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Foreclosure Incentives with Network Effects: A Framework for Screening Digital Mergers*

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Abstract

This paper proposes a simple yet useful framework for evaluating vertical mergers in digital markets by distinguishing between product-specific and ecosystem-specific network effects. Vis-á-vis no network effects, product-specific network effects amplify foreclosure and steering incentives, as a rival's growth directly undermines the platform's product value. Conversely, ecosystem-specific effects dampen foreclosure incentives, since rivals contribute to the overall value of the platform ecosystem. We develop a formal model illustrating how this distinction shapes platform behavior and competitive outcomes. We apply this distinction to real-world examples to illustrate its potential usefulness. Our distinction implies that regulators may want to adopt a stricter standard with no presumption of efficiencies where product-specific effects dominate. In contrast, when ecosystem-specific effects prevail, merger evaluation should mirror traditional vertical merger analysis. Thus, offering a more nuanced approach to merger evaluation by presenting a practical screening tool to identify problematic vertical mergers in markets featuring network effects.

Keywords: Network Externalities, Platforms, Vertical Integration

JEL Codes: L22, L41, L51

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1 Introduction

Mergers in digital markets are subject to increased antitrust scrutiny on both sides of the Atlantic, reflecting growing regulatory concern over their competitive effects.[1] This is unsurprising given the prevalence of network effects in these markets, which are well-known to result in tipping and dominance. In response, there have been increasing calls to treat mergers in digital markets with the same caution as horizontal mergers without any presumption of efficiencies.[2] While this approach is a valuable starting point, a more nuanced framework is needed to identify problematic mergers in markets characterized by complex and varied forms of network effects.

In this paper, we introduce a key conceptual distinction in the type of network effects — product-specific and ecosystem-specific effects — that can be employed as a simple initial merger screening tool for regulators. Product-specific network effects are those that enhance the value of a product as its network size increases, without affecting the value of other products.[3] Ecosystem network effects are those that enhance the core value proposition of the entire platform, not just one product. In other words, value creation (from increased network at one firm) is distributed across the platform, making all related products and services more valuable.

Examples of product-specific network effects can be found in music streaming and gaming platforms. From the perspective of Apple's App Store, music streaming and gaming apps generate network interactions that primarily enhance the value of their own products—for instance, by attracting more artists, listeners, or players. These within-app network effects tend to provide only limited benefits to other apps in the App Store ecosystem.

In contrast, ecosystem-wide network effects are more prominent in platforms where data is a key input or where multi-sided interactions are central. A good example is the ecosystem built around Advanced RISC Machines (ARM), a semiconductor and software design company, which hosts a community of developers serving ARM's customers. Customer feedback helps ARM improve its designs, which are then made available to all developers and users. As a result, developers benefit not only from the customers they serve, but also from improvements driven by the broader ecosystem.

To illustrate the significance of our typology, we consider an ecosystem, exhibiting network effects, consisting of an upstream monopolistic platform U that sells in the retail market while competing with another firm. This downstream rival requires the service of the upstream monopolist as an input.[4] In such a competitive landscape, we examine the incentive of the platform to shut down its rival. To focus on our main point, we make a distinction between two types of network effects: *product-specific* or

[1]See Microsoft/Activision merger, Booking/eTraveli, Meta-Within, Google-Fitbit among others.

[2]See Scott Morton et al. (2019) which suggests "*Courts should not presume efficiencies from vertical transactions. Crediting of efficiencies should require strong supporting evidence showing merger-specificity and verifiability*" (page 78). See Commission et al. (2021) which states that "*FTC will analyze mergers in accordance with its statutory mandate, which does not presume efficiencies for any category of mergers*".

[3]In other words, the benefit of additional users is confined to the product itself and does not spillover to other products within the platform's ecosystem.

[4]We focus on an upstream monopolist to discuss our point in relevant context where the platform (upstream firm) has market power. In case the upstream firm does not market power, then the regulatory concerns are limited.

ecosystem-specific network effects and consider foreclosure incentives.

We find that, vis-á-vis traditional markets without network effects, product-specific network effects exacerbate the incentive of the platform to foreclose a rival. Instead, ecosystem-specific network effects dampen the incentives to do so. The intuition for this result is that in the presence of ecosystem-specific network effects, the rival firm adds additional value to the whole ecosystem and then by extension also to product sold by the platform. As a consequence of this, the platform is more likely to accommodate its rival than in the case without network effects. Instead, when network effects are product-specific, any increase in sales of the rival lowers the output of the platform's sales by much more. This is because the rival's product becomes more attractive (due to network effects at the product level) which further attracts consumers away from the platform's product. Thus, the incentives to foreclose the rival are higher than without network effects. This distinction offers a simple screening tool for identifying potentially problematic vertical mergers in digital markets where network effects play an important role.

We show that this distinction and our main intuition also follow through when we consider steering in digital markets. Steering shifts attention away from downstream rivals and towards the platform's product, the rival's output falls while the platform's total output rise. Akin to foreclosure, product-specific network effects encourage steering (make it more likely), while ecosystem-specific network effect discourages it.

Our typology has some potentially practical implications. First, we further demonstrate the practical relevance of our typology through a series of illustrative examples, highlighting contexts in which network effects are likely to be either product-specific or ecosystem-specific. Second, our framework provides a simple yet powerful screening tool for regulators to identify problematic vertical mergers in digital markets. Where product-specific network effects dominate, we argue that policymakers should adopt a conservative stance, proceeding without any presumption of efficiencies, consistent with recent policy guidance. In contrast, when ecosystem-specific network effects are predominant, one may want to acknowledge the reduced foreclosure incentives and assess mergers with the same flexibility afforded to traditional vertical mergers in markets without network effects. This distinction may enhance antitrust analysis by offering a systematic method for differentiating between mergers that entrench dominance and those that may foster broader ecosystem value creation.

The rest of the paper is organized as follows. Section 2 discusses related literature. In Section 3 we lay down the model and characterize the equilibrium under vertical integration with the two types of network effect. Then we present a model with product steering in Section 4 and show that our results stay robust. In Section 5, we present the practical insights of our work and then we conclude in Section 6. All proofs are in the Appendix.

2 Related Literature

Vertical integration is an important theme in competition economics and one of the main concerns is foreclosure of rivals. The 'foreclosure doctrine' first proposed by Ordover et al. (1990) has been studied extensively (Hart et al. (1990), Bolton & Whinston (1991) among others).[5] This effect has been demonstrated empirically in various contexts (Waterman & Weiss (1996),Chipty (2001), Hastings & Gilbert (2005), Crawford et al. (2018), Boehm & Sonntag (2023) among others.)[6] Given the increasing prevalence of network effects in digital markets, this foreclosure doctrine has been studied keeping in mind network effects (Economides (1996), Pouyet & Trégouët (2021), Padilla et al. (2022)).[7] Economides (1996) shows how network effects between competing firms can encourage a quantity leader to encourage entry of rivals. De Corniere & Taylor (2014) show that entry through a vertical merger between a search engine platform and a publisher can lead to full foreclosure of rival publishers.[8] Miao (2009) provides a similar argument for a two-sided platform. Intuitively, the vertically-integrated entity forecloses when it cannot fully appropriate all profits from downstream interactions. We contribute to this emerging literature by focusing on how the incentives to foreclosure of ecosystems depends on the type of network effects. We find that product-specific network effects reinforce incentives to foreclose while ecosystem-wide network effects reduce incentives to foreclose.

Our work also contributes to the policy-oriented literature on methodologies for evaluating vertical mergers, with particular emphasis on the digital economy. While a substantial body of research has developed tools to assess the ability and incentive for foreclosure (see, for example, Moresi & Salop (2013), Froeb et al. (2018), Pittman (2017), Zenger (2020), Kadner-Graziano (2024)), our paper extends this literature by introducing a practical typology of network effects. This typology offers a meaningful conceptual distinction that can assist policymakers in the evaluation of vertical mergers involving network effects. In particular, it can serve as an initial screening tool for assessing foreclosure incentives in these complex and dynamic markets.

We also connect to the recent literature on self preferencing.[9] As in previous articles (Dendorfer (2024), Hagiu et al. (2022), Heidhues et al. (2023), Zou & Zhou (2024)), firms in our framework may practice self-preferencing by steering consumers, where steering affects which products consumers do (or do not) consider.[10] Motta (2023) suggests that self-preferencing is akin to foreclosure in vertically-related markets, and we provide a formal framework to show when this is indeed the case. Additionally, our typology contributes to this literature and provides guidance on which types of network effects encourage or discourage self-preferencing.

[5]A detailed review on foreclosure see Rey & Vergé (2004).

[6]Note that this result is not found in all contexts (see Asker (2016)).

[7]Carroni et al. (2024) study how a vertical merger affects exclusivity incentives of firms.

[8]On a similar note, Anderson & Bedre-Defolie (2020) considers the decision of a platform to compete with third party sellers. They find that entry of a platform increases seller fees which reduces seller participation thereby hurting consumers. van den Boom & Samranchit (2020) show that conglomerate mergers can lead to reduced entry which can hurt consumers.

[9]See Etro (2024) for a recent survey.

[10]See Farronato et al. (2023) for evidence that Amazon's own products are ranked higher than those of third-party sellers.

3 The baseline model

Players and environment. Consider an ecosystem (distribution network) formed by an upstream monopolistic platform (hereafter U) that also sells in the downstream market through its subsidiary D_1 which competes with an independent seller D_2.

Consumers are uniformly distributed according to their intrinsic value for the good r on the unit interval — i.e., $r \sim \mathcal{U}[0,1]$. The expected utility of a consumer of type r buying from D_i is[11]

$$u\left(x_i^e, X^e, P_i\right) \triangleq r + \underbrace{\theta(\alpha X^e + (1-\alpha)x_i^e)}_{\substack{\text{Importance of network} \\ \text{externalities } \mathcal{Z}_i(x_i^e, X^e)}} - P_i,$$

where $X^e \triangleq \sum_{i=1,2} x_i^e$ is the aggregate output that consumers expect D_1 and D_2 to distribute. The parameter $\theta \geq 0$ measures the strength of the network externality — i.e., the more users on the network, the more likely it is that other users will be interested in joining the network, as reflected by a higher willingness to pay (demand intercept as shown below). The parameter $\alpha \in [0,1]$ represents the importance of ecosystem-specific network externalities vis-à-vis product-specific network externalities. This can be seen after we rewrite $\mathcal{Z}_i(\cdot)$ as

$$\mathcal{Z}_i(x_i^e, X^e) = \theta(x_i^e + \alpha x_{-i}^e).$$

Thus, here α can also be interpreted as the importance of the rival's presence on the value generated on the product of firm i and thus also the value of ecosystem-specific network externalities.

Under the above specification, D_1 and D_2 have positive demand only if the following 'no arbitrage condition' holds and yields the common reservation value as

$$r^\star \triangleq P_1 - \mathcal{Z}_1(x_1^e, X^e) = P_2 - \mathcal{Z}_2(x_2^e, X^e).$$

Therefore, consumers buy the product only if $r \geq r^\star$ which then gives the total demand for the distribution network as

$$X \triangleq 1 - \Pr\left[r \leq r^\star\right] = 1 - (P_i - \mathcal{Z}_i(x_i^e, X^e)), \text{ for } i \in \{1,2\},$$

with $X \triangleq \sum_{i=1,2} x_i$ being the sum of D_1 and D_2's outputs.

We assume that D_1 and D_2 compete by setting quantities. The inverse demand function of each seller $i \in \{1,2\}$ is then

$$P_i(\mathcal{Z}_i(x_i^e, X^e), X) \triangleq \max\left\{0, 1 + \mathcal{Z}_i(x_i^e, X^e) - X\right\}.$$

As Katz & Shapiro (1985) we assume that consumers form expectations before third-party sellers choose output, but after listing contracts have been offered — i.e., contracts have a signaling content to the extent that consumers infer outputs from these deals.

[11] The microfoundations are adapted from Katz & Shapiro (1985).

Timing, contracts and equilibrium concept. The timing of the game is as follows:

$t = 1$ U publicly sets the listing fees w_2 charged per unit to its downstream rival. Consumers observe contracts and form an expectation on the outputs X^e and x_i^e.

$t = 2$ Sellers choose outputs, profits materialize and payments are made.

Notice that U can choose to foreclose D_2 by setting a sufficiently large per-unit fee w_2 (i.e., such that $x_2 = 0$). Focusing on the conservative case in which the benefits associated with a foreclosure strategy are maximized, we assume that D_2 has no outside option, meaning that it has no access to an alternative (even inferior) platform. Therefore, if U decides to (fully) foreclose, D_2 exits the market and U-D_1 is a monopolist.

As Katz & Shapiro (1985), our solution concept in the downstream competition game is Fulfilled Expectations Cournot Equilibrium, where each seller chooses its output level under the assumption that consumers' expectations are consistent with the equilibrium outcome — i.e., rational expectations.[12] Finally, in order to ensure that $\Pr[r \geq r^\star] \in (0, 1)$ we impose the following technical requirement:

A1. The value of network externality is not very high — i.e., $0 < \theta < 0.675$.

The above restriction is sufficient for concavity.

3.1 Analysis

Throughout, we conjecture and verify ex-post the conditions under which foreclosure does not occur at equilibrium.

Quantity setting stage. In the second period, for given w_2, the merged entity U-D_1 and its non-integrated rival D_2 set outputs to maximize their profits. Specifically, U-D_1 solves

$$\max_{x_1} \underbrace{P_1\left(\mathcal{Z}_1(x_1^e, X^e), X\right) x_1}_{\text{Direct sales}} + \underbrace{w_2 x_2}_{\text{Indirect revenue}},$$

which is the sum of the profit made through the direct sales channel (i.e., the integrated unit) and the revenue collected from the independent seller. D_2 solves

$$\max_{x_2} \left(P_2\left(\mathcal{Z}_2(x_2^e, X^e), X\right) - w_2\right) x_2.$$

Differentiating with respect to x_1 and x_2 respectively and imposing rational expectations — i.e., $X^e = \sum_{i=1,2} x_i^{VI}$, yields the following set of equations whose solution determines output as a function of listing

[12] See also, Belleflamme & Peitz (2019) for a related paper that models competition between sellers in a Cournot setting.

fees.

$$
\begin{aligned}
P_1(\cdot) + x_1 \frac{\partial P_1(\cdot)}{\partial X} &= 0, &(1)\\
(P_2(\cdot) - w_2) + x_2 \frac{\partial P_2(\cdot)}{\partial X} &= 0, &(2)\\
x_1^e = x_1^\star,\ x_2^e = x_2^\star,\ x_1^\star + x_2^\star &= X^e. &(3)
\end{aligned}
$$

It is straightforward to observe from the above that for any $w_2 > 0$, we have that the rival seller's output is lower than first party (integrated) seller of the platform $x_1^\star(w_2) > x_2^\star(w_2)$. This arises directly from the fact that the margin of seller 2 is lower than the margin of the integrated seller 1 for any $w_2 > 0$. Further, we can show that the following comparative statics hold: $\frac{\partial x_1^\star(w_2)}{\partial w_2} > 0$, $\frac{\partial x_2^\star(w_2)}{\partial w_2} < 0$, and $\frac{\partial x_1^\star(w_2)}{\partial w_2} + \frac{\partial x_2^\star(w_2)}{\partial w_2} < 0$. Specifically, an increase in the listing fee w_2 directly lowers the output of seller 2 by lowering its margin. The (integrated) first party seller responds by increasing its output as outputs are strategic substitutes. However, this response to 2's output change does not compensate for changes in seller $1's$ output. In an interior solution, aggregate output is

$$
X^\star(w_2) \triangleq \sum_{i=1,2} x_i^\star(w_2).
$$

A direct implication of the comparative static of outputs with respect to w_2 is that the above total output is falling in w_2. As before, holding w_2 constant, a higher θ expands aggregate output. The inverse demand at each seller i is then

$$
P_i^\star(w_2) \triangleq P_i\left(\mathcal{Z}_i(x_i^\star(\cdot), X^\star(\cdot)), X^\star(\cdot)\right).
$$

Before proceeding forward, it is worth discussing how listing fees affect output choice of the non-integrated third party seller. From a cursory glance at equation (2), we notice that $x_2^\star(w_2) \geq 0$ if and only if its margin in the output setting stage is positive — i.e., $P_2^\star(\cdot) \geq w_2$. This condition gives us the choke listing fee denoted as $\bar{w}(\alpha, \theta)$ above which the rival is foreclosed. This choke listing fee is determined by the solution to the following condition

$$
\overline{w}(\alpha, \theta) = P_2^\star(\overline{w}(\alpha, \theta)). \tag{4}
$$

Performing some comparative statics on this choke price, we present our results in the following Lemma.

Lemma 1 *The 'choke listing fee' $\bar{w}(\alpha, \theta)$ is increasing in α. As θ increases, the choke listing fee increases if and only if $\alpha > \tilde{\alpha}$. Else, the choke listing fee decreases with an increase in θ.*

The 'choke listing fee' $\bar{w}(\alpha, \theta)$ is increasing in α — i.e., full foreclosure is more difficult when the importance of ecosystem level of network externalities increases. As the non-integrated seller itself benefits from more ecosystem-specific network effects, the (integrated) platform finds it less profitable to foreclose the rival seller. The comparative static of the choke listing fee with respect to the value of network externality θ is more nuanced. Note that a larger θ reinforces the value associated with network effects. However, the manner in which it affects the choke price depends on α. To see how, recall our previous result that an increase in w_2 raises $x_1^\star$ while lowering $x_2^\star$: When α is low, the value associated with D_2's network effects are mainly driven by its own output (network); so as θ increases, an increase in w_2 decreases the network effects of D_2 faster which then lower its output as well. This yields the result that a lower choke price suffices to foreclose the rival. Instead, when α is large, D_2 benefits from the value associated with its own network as well as the network of $U - D_1$ (in other words ecosystem specific network effects). In this case, the negative effect of an increase in w_2 on $x_2^\star$ is dampened by the increase in the output of $U - D_1$. Thus, yielding the result that a larger choke price is required to foreclose D_2 as θ increases.

Contracting stage $t = 1$. In stage 1, U maximizes the sum of D_1's direct sales profit and the intermediation revenue collected from D_2 — i.e.,

$$\max_{w_2} \underbrace{P_1^\star(w_2)x_1^\star(w_2)}_{D_1\text{'s sales profit}} + \underbrace{w_2 x_2^\star(w_2)}_{\text{Downstream revenue}}.$$

Differentiating with respect to w_2, by the Envelope Theorem, we obtain

$$\underbrace{\left[x_2^\star(\cdot) + w_2 \frac{\partial x_2^\star(\cdot)}{\partial w_2}\right]}_{\text{Marginal Downstream Revenue}} + x_1^\star(\cdot)\left(\underbrace{\frac{\partial P_1(\cdot)}{\partial X}\frac{\partial x_2^\star(\cdot)}{\partial w_2}}_{\text{Strategic Effect }(+)} + \underbrace{\frac{\partial P_1(\cdot)}{\partial \mathcal{Z}_1}\theta\left(\underbrace{\alpha\frac{\partial X^\star(\cdot)}{\partial w_2}}_{\substack{\text{Ecosystem-Specific}\\ \text{Effect }(-)}} + \underbrace{(1-\alpha)\frac{\partial x_1^\star(\cdot)}{\partial w_2}}_{\substack{\text{Product-Specific}\\ \text{Effect }(+)}}\right)}_{\text{Network Externalities Effect}}\right) = 0. \tag{5}$$

The above first order condition presents the forces at play that the platform must consider when choosing the listing fee. The first term presents how a unit change in the listing fee affects the intermediation revenue of the platform. This is just the classic trade-off between margins and volume. The second term describes the classic strategic effect which encourages the platform to increase its fees to divert sales towards its own sales channel away from seller 2. The third term captures the impact of network effects. If $\theta = 0$, we are back in the traditional no network effects setting as in Hart et al. (1990) but if $\theta > 0$, network effects impact listing fees. The platform trades off two opposing forces when considering the effect of network externalities on its margins. First, an increase in fee w_2 lowers total output and thus reduces the value generated by the whole ecosystem. This ecosystem-specific effect discourages the platform from raising its fee. Second, a unit increase in the listing fee increases own output and thus the benefits arising from product-specific network effects. The sum of these opposing effects determines if the platform is more (or less) likely to shut down the rival seller 2 vis-à-vis the case without network effects (when $\theta = 0$). Which of the two (opposing) effects dominates depends on how important ecosystem-specific network externalities are vis-à-vis product-specific network effects — i.e., the magnitude of $\alpha \in [0, 1]$ plays a key role.

Solving the above first order condition, we denote the equilibrium listing fee. Before proceeding forward, it is worth focusing on the case without any network effects. This analysis then allows a neat comparison on how the two types of network externalities affect incentives to foreclose.

Lemma 2 *In absence of any network externalities ($\theta = 0$), the rival seller is always fully foreclosed.*

The above result is straightforward and is just a reproduction of the result in Hart et al. (1990). To show this, we set $\theta = 0$ in equation (5) yields

$$\underbrace{\left[x_2^\star(\cdot) + w_2 \frac{\partial x_2^\star(\cdot)}{\partial w_2}\right]}_{\text{Marginal Downstream Revenue}} + x_1^\star(\cdot) \underbrace{\frac{\partial P_1(\cdot)}{\partial X}\frac{\partial x_2^\star(\cdot)}{\partial w_2}}_{\text{Strategic Effect }(+)} = 0. \tag{6}$$

We can rewrite the above as

$$x_2^\star + \left(x_1^\star(\cdot)\frac{\partial P_1(\cdot)}{\partial X} + w_2\right)\frac{\partial x_2^\star(\cdot)}{\partial w_2} = 0.$$

Plugging in $w_2^\star = P_1^\star(0, X^\star)$, we observe that this is the unique solution to the above first order condition. This is because at $w_2 = P_2^\star(\cdot) = P_1^\star(0, X)$, we have $x_2^\star = 0$ and the term in the brackets is zero due to the envelope theorem.

For the case of $\theta > 0$, the equilibrium listing fee is denoted by $w^\star(\alpha, \theta)$ can be characterized as follows.

Proposition 1 *There exists a threshold $\alpha^F = \frac{3-\theta}{4-\theta}$ such that equilibrium listing fee is given as*

$$w^\star = \begin{cases} \frac{(1-\theta(1-\alpha))(5-\theta(4-\theta(1-\alpha^2)))}{2(5-\theta(11-2\alpha(3-\theta)-\theta(6-\theta)+\alpha^2\theta(3-\theta)))} & \text{if } \alpha \geq \alpha^F, \\ w \in (\overline{w}(\cdot), \infty) & \text{if } \alpha < \alpha^F. \end{cases}$$

The rival seller 2 is foreclosed if and only if $\alpha \leq \alpha^F$ — i.e., $x_2^\star = 0$ iff $\alpha \leq \alpha^F$. This critical threshold α^F is falling with an increase in θ.

The above result follows directly from the first order condition presented in equation (5). When α is sufficiently high, the ecosystem-specific effect encourages the platform firm to lower the listing fee below the level that forecloses the rival seller 2. In other words, the rival seller is accommodated when the ecosystem-specific effect (α) is high enough. In contrast, when the value associated with product-specific effect is large ($\alpha \leq \alpha_F$), the rival seller is foreclosed. Interestingly, this threshold level α^F decreases as θ increases which implies that foreclosure is less likely as the value associated with network externalities increases. In the following, we present two extreme examples to showcase our results and cleanly present our insights in relation to the case without network effects.

Example 1: Only Product-Specific Externalities ($\alpha = 0$). This example focuses on the incentive of a platform firm to foreclose a rival after a vertical merger. These are markets where product-specific network effects dominate the value the seller adds to the whole ecosystem. For instance, in the app-store, music streaming apps such as Spotify have stronger product-specific network effects than the value they add to the whole app store ecosystem. The following analysis presents the foreclosure incentive of a platform firm in a clean manner by assuming that $\alpha = 0$. In this case, each seller exhibits stronger product-specific network externalities. To understand the incentive of the platform firm to shut down the rival seller 2, we plug in the choke listing fee given by $w_2 = \bar{w}(0, \theta)$, $x_2^\star = 0$, $x_1^\star(\cdot) = P_1^\star$ and $\frac{\partial P_1(\cdot)}{\partial X} = -1$, in the first order equation (5), rearranging yields

$$\underbrace{\frac{\partial P_1(\cdot)}{\partial X}\left(\frac{\partial x_2^\star(\cdot)}{\partial w_2}(P_1^\star(\cdot) - P_2^\star(\cdot)) - \theta\frac{\partial x_1^\star(\cdot)}{\partial w_2}\right)}_{(+)} > 0. \tag{7}$$

The above suggests that the listing fee should be above even the choke fee — $\bar{w}(0, \theta)$. Indeed, with only product-specific network effects, the first-order condition increase, illustrating that incentives to foreclose increase. This suggests that in markets with predominantly "product-specific network effects" foreclosure is more likely than even in traditional markets.

Example 2: Only Ecosystem-Specific Externalities ($\alpha = 1$). In this example, we focus on the markets characterized mainly by ecosystem-specific network effects. In these markets, output of firms increases value of the whole ecosystem and thus also benefits the first party seller of the platform. Proceeding as above, we set $\alpha = 1$ and plug the choke fee level $\bar{w}(1, \theta)$ in equation (5) and then rewrite it as follows.

$$\underbrace{\left[P_2^\star(\cdot)\frac{\partial x_2^\star(\cdot)}{\partial w_2}\right]}_{\text{Marginal Downstream Revenue}} + x_1^\star(\cdot)\left(\underbrace{\frac{\partial P_1(\cdot)}{\partial X}\frac{\partial x_2^\star(\cdot)}{\partial w_2}}_{\text{Strategic Effect }(+)} + \underbrace{\frac{\partial P_1(\cdot)}{\partial \mathcal{Z}_1}\theta\left(\frac{\partial x_2^\star(\cdot)}{\partial w_2} + \frac{\partial x_1^\star(\cdot)}{\partial w_2}\right)}_{\text{Network Externalities Effect}}\right) < 0. \tag{8}$$

The sign of the above expression is negative at $w = \bar{w}(1, \theta)$. To see this, recall that when $\alpha = 1$ all firms benefit from the whole ecosystem level network effects implying that $P_1^\star(\cdot) = P_2^\star(\cdot)$ and $x_2^\star = 0$, we can rewrite the above as

$$\frac{\partial x_2^\star(\cdot)}{\partial w_2}\underbrace{\left[P_1^\star(\cdot) + \frac{\partial P_1^\star(\cdot)}{\partial X}X^\star(\cdot)\right]}_{\text{Monopoly rule}} + \underbrace{x_1^\star(\cdot)\frac{\partial P_1(\cdot)}{\partial \mathcal{Z}_1}\theta\left(\frac{\partial X^\star(\cdot)}{\partial w_2}\right)}_{(-)} < 0.$$

The above analysis suggests that the listing fee should always be below the choke price — $P_2^\star(\cdot)$.[13] Thus, we show that in this case the platform always accommodates the rival seller 2.

Summing up these two examples, we present our observation below.

Corollary 1 *In markets where products exhibit predominantly product-specific network externalities, foreclosure incentives (after vertical integration) are higher than markets without network effects. In markets*

[13]This example has already been demonstrated in Padilla et al. (2022). We are just reiterating this for clear exposition.

where products exhibit ecosystem-specific network externalities, foreclosure of rivals (after vertical integration) is less likely than in markets without any network effects.

The above proposition offers interesting insights for policymakers on how to view foreclosure incentives (and the ensuing harms) in markets featuring network effects. To put our results into perspective, we compare our results with a setting without network effects for which there are well-established merger guidelines namely the *Non-Horizontal Merger Guidelines (NHMG)*.[14] These merger guidelines are well understood and have been regularly applied in vertical merger deliberations. The above proposition states that when policy makers face vertical mergers in platform markets, they must consider which type of network externality is predominant in the platform market. If the predominant network effect is product-specific, policy makers should consider a stricter merger control regime than the one without network effects. In this case, it may be useful to proceed with merger deliberations without presumption of efficiencies as in horizontal mergers. On the contrary, if the predominant network effect is at the ecosystem level, it may be useful to proceed with the same level of scrutiny as in traditional vertical merger proceedings. In these cases, the competition authorities may want to employ a conservative approach with potentially lower likelihood of foreclosure than without network effects.

4 Steering

We now demonstrate that we obtain similar results for steering, i.e. that the ecosystem fully steers users away from the independent seller if the ecosystem-specific network externality is sufficiently weak, and accommodates independent sellers otherwise.

We adapt our model from Section 3 to capture steering. Instead of choosing listing fees, $U - D_1$ can steer consumers away from the downstream rival. We model steering as the probability that consumers observe the independent seller. This captures, for example, that the platform may choose to depict the independent seller as a search outcome or not. This also captures the degree to which the platform institutes its own products as defaults, thereby keeping attention away from other alternative products.

For simplicity, we assume consumers observe D_1 with probability one. With probability $\sigma \in [0, 1]$, consumers are steered and observe only D_1. If consumers are steered, they only observe x_1^S, the output that $U - D_1$ makes available for a steered consumers. With probability $(1 - \sigma)$ they are not steered and observe the total output on the joint segment $x_1^J + x_2$, where x_1^J and x_2 are the output of $U - D_1$ and D_2 on the joint segment, respectively. We denote the total output of $U - D_1$ as $x_1 = x_1^S + x_1^J$, and the total output in the market as $X = x_1 + x_2$.

The inverse demand on the steered segment and the joint segment is[15]

$$P_1^S(\mathcal{Z}_1(x_1^e, x_2^e), x_1, x_2) \triangleq \max\left\{0, 1 + \mathcal{Z}_1(x_2^e, x_1^e) - \frac{1}{\sigma} x_1^S\right\}$$

[14] See Commission (2008) for more details.

[15] We provide the detailed microfoundations of the demand in the Proof of Proposition (2).

and

$$P_i(\mathcal{Z}_i(x_i^e, x_{0i}^e), x_i, x_{-i}) \triangleq \max\left\{0, 1 + \mathcal{Z}_i(x_i^e, x_{-i}^e) - \frac{1}{1-\sigma}\left(x_1^J + x_2\right)\right\} \text{ for } i \in \{1,2\}.$$

Steering has two effects on demand. First, steering makes consumers more price sensitive on the joint segment. Intuitively, as σ increases, consumers are less likely to be on the joint market segment, so a given output in that segment induces a smaller price for markets to clear. Second, steering makes consumers less price sensitive on the steered segment. More consumers perceive only $U - D_1$, which is why a given output on this segment leads to a larger price.

The timing is similar as in the main model. The only difference is that in Stage 1, the platform no longer chooses listing fees, but the steering level σ.

To understand how steering affects network effects, we now explain how steering affects output. Steering permits the platform to shift output from the joint- to the steered segment; this raises the platform's output, but lowers overall output. Intuitively, steering makes consumers on the joint segment more price sensitive; firms respond by lowering their output on this segment. In the steered segment, consumers become less price sensitive, which is why the platform raises output on this segment. Overall, the platform raises its own output and, since the platform has more market power on the steered segment, total output decreases. As a result, steering has similar effects on output as foreclosure in the above model. The following proposition summarizes the main insights.

Proposition 2 *There exists a threshold $\alpha^F = \min\{\frac{(5-\theta)(2+\theta)}{\theta(14-\theta)}, 1\} \in (0,1]$ such that equilibrium steering level is given as*

$$\sigma^\star = \begin{cases} \frac{2(1-\theta(1-\alpha))(15-\theta(4-\theta+\alpha(1+\alpha\theta)))}{\theta((1-\alpha)\theta(13+22\alpha)+52\alpha-2\theta^2(1-\alpha)^2)(1+\alpha)-47} & \text{if } \alpha > \alpha^F, \\ 1 & \text{if } \alpha \leq \alpha^F. \end{cases}$$

The rival seller 2 is fully foreclosed ($x_2^\star = 0$) if and only if $\alpha < \alpha^F$. Otherwise, D_2 is accommodated. This critical threshold α^F is decreasing in the network externality θ.

Note that for $\theta = 0$, we have $\sigma = 1$ implying that consumers are fully steered away from the rival. When α is sufficiently high, the ecosystem-specific effect encourages the platform firm to set steering below the level that forecloses the rival seller 2. Otherwise, if α is sufficiently low, the rival is foreclosed. As in the main model, this threshold level α^F decreases as θ increases implying that full steering is less likely as the value associated with network externalities increases.

Discussion: It is worth mentioning that this extension is quite different from the main model. Specifically, listing fees directly extract revenue from the rival seller while steering, in this simple model, does not. This implies that we stack the odds in favor of foreclosure even more than in the listing fee model. Nonetheless, also in this model, foreclosure is less likely to occur when ecosystem specific network effects are high. Thus, we demonstrate that, despite these differences, our main result from listing fees translates to this setting.

5 Practical Insights

Having established the intuition of our main results, we are now in a position to discuss their application in merger proceedings. In the following, we focus our attention on products and services which exhibit network effects.

In digital markets, products and services can exhibit network effects. However, the type of network effects these products exhibit is often not clear and cannot be easily distinguished into *product-specific* or *ecosystem-specific* network effects. For example, many products on a platform generate data which can be valuable for different levels of the platform's technological stack. This data can be helpful in adding value at the product level directly as well as the platform level (ecosystem level). To gain insights from such a complex environment, one must consider which type of network effect is dominant in value generation from the perspective of the platform. To further understand this, we elaborate our point employing examples. We only use these cases to illustrate how our conceptual framework can help gain insights.

Product-specific network effects. This type of network effect enhances the value of a product as the associated network (demand) increases. There is no direct value for other services. In this case, the greater network the product acquires, the more value it has which then further attracts a greater network. Case study: Apple Music vs. Spotify. Many users access music streaming apps like Spotify via app stores. In particular, for any customer that accessed Spotify via the Apple app store, Apple gets a cut from in-app purchases (like monthly subscriptions). Product-specific network effects are arguably important in the music streaming industry. First, with more consumers, streaming services can improve their recommendation algorithms, which improves their own product. Second, music-streaming services are themselves platforms that benefit from network effects: if a music-streaming service hosts more artists, it becomes more attractive to consumers. Both of these network effects improve a streaming-service's own product and are therefore rather product-specific. From this perspective, it may not be surprising that Spotify accused Apple of using its app store for overcharging or self-preferencing.
Case study: Apple vs. Epic. A similar case can be made for gaming applications such as EPIC. Specifically, EPIC competes with Apple's own gaming platform called Apple Arcade on the App Store to attract customers. EPIC is a gaming platform with game developers on one side and gamers on the other side. In this case, the benefits of network effects are confined within the EPIC gaming platform and there is relatively lower spillover across the Apple ecosystem. As product-specific network effects seem quite relevant, employing our conceptual framework suggests there could be a risk of Apple overcharging and self-preferencing.

Ecosystem-specific network effects. This type of network effect implies that an increase in the network size of a product enhances the value of the ecosystem and all the products on the ecosystem. In turn, this increases demand for all product which then further makes the ecosystem more valuable. Example of this type of network effect can be data collected and used to improve the core functioning (value proposition) of an ecosystem. In the following, we present two where such network effects may be relevant.

Case Study: Advanced RISC Machines (ARM) chip Ecosystem. ARM is a key player in the chip design market that licenses its designs to downstream chip integration and manufacturing firms. Among its customers are chip manufacturers like NVIDIA, Qualcomm and TSMC. In this context, network effects may be ecosystem-specific. First, ARM collects feedback from its customers to improve its future design and these designs are available to all its customers.[16] Second, ARM publishes information on design errata that benefits all its customers. Third, ARM hosts a partner ecosystem that develops tools to implement ARM designs. Then, this ecosystem is available to all its customers. The greater the demand for ARM designs from any customers, a larger number of design and implementation partners are available. This also increases the value of the ARM system for all customers. In this market, if ARM decided to enter the chip making business by merging with one of the chip manufacturers such as Qualcomm, Nvidia among others, it is sufficient to employ the standard classical vertical non-horizontal merger guidelines (NHMG) to these mergers. A stricter standard as in horizontal merger may not be necessary. This was indeed the merger control procedure for this case.[17] Interestingly, ARM decided to enter the chip making business beyond just licensing its designs.[18]

Case Study: Google/Fitbit. Google acquired Fitbit in 2021. Fitbit produces smartwatches which gather data about their users' health and fitness. A concern of the commission was that Google may put other producers of smartwatches at a competitive disadvantage by affecting its interoperability with Android.[19] We believe that our typology provides some useful insights into this environment. On the one hand, the acquisition gave Google access to Fitbit's data, which could have improved Google's ad targeting. The more data Fitbit gathers, the larger the benefit that Google may get from these data, which represents product-specific network effects. On the other hand, many users of smartwatches, including rivals of Fitbit, use Google fit and choose to share their data with Google by using the app Google fit. Thus, to the extent that users share their data with Google anyway, network effects are also ecosystem-specific so that sales of Fitbit's rivals also create data for Google. Our typology suggests that the magnitude of this data sharing by customers of Fitbit's rivals could be a useful indicator of the magnitude of such ecosystem-wide network effects.

Case Study: Google's ecosystem. Google's major business model is offering its clients a reliable advertising platform. To ensure the reliability of its ad platform, Google requires relevant and continuous data on consumers to make its ad products attractive to its clients. To ensure greater data collection, Google may be willing to open its ecosystem to a larger set of third party complementors even if they compete with its own application offerings. This is because the data from all these complementors can help it refine the offering of its advertising ecosystem. The extent to which this applies may depend, akin to Google/Fitbit above, on the degree to which Google accesses data generated by its complementors.

[16] See ARM's design review (link).

[17] See the Competition and Market Authority summary of this case here.

[18] On 13th February, ARM announced its foray into the chip making business. See (link).

[19] See `https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2484`, accessed March 26th, 2025.

Additionally, Google might be more willing to foreclose complementors if it can better monetize ads in its own products than via third party complementors. For example, Motta (2023) argues that third party services that Google lists as organic search results do not pay Google for that rank, because they are not listed as an ad. This gives Google incentives for self-preferencing its own services, where they can better monetize ad revenues.

6 Conclusions

We studied the foreclosure incentives of a platform following a vertical merger in the presence of network effects. Our analysis demonstrated that vertical mergers in markets characterized by network effects may lead to either an increased or decreased likelihood of rival foreclosure compared to traditional markets without network effects. To establish this result, we introduced a conceptual distinction between two types of network effects: *ecosystem-specific* and *product-specific* network effects. Our findings indicate that vertical mergers in markets dominated by ecosystem-specific network effects are less likely to result in rival foreclosure. In contrast, when markets exhibit product-specific network effects, the likelihood of foreclosure following a vertical merger increases. This distinction provides a clear and practical screening tool for identifying potentially problematic mergers in markets featuring network effects.

A Appendix

Proof of Lemma 1. Solving the expression in equation 4 for w yields the chokeprice as

$$\bar{w}(\alpha,\theta) \triangleq \frac{1+\alpha\theta-\theta}{2-\theta}.$$

Differentiating $\bar{w}(\alpha,\theta)$ with respect to α and θ yields

$$\frac{\partial \bar{w}}{\partial \alpha} = \frac{\theta}{2-\theta} > 0 \text{ and } \frac{\partial \bar{w}(\cdot)}{\partial \theta} = -\frac{1-2\alpha}{(2-\theta)^2}.$$

The proof follows through from a cursory glance at the above expressions.

■

Proof of Lemma 2. It is straightforward from the discussion after the Lemma. ■

Proof of Proposition 1. Solving the expression presented in equation (5) for w yields

$$w^\star = \frac{(1-\theta(1-\alpha))(5-\theta(4-\theta(1-\alpha^2)))}{2(5-\theta(11-2\alpha(3-\theta)-\theta(6-\theta)+\alpha^2\theta(3-\theta)))}.$$

Differentiating the above expression with respect to α, we note that

$$\frac{\partial w^\star}{\partial \alpha} = -\frac{\theta A}{2(5-\theta(11-2\alpha(3-\theta)-\theta(6-\theta)+\alpha^2\theta(3-\theta)))^2} < 0,$$

where $A \triangleq \theta((\alpha^2-1)^2\theta^4 + \left(6\alpha^2+32\alpha-31\right)\theta - (\alpha-1)(\alpha(\alpha+3)(3\alpha-2)-8)\theta^3 + 2(\alpha(6(\alpha-2)\alpha-7)+12)\theta^2 - 20\alpha+11) + 5 > 0$. It is tedious but straightforward to show that $A > 0$ in the relevant parameter range. We skip this in favor of brevity.

Next, equating $w^\star = \bar{w}$ and solving for α yields the solution $\alpha^F = \frac{3-\theta}{4-\theta} \in [0,1)$. Differentiating α^F with respect to θ yields $\frac{\partial \alpha^F}{\partial \theta} = -\frac{1}{(4-\theta)^2} < 0$. Thus, we demonstrate that α^F falls in θ.

■

Proof of Proposition 2. Consider an ecosystem formed by an upstream monopolistic platform (U) that also sells in the downstream market through its subsidiary D_1 which competes with an independent seller D_2.

We model steering as the probability that consumers observe only the platform's seller (or its own product). This captures, for example, that the platform may choose to depict the independent sellers as a search outcome or not. This also captures the degree to which the platform institutes its own products as defaults, thereby keeping attention away from other alternative products. For simplicity, we assume consumers observe D_1 with probability one. With probability σ, consumers were steered and they observe only D_1; with probability $(1-\sigma)$ they were not steered so they observe D_1 and D_2.

Firm 2 produces total output x_2, which is entirely available on the joint segment. Firm 1 chooses output x_1^S and x_1^J for the steered and the joint segment, respectively. The total output of firm 1 is $x_1 = x_1^S + x_1^J$. We denote the total output in the market as $X = x_1 + x_2$, and the total output in the joint segment as X^J.

We assume that sellers have zero marginal cost to produce output. Setting a positive steering parameter $\sigma > 0$ implies that the platform steers consumers away from an independent seller, the platform may have to manipulate its search algorithm.

To start, we derive the demand of the independent seller D_2. A consumer who is aware of D_2 gets the utility from D_2 of

$$\begin{aligned} u_2\left(x_2^e, x_1^e, P_2\right) &\triangleq r + \theta(\alpha \cdot (x_1^e + x_2^e) + (1-\alpha)x_2^e) - P_2, \\ &= r + \underbrace{\theta(x_2^e + \alpha x_1^e)}_{\substack{\text{Importance of network} \\ \text{externalities } \mathcal{Z}_2(x_2^e, x_1^e)}} - P_2 \end{aligned}$$

and a utility from D_1 of

$$u_1\left(x_1^e, x_2^e, P_1\right) \triangleq r + \underbrace{\theta(x_1^e + \alpha x_2^e)}_{\substack{\text{Importance of network} \\ \text{externalities } \mathcal{Z}_1(x_1^e, x_2^e)}} - P_1.$$

Consumers who are aware of both firms can freely choose from which firm to purchase, so the 'no arbitrage condition' yields

$$r^\star \triangleq P_1 - \mathcal{Z}_1(x_1^e, x_2^e) = P_2 - \mathcal{Z}_2(x_2^e, x_1^e).$$

We can now derive the demand for D_2, starting from

$$x_1^J + x_2 = (1-\sigma)\Pr\left[r \geq r^\star\right] = (1-\sigma)\left(1 - P_2 + \mathcal{Z}_2(x_2^e, x_1^e)\right).$$

The first expression states that total output in the joint segment must equal the probability that a consumer is in the steered segment times the probability that they obtain a utility above the reservation utility.

Because we assume D_1 and D_2 compete by setting quantities, this leads to

$$P_2(\mathcal{Z}_2(x_2^e, x_1^e), x_1, x_2) \triangleq \max\left\{0, 1 + \mathcal{Z}_2(x_1^e, x_2^e) - \frac{1}{1-\sigma}\left(x_1^J + x_2\right)\right\}.$$

We make a key observation here steering makes consumers more price sensitive on this segment. Intuitively, as σ increases, the joint market segment shrinks, so a given output in that segment induces a smaller price for markets to clear.

We derive the demand of D_1 in two steps: (i) the demand on the joint segment, (ii) demand on the steered segment.

Step (i). The demand of D_1 on the joint segment follows directly from the arbitrage condition above. Plugging $P_2(\mathcal{Z}_2(x_2^e, x_1^e), x_1, x_2)$ into the no-arbitrage condition and solving for P_1 leads to

$$P_1^J(\mathcal{Z}_1(x_1^e, x_2^e), x_1, x_2) \triangleq \max\left\{0, 1 + \mathcal{Z}_1(x_2^e, x_1^e) - \frac{1}{1-\sigma}\left(x_1^J + x_2\right)\right\}.$$

Step (ii). On the steered segment, the overall quantity available is different than on the joint segment, which induces a different price. Thus, we get demand from the expression

$$x_1^S = \sigma \Pr\left[r \geq P_1^S - \mathcal{Z}_1(x_1^e, x_2^e)\right] = \sigma\left(1 - P_1^S + \mathcal{Z}_1(x_1^e, x_2^e)\right).$$

The output available on this segment is σx_1, which induces the demand

$$P_1^S(\mathcal{Z}_1(x_1^e, x_2^e), x_1, x_2) \triangleq \max\left\{0, 1 + \mathcal{Z}_1(x_2^e, x_1^e) - \frac{1}{\sigma}x_1^S\right\}.$$

This expression shows that steering makes demand less price sensitive for steered consumers. Intuitively, more consumers perceive only $U - D_1$, which is why a given output on this segment leads to a larger price.

We assume that $0 \leq \theta \leq 1$, $0 < \sigma < 1$ and $0 < \alpha < 1$. These are sufficient conditions that guarantee concavity in our setup.

Timing. The timing of the game is as follows: $(t = 1)$. U publicly sets the steering parameter σ. Consumers form an expectation on the outputs x_1^e and x_2^e.) $(t = 2)$. Sellers choose outputs, profits materialize and payments are made.

Quantity setting stage. In the second period, for given σ, the merged entity U-D_1 and its non-integrated rival D_2 set outputs to maximize their profits. Specifically, U-D_1 solves

$$\max_{x_1} \underbrace{P_1^S\left(\mathcal{Z}_1(x_1^e, x_2^e), x_1^S\right)x_1^S}_{\text{Sales on steered segment}} + \underbrace{P_1^J\left(\mathcal{Z}_1(x_1^e, x_2^e), x_1^J, x_2\right)x_1^J}_{\text{Sales on joint segment}}.$$

which is the sum of the profit made through the direct sales channel (i.e., the integrated unit) and the costs of lost advertisement by steering. D_2 solves

$$\max_{x_2} P_2\left(\mathcal{Z}_2(x_1^e, x_2^e), x_1, x_2\right)x_2.$$

Differentiating with respect to x_1 and x_2 respectively and imposing rational expectations, yields the following set of equations whose solution determines output as a function of σ.

$$\begin{aligned} P_1^S(\cdot) + x_1^S \frac{\partial P_1^S(\cdot)}{\partial x_1^S} &= 0, \\ P_1^J(\cdot) + x_1^J \frac{\partial P_1^J(\cdot)}{\partial x_1^J} &= 0, \\ P_2(\cdot) + x_2 \frac{\partial P_2(\cdot)}{\partial x_2} &= 0, \\ x_1^e = x_1^\star,\ x_2^e = x_2^\star. \end{aligned}$$

Solving the above system first order conditions yields outputs as function of steering choice by the platform.

$$\begin{aligned} x_1^{S\star}(\sigma) &= \frac{3\sigma(1-\theta(1-\alpha-\sigma+\sigma\alpha))}{6+2\theta^2(1-\alpha^2)(1-\sigma)-\theta(8-4\alpha(1-\sigma)-5\sigma)}, \\ x_1^{J\star}(\sigma) &= \frac{(1-\sigma)(2-\theta(1-\alpha)(2-3\sigma)}{6+2\theta^2(1-\alpha^2)(1-\sigma)-\theta(8-4\alpha(1-\sigma)-5\sigma)}, \\ x_2^\star(\sigma) &= -\frac{2(1-\sigma)(1-\theta(1-\alpha))}{6+2\theta^2(1-\alpha^2)(1-\sigma)-\theta(8-4\alpha(1-\sigma)-5\sigma)}. \end{aligned}$$

We make three observations that will be relevant below. First, one can show that $\frac{\partial x_1^{S\star}(\cdot)}{\partial \sigma} > 0$, $\frac{\partial x_1^{J\star}(\cdot)}{\partial \sigma} < 0$, $\frac{\partial x_1^\star(\cdot)}{\partial \sigma} = \frac{\partial (x_1^{S\star}(\cdot)+x_1^{J\star}(\cdot))}{\partial \sigma} > 0$, and $\frac{\partial x_2^\star}{\partial \sigma} < 0$. Intuitively, steering, i.e. a larger σ, shrinks the joint market segment, which is why a given output on this segment will lead to a lower price (or in other words consumers are more sensitive to increases in output in this segment). To compensate for this lower margin due to an increase in σ, both D_2 and $U-D_1$ finds it optimal to lower their output. Thus, we have that total output in this segment falls.

Second, even though $U-D_1$ lowers its output on the joint segment, it raises its output on the steered segment and increases its overall output.

Third, the ecosystem $U-D_1$ can fully foreclose D_2 by setting $\sigma = 1$. In this case, D_2 sets $x_2^\star = 0$.

Steering. U chooses the degree of steering consumers away from D_2 to maximize their profit

$$\max_\sigma P_1^S\left(\mathcal{Z}_1(x_1^\star(\sigma), x_2^\star(\sigma)), x_1^{S\star}(\sigma)\right) \cdot x_1^{S\star}(\sigma) + P_1^J\left(\mathcal{Z}_1(x_1^\star(\sigma), x_2^\star(\sigma)), x_1^{J\star}(\sigma) + x_2^\star(\sigma)\right) \cdot x_1^{J\star}(\sigma).$$

Differentiating with respect to σ and using the envelope theorem, we obtain

$$\underbrace{\frac{\partial P_1^J}{\partial x_2}\frac{\partial x_2^\star}{\partial \sigma}x_1^{J\star} + \frac{\partial P_1^S}{\partial \sigma}x_1^{S\star} + \frac{\partial P_1^J}{\partial \sigma}x_1^{J\star}}_{\text{Impact on Competition}} + \underbrace{\left[x_1^{J\star}\cdot\frac{\partial P_1^J}{\partial \mathcal{Z}_1} + x_1^{S\star}\cdot\frac{\partial P_1^S}{\partial \mathcal{Z}_1}\right]\cdot\theta\cdot\frac{\partial\left[x_1^\star+\alpha x_2^\star\right]}{\partial \sigma}}_{\text{Impact on Network Effects}} = 0. \tag{9}$$

Using that by the first-order-condition of D_1 in stage 2, we have $\frac{\partial P_1^J}{\partial x_2^\star}x_1^{J\star} = \frac{\partial P_1^J}{\partial x_1^{J\star}}x_1^{J\star} = -P_1^J$, and that

$\frac{\partial P_1^J}{\partial \mathcal{Z}_1} = 1$, we can rewrite as

$$\underbrace{-P_1^J \frac{\partial x_2^\star}{\partial \sigma} + \frac{\partial P_1^S}{\partial \sigma} x_1^{S\star} + \frac{\partial P_1^J}{\partial \sigma} x_1^{J\star}}_{\text{Impact on Competition}} + \underbrace{x_1^\star \cdot \theta \cdot \frac{\partial \left[x_1^\star + \alpha x_2^\star\right]}{\partial \sigma}}_{\text{Impact on Network Effects}} = 0. \tag{10}$$

Solving the above first order condition yields the optimal steering level as

$$\sigma^\star = \frac{2(1-\theta(1-\alpha))(15-\theta(4-\theta+\alpha(1+\alpha\theta)))}{\theta((1-\alpha)\theta(13+22\alpha)+52\alpha-2\theta^2(1-\alpha)^2)(1+\alpha)-47}.$$

The above solution is always falling with an increase in α for any $1 > \theta > 0$ and $1 \leq \alpha \geq 0$. To show this, differentiating the above solution with respect to α yields

$$\frac{\partial \sigma^\star}{\partial \alpha} = -\frac{12(130-\theta(103-\alpha^3\theta^2(14-\theta))-\alpha(5-\theta)(11-\theta)(2+\theta)-\theta(56-11\theta)-\alpha^2\theta(62-\theta(17-2\theta)))}{\theta(((1-\alpha)\theta(13+22\alpha)+52\alpha-2\theta^2(1-\alpha)^2)(1+\alpha)-47)^2} < 0.$$

Next, equating $\sigma^\star = 1$ and solving for α yields the solution $\alpha^F = \frac{(5-\theta)(2+\theta)}{\theta(14-\theta)}$. Further, it is easy to show that α^F strictly decreases in θ with $\alpha^F \in (0,1]$ for $\theta \geq 10/11$.

From the above discussion, it is straightforward that for all $\alpha < \alpha^F$, $\sigma^\star = 1$. Instead when $\theta > 10/11$ and $\alpha > \alpha^F$, we have $\sigma^\star \in (0,1)$.

■

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