homing demand of the large platform may decrease in θ for low levels of interoperability and increase for higher levels. To understand the intuition, consider the variations of the location of the marginal users, given by equations (8) and (9), with respect to the level of interoperability θ :

$$\frac{d\hat{x}_A}{d\theta} = \frac{\alpha}{t} \left[-(SH_A + \delta) + (1 - \theta) \frac{d\hat{x}_B}{d\theta} \right] \quad (10)$$

$$\frac{d\hat{x}_B}{d\theta} = \frac{\alpha}{t} \left[SH_B + (1 - \theta) \frac{d\hat{x}_A}{d\theta} \right]. \quad (11)$$

As in the symmetric case, the first terms in equations (10) and (11) represent a direct effect of a higher level of interoperability, taking the demand composition as given. Since it allows a higher quality of interaction with the other network, a higher level of interoperability

reduces the incentive to multi-home and instead pushes to single-home. Also, since we have $SH_A + \delta > SH_B$, the increase in single-homing is greater for the small platform (B) than for the large one (A).

The second terms in (10) and (11) represent an (opposite) indirect effect: since a higher level of interoperability increases the single-homing demand of each platform, it also makes multi-homing more attractive. For example, an increase in the single-homing demand of platform B ($d\hat{x}_A/d\theta \leq 0$) increases the incentives of the single-homing users of platform A to multi-home.

Since the direct effect is larger for the small platform than for the large platform, this negative feedback loop is more significant for the large platform. Therefore, a higher level of interoperability leads to a greater increase in single-homing demand for the small platform than for the large one. For low levels of interoperability, the indirect effect plays a more important role and the large platform's single-homing demand may actually decrease with a higher level of interoperability.

Since the total demand of a platform decreases with the single-homing demand of the competing platform, Lemma 7 implies that:

Corollary 2. *An increase in the level of interoperability decreases platform A 's total demand in the competitive segment. Platform B 's total demand increases if $\theta < \hat{\theta}$ and decreases otherwise.*

Therefore, interoperability reduces the total demand of the large platform in the competitive segment, but it does not always benefit the small platform. While the single-homing demand of the small platform, which is more valuable to advertisers, increases with interoperability, its total demand may either increase or decrease. However, we find that the difference in total demand between the large and the small platforms decreases with the level of interoperability. Therefore, interoperability levels the playing field between them in terms of network effects.

We now turn to the non-cooperative interoperability decisions of the platforms. At Stage 1, the platforms' profits are:

$$\Pi_A(\theta_A, \theta_B) = \sigma(\delta + SH_A(\theta)) + \beta\sigma MH(\theta) \quad (12)$$

$$\Pi_B(\theta_A, \theta_B) = \sigma SH_B(\theta) + \beta\sigma MH(\theta), \quad (13)$$

with $\theta = \min\{\theta_A, \theta_B\}$.

We begin by characterizing the level of interoperability that each platform would prefer (i.e., if it could choose the level of interoperability θ between them):

Proposition 4 (*Platforms' interoperability choices with platform asymmetry*). *The large platform, A, prefers a lower level of interoperability than the small platform, B. Besides, there are thresholds $\hat{\delta}_A$, $\hat{\delta}_B^0$, and $\hat{\delta}_B^1$, with $\hat{\delta}_A \leq \hat{\delta}_B^0 \leq \hat{\delta}_B^1$, such that:*

- *If $\beta \leq 1/2$, platform A prefers $\theta_A = 1$ if $\delta < \hat{\delta}_A$, and $\theta_A = 0$ otherwise. Platform B prefers $\theta_B = 1$.*
- *If $\beta > 1/2$, platform A prefers $\theta_A = 0$. Platform B prefers $\theta_B = 0$ if $\delta < \hat{\delta}_B^0$, $\theta_B = 1$ if $\delta > \hat{\delta}_B^1$, and an intermediate level of interoperability $\theta_B \in (0, 1)$ if $\delta \in (\hat{\delta}_B^0, \hat{\delta}_B^1)$.*

Proof. See appendix. □

Thus, if the platform asymmetry is large enough, the large platform will be less willing to interoperate and the small platform more willing to interoperate compared to the baseline case with symmetric platforms.

The intuition is that the installed base of the large platform affects the *market power* and *total viewership* effects differently for the small and large platforms. The *market power* effect is larger for the small platform than for the large platform, and the difference increases with the size of the installed base. Conversely, the *total viewership* effect, which provides an incentive to resist interoperability, is larger for the large platform than for the small platform, and again the difference increases with the size of the installed base. Therefore, the small platform faces a larger *market power* effect and a smaller *total viewership* effect, so its incentive to interoperate is higher. In contrast, the large platform faces a smaller *market power* effect and a higher *total viewership* effect, so its incentive to interoperate is lower.

Our result is similar to Crémer, Rey and Tirole (2000), who also find that a large network is less willing to interconnect than a small network. However, the mechanism that leads to this result is different. In Crémer, Rey and Tirole (2000), interoperability has two effects: a demand expansion effect, which benefits both the small and large networks; and a quality differentiation effect, which means that interoperability reduces the differentiation between the two networks in terms of network effects. In our framework, the demand expansion effect is absent because the total demand is fixed in the Hotelling setting, while the quality differentiation effect is at play as discussed after Corollary 2. However, due to the two-sided business model of the platforms, we also have two new effects, the market power effect and the total viewership effect, which affect the incentives of the small and large platforms to make their services interoperable.

Since the small platform has a higher incentive to interoperate than the large platform, the equilibrium level of interoperability, $\theta = \min\{\theta_A, \theta_B\}$, is always determined by the large platform (i.e., equal to θ_A). Therefore, we have:

Corollary 3. *In equilibrium, the level of interoperability is $\theta^* = 1$ if $\beta \leq 1/2$ and $\delta < \hat{\delta}_A$, and $\theta^* = 0$ if $\beta > 1/2$ or $\beta \leq 1/2$ and $\delta \geq \hat{\delta}_A$.*

Therefore, if the large platform's installed base advantage is not too strong ($\delta < \hat{\delta}_A$), the equilibrium outcome is the same as in the symmetric baseline case. Otherwise, if the large platform has a large locked-in customer base ($\delta \geq \hat{\delta}_A$), interoperability never arises in equilibrium.

4.3 Welfare analysis

We now discuss how interoperability affects the surplus of market participants and the optimal choice of interoperability by a welfare-maximizing regulator.

Taking into account the surplus of locked-in consumers, consumer surplus is given by⁸:

$$CS(\theta) = \delta u_A(\theta, 0) + \int_0^{\hat{x}_B(\theta)} u_A(\theta, x) dx + \int_{\hat{x}_B(\theta)}^{\hat{x}_A(\theta)} u_{AB} dx + \int_{\hat{x}_A(\theta)}^1 u_B(\theta, x) dx. \quad (14)$$

We find that:

$$\frac{dCS}{d\theta} = 2\alpha(\hat{x}_B + \delta)(1 - \hat{x}_A) + \alpha(1 - \theta) \left[(\hat{x}_B + \delta) \frac{d\hat{x}_A}{d\theta} - (1 - \hat{x}_A) \frac{d\hat{x}_B}{d\theta} \right]. \quad (15)$$

As in the symmetric case, the first term in (15) represents the gain in consumer surplus from a higher quality of interaction between single-homers, where the volume of these interactions is equal to $(\hat{x}_B + \delta)(1 - \hat{x}_A)$. From Lemma 6, we know that a larger installed base increases the number of single-homers on the large platform and decreases it for the small platform. Therefore, the effect of a larger installed base on the volume of interactions between single-homers (including locked-in users) is a priori ambiguous. We find that it is positive if δ is not too high, and negative otherwise.

The second term in (15) represents a change in utility for the single-homers of both platforms as the marginal consumers located at \hat{x}_A and \hat{x}_B shift toward single-homing (loss) or multi-homing (gain). A priori, the sign of this term is ambiguous, since $d\hat{x}_B/d\theta$ can be positive or negative. However, we find that it is always negative. Therefore, this term represents a loss of

⁸We make the natural (but not crucial) assumption that the locked-in consumers are located at $x = 0$, and thus do not incur any transportation costs.

utility. Besides, a larger installed base increases the magnitude of this negative indirect effect.

Since $d^2CS/d\theta^2 \leq 0$, consumer surplus can be maximized either at $\theta = 0$ or at $\theta = 1$. We find that for low degrees of asymmetry (i.e., low δ), consumer surplus increases with the level of interoperability, and thus is maximized at $\theta = 1$ as in the baseline case. In this case, the direct effect dominates the negative indirect effect. For higher values of δ , we can find cases where consumer surplus decreases and is maximized at $\theta = 0$. In these cases, the magnitude of the direct effect becomes smaller and is dominated by the indirect effect.

Producer surplus is given by:

$$PS = \sigma(1 + \delta) + \beta\sigma MH.$$

As in the symmetric case, a higher level of interoperability decreases producer surplus by reducing multi-homing in the market, which prevents advertisers from reaching the same consumer twice. Therefore, no interoperability is preferable from an industry perspective.

From the previous discussion, if the installed base advantage of the large platform is small, consumers would prefer full interoperability and the industry would prefer no interoperability. Thus, the regulator faces a trade-off as in the symmetric baseline case. However, if the installed base advantage is large, consumers may also prefer no interoperability. In this case, total welfare would be maximized with no interoperability ($\theta = 0$).

As an illustration, Figure 3 shows the variations of consumer surplus, producer surplus as well as total welfare with respect to the level of interoperability θ . The left panel shows a case where total welfare is maximized at $\theta = 1$ when platforms are relatively symmetric (i.e., with low δ), while the right panel shows a case where total welfare is maximized at $\theta = 0$ for a higher value of δ , although consumer surplus is maximised at $\theta = 1$. This suggests that interoperability may be undesirable from a total welfare point of view in markets with strong size imbalance between platforms.

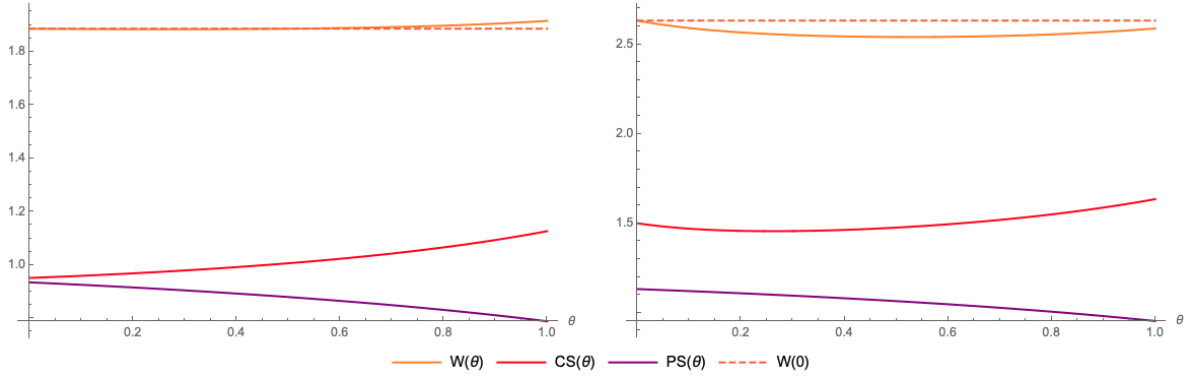


Figure 3: Market participants' surplus as a function of the level of interoperability (left panel: small installed base; right panel: large installed base).⁹

5 Conclusions and policy implications

Theoretical contributions In this paper, we have studied the effect of interoperability between ad-financed platforms when consumers can multi-home. We showed that interoperability affects the demand composition of the platforms by reducing multi-homing and increasing single-homing. To the extent that multi-homers are less valuable to advertisers than single-homers, interoperability increases the market power of platforms vis-à-vis advertisers. However, it also reduces the total viewership they can monetize on the advertiser side. Consequently, interoperability between symmetric platforms emerges in an unregulated environment if advertisers discount multi-homers at a high rate.

However, platforms may set the level of interoperability either too low or too high relative to what would be socially optimal. There are two sources of market failure. First, platforms do not internalize the consumer gains from higher levels of interoperability that result from higher quality interactions, leading them to choose too low a level of interoperability. Second, platforms do not fully internalize the surplus created by advertising in the multi-homing segment, leading them to set too high a level of interoperability.

In markets with a large, dominant platform and a smaller platform, interoperability levels the playing field by reducing the difference in network effects between them. Interoperability also affects the market power and total viewership effects differently for the small and large platforms. As a result, the large platform is less willing to make its service interoperable than the small platform. However, mandating interoperability between the asymmetric platforms is not always socially optimal.

⁹We use the following parameter values: $t = 1.15$, $\alpha = 0.75$, $v = 1$, $\gamma = 0.4$, $\sigma = 0.75$, and $\beta = 0.5$. We have $\delta = 0.03$ on the left panel, and $\delta = 0.25$ on the right panel.

We have assumed that consumers cannot observe ad levels before deciding which platform(s) to join. However, we believe that the main insights of our model would remain valid if consumers were able to observe ad levels to the extent that platforms still price at *incremental value*. In our model, each platform’s advertising intensity could be interpreted as a level of data collection, where the platforms monetize the data in a data broker market and consumers suffer nuisance from data monetization. As in our setup, it would still make sense to assume that the data collected about a multi-homer has less value than the data about an exclusive single-homer. Finally, we have ignored the cost of implementing interoperability. In practice, interoperability is likely to be costly to firms and proportional to the level of interoperability. The main insights of the model would remain valid by considering such a cost of interoperability, while reducing the incentives to set high levels of interoperability.

Policy implications Our results are relevant for assessing the potential impact of interoperability obligations for ad-financed platforms, such as the horizontal interoperability obligation for messaging services implemented in the Digital Markets Act in the European Union. First, we show that it is important to consider the multi-sided nature of these platforms, as interoperability on the consumer side has implications on the advertiser side through the changes in demand composition that it induces. Thus, a regulator should balance the consumer benefits of interoperability against the potentially adverse effects on other market participants. In particular, we show that interoperability may increase the market power of platforms in the advertising market, which may raise antitrust concerns.

Besides, note that in our framework, if the platforms were to merge, it would lead them to charge the monopoly price in the advertising market for all consumers. The merged entity would therefore have no incentive to implement interoperability between the two services. In practice, we do not observe that messaging platforms belonging to the same entity (such as Facebook Messenger, WhatsApp and Instagram) are interoperable. Therefore, when reviewing a merger in digital markets, the antitrust authority should consider the reduced incentives for interoperability as a potential negative effect.

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Appendix

Proof of Proposition 2

The regulator chooses the level of interoperability to maximize total welfare, $W = CS + PS$.

The variations of welfare with respect to the level of interoperability θ are given by:

$$\begin{aligned}\frac{dW}{d\theta} &= \frac{dCS}{d\theta} + \frac{dPS}{d\theta} \\ &= \frac{2\alpha t}{t + \alpha(1 - \theta)} (\hat{x}_B)^2 - \frac{2\beta\alpha\sigma}{t + \alpha(1 - \theta)} \hat{x}_B \\ &= \frac{2\alpha\hat{x}_B}{t + \alpha(1 - \theta)} [t\hat{x}_B - \beta\sigma].\end{aligned}$$

Since $\hat{x}_B(\theta)$ increases in θ , there are three possible cases: (i) if $\beta\sigma \leq t\hat{x}_B(0)$, W is increasing in θ , and thus, maximized at $\theta = 1$; (ii) if $\beta\sigma > t\hat{x}_B(1)$, W is decreasing in θ , and thus, maximized at $\theta = 0$; (iii) if $t\hat{x}_B(0) < \beta\sigma < t\hat{x}_B(1)$, W is first decreasing then increasing and therefore maximized either at $\theta = 0$ or $\theta = 1$. Therefore, for all three cases, it suffices to compare welfare at $\theta = 0$ and $\theta = 1$. We find that $W(\theta = 1) > W(\theta = 0)$ if and only if $\beta < \beta^W$, with

$$\beta^W = \frac{(\gamma + t - v)(\alpha + 2t)}{2\sigma(\alpha + t)}.$$

Proof of Lemma 7

Derivating equations (8) and (9) with respect to the level of interoperability θ , we obtain:

$$\begin{aligned}\frac{d\hat{x}_A}{d\theta} &= \frac{\alpha}{t} \left[-(SH_A + \delta) + (1 - \theta) \frac{d\hat{x}_B}{d\theta} \right] \\ \frac{d\hat{x}_B}{d\theta} &= \frac{\alpha}{t} \left[SH_B + (1 - \theta) \frac{d\hat{x}_A}{d\theta} \right].\end{aligned}$$

Let e_i be the exclusive demand of platform i . So, $e_A = SH_A + \delta$ and $e_B = SH_B$. Solving the system of equations above for $d\hat{x}_A/d\theta$ and $d\hat{x}_B/d\theta$, we obtain:

$$\begin{aligned}\frac{d\hat{x}_A}{d\theta} &= \frac{-\alpha}{t^2 - \alpha^2(1 - \theta)^2} [te_A - \alpha(1 - \theta)e_B] \\ \frac{d\hat{x}_B}{d\theta} &= \frac{\alpha}{t^2 - \alpha^2(1 - \theta)^2} [te_B - \alpha(1 - \theta)e_A].\end{aligned}$$

We have

$$\frac{dMH}{d\theta} = \frac{d\hat{x}_A}{d\theta} - \frac{d\hat{x}_B}{d\theta} = -\frac{\alpha(e_A + e_B)}{t + \alpha(1 - \theta)} < 0.$$

Besides, since $t > \alpha(1 - \theta)$ from Assumption 1 and $e_A > e_B$, then $d\hat{x}_A/d\theta < 0$, which implies that $dSH_B/d\theta > 0$. By contrast, the sign of $d\hat{x}_A/d\theta$ is ambiguous. We find that:

$$\frac{SH_A}{d\theta} = \frac{d\hat{x}_A}{d\theta} = \frac{\alpha}{2} \left[\frac{-\delta t}{[t - \alpha(1 - \theta)]^2} + \frac{2(\gamma + t - v) + \delta t}{[t + \alpha(1 - \theta)]^2} \right].$$

We find that this expression is positive, and thus $dSH_A/d\theta > 0$, if and only if $\theta > \theta^{sup}$, where

$$\theta^{sup} = \frac{-\alpha(t - \alpha)(\gamma + t - v) - \alpha\delta t^2 + \alpha t \sqrt{\delta t [2(\gamma + t - v) + \delta t]}}{(\gamma + t - v)\alpha^2}.$$

Besides, we have $\theta^{sup} > 0$ if and only $\delta > \hat{\delta}$, with

$$\hat{\delta} = \frac{(t - \alpha)^2(\gamma + t - v)}{2\alpha t^2} < \delta^{\max}.$$

To complete the proof, we then define $\hat{\theta} = \max\{0, \theta^{sup}\}$.

Proof of Proposition 4

The platforms' profits are $\Pi_A = \sigma(\delta + SH_A(\theta)) + \beta\sigma MH(\theta)$ and $\Pi_B = \sigma SH_B(\theta) + \beta\sigma MH(\theta)$.

Taking the derivatives with respect to the level of interoperability, we obtain:

$$\begin{aligned} \frac{d\Pi_A}{d\theta} &= \sigma(1 - \beta) \frac{d\hat{x}_B}{d\theta} + \beta\sigma \frac{d\hat{x}_A}{d\theta} \\ \frac{d\Pi_B}{d\theta} &= \sigma(1 - \beta) \left(-\frac{d\hat{x}_A}{d\theta} \right) + \beta\sigma \left(-\frac{d\hat{x}_B}{d\theta} \right). \end{aligned}$$

Since $d\hat{x}_B/d\theta < -d\hat{x}_A/d\theta$, the first term, which represents the *market power* effect, is larger for platform *B* than platform *A*. Conversely, the second term, which represents the *total viewership* effect, is larger in magnitude for platform *A* than platform *B*.

Replacing $d\hat{x}_A/d\theta$ and $d\hat{x}_B/d\theta$ by their expressions, we obtain:

$$\begin{aligned} \frac{d\Pi_A}{d\theta} &= \frac{\alpha\sigma}{2} \left[\frac{-t\delta}{[t - \alpha(1 - \theta)]^2} - \frac{(2\beta - 1)[2(\gamma + t - v) + \delta t]}{[t + \alpha(1 - \theta)]^2} \right] \\ \frac{d\Pi_B}{d\theta} &= \frac{\alpha\sigma}{2} \left[\frac{t\delta}{[t - \alpha(1 - \theta)]^2} - \frac{(2\beta - 1)[2(\gamma + t - v) + \delta t]}{[t + \alpha(1 - \theta)]^2} \right]. \end{aligned}$$

Note that for any $\delta > 0$, we have

$$\frac{d\Pi_B}{d\theta} - \frac{d\Pi_A}{d\theta} = \frac{\delta t \alpha \sigma}{[t - \alpha(1 - \theta)]^2} > 0,$$

so platform B always has a higher incentive to interoperate than platform A .

Case 1: $\beta \leq 1/2$. First, note that in this case, we have $d\Pi_B/d\theta > 0$, so platform B is willing to set the maximum level of interoperability ($\theta_B = 1$).

Consider now platform A 's profit. We find that $d^2\Pi_A/d\theta^2 \geq 0$. Therefore, $d\Pi_A/d\theta$ is increasing in θ . It follows that Π_A is maximized either at $\theta = 0$ or $\theta = 1$. We find that $\Pi_A(1) > \Pi_A(0)$ if and only if $\delta \leq \hat{\delta}_A$, with

$$\hat{\delta}_A = \frac{(t - \alpha)(1 - 2\beta)(\gamma + t - v)}{t(\alpha + (t - \alpha)\beta)}.$$

Case 2: $\beta > 1/2$. First, note that in this case, we have $d\Pi_A/d\theta < 0$, so platform A is willing to set the minimum level of interoperability ($\theta_A = 0$).

Consider now platform B 's profit. We find that $d^2\Pi_B/d\theta^2 \leq 0$. Therefore, $d\Pi_B/d\theta$ is decreasing in θ . We compute the value of $d\Pi_B/d\theta$ at the two extremes, $\theta = 0$ and $\theta = 1$. We find that

$$\left. \frac{d\Pi_B}{d\theta} \right|_{\theta=1} = \frac{\alpha\sigma}{t^2} [\delta(1 - \beta)t - (2\beta - 1)(\gamma + t - v)] > 0 \iff \delta > \frac{(2\beta - 1)(\gamma + t - v)}{t(1 - \beta)} \equiv \hat{\delta}_B^1.$$

Similarly, we find that

$$\left. \frac{d\Pi_B}{d\theta} \right|_{\theta=0} > 0 \iff \delta > \frac{(2\beta - 1)(t - \alpha)^2(\gamma + t - v)}{t(t^2 + \alpha^2) + \beta t(t - \alpha)^2} \equiv \hat{\delta}_B^0.$$

We have $\hat{\delta}_A \leq \hat{\delta}_B^0 \leq \hat{\delta}_B^1$.

Summing up, if $\delta < \hat{\delta}_B^0$, then $d\Pi_B/d\theta|_{\theta=0} \leq 0$. So, Π_B is decreasing and maximized at $\theta = 0$. If $\delta > \hat{\delta}_B^1$, then $d\Pi_B/d\theta|_{\theta=1} \geq 0$. So, Π_B is increasing and maximized at $\theta = 1$. Finally, if $\delta \in (\hat{\delta}_B^0, \hat{\delta}_B^1)$, then Π_B is first increasing then decreasing, hence, maximized at an interior level of interoperability.