Denial of interoperability and future first-party entry*

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VERY PRELIMINARY

March 15, 2023

Abstract

Motivated by the Google v. EnelX case at the Italian competition authority, we develop a theory of harm for Google's denial of access of EnelX's app to Google's app store when EnelX's app offered a functionality not offered by other apps. Our theory rests on data-induced network effects across periods. A platform may consider offering a first-party app in the future. By not allowing a third-party app to be listed on its app store, it makes sure that the third-party app would be a weaker competitor to its own app in the future. This makes denial of access attractive as a full or partial foreclosure strategy, which is costly in the short run but may be beneficial in the long run. Consumers are harmed by this practice. Thus, we identify market environments when compulsory access raises consumer surplus.

Keywords: Exclusionary practices. Vertical interoperability. Denial of access. Digital platforms. Vertical foreclosure. Data-induced network effects.

JEL Classification: K21, L10, L40

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*Peitz acknowledges support by Deutsche Forschungsgemeinschaft through CRC TR 224 (project B05).

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1 Introduction

In 2021, the Italian Competition Authority (ICA) found Google to have behaved anti-competitively because it had denied EnelX's app JuicePass — an app providing functionalities for recharging electric vehicles — access to Android Auto.[1] What is striking in this antitrust case (which is described in more detail in Section 2) is that Google itself at the time did not offer the same functionalities — although Google Maps has later incorporated (or has allegedly planned to incorporate) some of them. This is therefore a very unusual case in which vertical foreclosure takes place without the owner of the input being integrated.

In this paper, we propose a theory of anti-competitive foreclosure which is motivated by this case. The main idea is that a platform which is considering future first-party entry in a downstream market may refuse interoperability to a third-party app in order to prevent the latter from acquiring data which would confer it a competitive advantage over the former. In particular, consistent with our motivating case — where usage data determine the future quality of the app — we assume that more users of an app today will imply higher utility for future users of the same app.

Our economic mechanism relies on data-induced network effects and captures that the interaction with clients and users may allow a firm to be able to better interpret their needs and hence improve the quality of its products.[2] The same mechanism applies to standard network effects according to which future consumers benefit from the participation of today's consumers; see the discussion in Section 3. A similar mechanism can work on the supply side through learning by doing, whereby production costs fall with cumulative output.

We show that the denial of interoperability involves a trade-off for the platform. On the one hand, it improves the (future) competitive condition of its first-party app, and hence it increases future profits. On the other, since the platform appropriates a share of the third party's profits, the denial reduces current profits. At equilibrium, denial of interoperability is more likely to occur, ceteris paribus, the lower the platform's share of third-party profits and the higher the mass of future consumers.

In our deliberately simple base model, where the platform's entry costs are assumed so small that first-party entry always occurs in the second period and denial of interoperability can take place only in the first period (for instance, because regulation rules out self-preferencing), we show that a compulsory period-1 access policy is unambiguously beneficial to consumers.

When we consider extensions of the model where interoperability can be decided in any period and where first-party entry is costly, we find particular circumstances where compulsory access policies might backfire. For instance, when first-party entry is costly, denial of interoperability in

[1]The ICA's decision, dating from 13 May 2021, imposed a 102 million euro fine and an order to allow access. It was fully upheld by the TAR, Italy's court of first instance, in its Judgment n. 10147 of 18 July 2022. When quoting the Decision and the Judgment, the translations from Italian are ours.

[2]For instance, in the *General Electric/Alstom* merger case, a key ingredient for innovation appears to be the number of servicing contracts, as the interaction with customers provides opportunities and ideas for improving the quality and performance of gas turbines. As a result, the EC imposed a remedy whereby the buyer of the turbines divested from the merging parties, should also have a sufficient number of servicing contracts, without which it would not have had the ability to compete.

period 1 may increase expected first-party profits, thereby facilitating the entry of the platform's own app, which is beneficial to consumers.

In another extension, we explore the effects of compulsory data sharing with competitors: under such a policy, the third-party app is given access from the start, but a later entrant — such as the first-party app — would benefit from data-induced network effects as well. A more-effective data-sharing obligation increases spillovers and makes the platform less inclined to deny access; in this sense, this policy is a partial substitute for compulsory access. We also consider the possibility of combining compulsory access with sharing of data with competitors: under such a policy, the third-party app is given access from the start, but a later entrant — such as the first-party app — would benefit from data-induced network effects as well.[TO BE ADDED IN SECTION 5]

Other applications We believe that the theory proposed here has applications which might go well beyond the case at hand. For instance, Spotify's complaints about Apple included not only the payment of a 30% fee on the App Store payments by Premium subscribers but also various ways in which Apple allegedly hindered access to its App Store for Spotify's apps. While it is possible that Apple's behaviour was part of a strategy to force Spotify to pay more fees, in the wake of the decision to launch Apple Music it might also have been motivated (or reinforced) by the desire of reducing Spotify's incumbency advantage.[3]

Related literature Our paper belongs to the literature which studies incumbent firms' exclusionary strategies, and more particularly vertical foreclosure.[4] Our main contribution in this context is twofold. Firstly, we show that a firm which owns a necessary input (in our case, access to a platform) may deny access even when it is not yet vertically integrated, as a way to improve the *future* competitive position of its subsidiary (in our case, a first-party app). We are not aware of any other paper which has identified a similar mechanism.

Secondly, while in many vertical foreclosure models (think, e.g., of Ordover et al., 1990) the incumbent needs to commit to a particular action, say, refusal to supply, to deter or marginalise entry — and if entry did take place, the incumbent would have the incentive to renege its choice — here the denial of interoperability can be an equilibrium decision even when the entrant is already in the market. Other papers where an ex-post incentive to deny or degrade the input, or its interoperability, are Allain et al. (2016) and the network-effect model (but not the fixed-cost one) in Fumagalli and Motta (2020).

Since we provide a mechanism in which market structure can change over time, it speaks to the dynamic foreclosure theory of harm first proposed by Carlton and Waldman (2002) in the shape of tying of complementary products and then applied by Fumagalli and Motta (2020) in a vertical setting. In those papers, though, the incumbent is integrated, and its objective when foreclosing

[3]Particularly relevant seems to be the fact that Spotify could not have access to data about its iOS clients. On 28 February 2023, the European Commission announced a revised Statement of Objections which focuses on Apple's "anti-steering obligations". If the EC eventually forces Apple to let Spotify inform its iOS users of alternative means to pay the subscription and redirect them to its website, Spotify will also have access to information about them.

[4]See Fumagalli et al. (2018) for a discussion of this literature.

is to preserve its monopolistic position in the primary (or respectively upstream) market. Here instead, the objective is to improve its competitive position in a market which it has not entered yet. Given that how this objective is achieved consists in refusing interoperability to the third-party app, thereby denying it data-induced network effects, our mechanism might be interpreted as "raising rivals' costs" (or "reducing rivals' scale"), in the spirit of Ordover et al. (1990) and the following vast literature.

Our paper also speaks to the literature on network effects and incumbency advantage. Biglaiser et al. (2019) review this literature and point out reasons why an installed firm (in our analysis the complementor when the platform does not deny access) enjoys an incumbency advantage, which they define as "the fact that an incumbent, that is, a firm already with an installed base, will be able to generate higher profits than a new firm (an entrant) even if the entrant offers identical terms to consumers..." (p. 41) More specifically on data network effects, de Cornière and Taylor (2020) explain how the use of data can improve product quality from which future consumers will benefit and thus create an incumbency advantage. Data-induced network effects also arise when more user data reduce the marginal cost of quality improvements, as postulated and analyzed by Prüfer and Schottmüller (2021). Hagiu and Wright (forthcoming) consider "data-enabled learning", which encompasses data-induced network effects, and analyze dynamic competition with the feature that superior access to data gives an incumbency advantage.[5] Different from these works, in our model, the platform can deny the complementor early market access and thereby deprive it of offering higher quality that would be the result of data-induced network effects.

Plan of the paper The paper continues as follows. In Section 2 we describe in some detail the Google v. EnelX case that inspired us. Section 3 presents the base model. In section 4 we study when denial of interoperability may occur in equilibrium and analyze the effects of a compulsory access policy. In Section 5 we consider a few model extensions, and Section 6 concludes.

2 The Google v. EnelX case

On 13 May 2021, the Italian Competition Authority (ICA) found that Google had abused a dominant position because it had denied Enel X (a subsidiary of Enel, the main energy company in Italy) the possibility of developing a version of its JuicePass app compatible with Android Auto, a feature of the Android OS that allows apps to be used safely while driving. JuicePass offered a series of functionalities for recharging electric vehicles, including searching for charging stations, reserving a place in them, managing and monitoring the recharge, and paying for it. At the time of the conduct at hand, Google Maps was not offering any of these functionalities, with the exception of the location of charging stations.

[5] Data can also operate on the supply side. Learning by doing through data can make a firm more competitive when data enables firms to make a better choice between alternative production techniques (Faboodi et al., 2019); for earlier work on dynamic competition according to which learning-by-doing can reduce a firm's production cost, see, e.g. Cabral and Riordan (1994).

Google repeatedly denied Enel X the necessary tools for programming a version of JuicePass compatible with Android Auto, arguing among other things that templates for developing compatible apps were available only for media and messaging apps. The ICA notes that not only Google's own apps, Google Maps and Waze, had a compatible version but also that Google had allowed certain developers to have "custom apps" (apps which could be developed without a template). It also notes that Google had offered Enel X to include some of its functionalities directly in Google Maps, an offer Enel X did not accept because the user would have interacted with, Google Maps rather than with JuicePass, with the former appropriating thus crucial data, and because she could not have access to the booking functionalities of JuicePass (ICA, 2021: para.169-170). Importantly, Enel had also offered to carry out all the necessary investments for the development of a compatible app but Google replied that it was not possible to provide any further information in this regard and that, ultimately, the product managers were against an expansion of the types of apps present on Android Auto (TAR, 2022: p.11). Google also explained the denial with limited resources which would prevent it from developing templates for apps which are not considered a priority. However, the ICA and the TAR countered that Google could have asked Enel X to contribute to the development both financially and with technical resources, but never did so.[6]

Relevant to our discussion, the ICA found that between JuicePass and Google Maps, there was not only (limited) effective competition in that both apps allowed users to find charging stations, and more generally, competition for users' data, but also potential competition because of "Google's intention, highlighted in some documents acquired during the proceedings, to integrate into Google Maps the other functionalities currently covered by JuicePass".[7]

It is also worth noting that both the ICA and the Tribunal found that access to Android Auto is indispensable because it is essential for drivers to use the app without having to stop the car, as also confirmed by the full integration of the first-party apps Google Maps and Waze into Android Auto (TAR, 2022: p. 12).

Finally, the ICA and Tribunal stress that the refusal of interoperability has long-term consequences on the market: "Due to Google's rejection, the app JuicePass was excluded from the Android Auto platform throughout 2020 and early 2021 and, thus, at the beginning of the 2020-2025 period, in which significant growth was expected of sales of electric vehicles, which significantly limited the chances of market success of the product. In the context under consideration, in fact, the existence of network effects and winner-takes-all phenomena imply that the deferment of the availability of the JuicePass app on Android Auto was apt to prevent it from gaining an adequate user base to establish itself." (TAR, 2022: 13; see also ICA, 2021, e.g. at paragraphs 275 and 383).

In particular, the ICA emphasises the importance of data as a necessary input for the improvement of the quality of the services offered and for the profiling of users and of their needs: "Since users are a source of data and data on searches for charging stations are of particular relevance for

[6]At a later stage and with the investigation well advanced, Google developed a beta version of a template for electric recharge, but Enel X chose not to enter the beta testing process it because of the lack of visibility of the app to users and because of uncertainty about the timing of the development of a standard version (ICA, 2021: para. 179.

[7]See TAR (2022: p. 9), and ICA (2021: e.g. at paragraphs 111-119 and 334-341).

the analysis of the demand for charging services, Google's conduct has deprived and may deprive in the future Enel X Italia of the possibility of acquiring a valuable data flow to define its operations in the field of electric mobility and to improve the quality of its services." (ICA, 2021: 389; see also paragraphs 306-308).

3 A model with data-induced network effects

Our analysis is motivated by Google v. EnelX case at the Italian competition authority. We develop a theory of harm for Google's denial of access of EnelX's app to Google's app store when EnelX's app offered a functionality not offered by other apps, and identify the market environments in which there is consumer harm. Our theory has a broader range of applications, as we will spell out in Section 6.

A firm P (*P*latform) operates a platform, which consumers can use to access the listed apps. Consumers do not intrinsically value the platform and can use an app only if they have access to the platform.

A firm C (*C*omplementor) may enter with a new (third-party) app in the early or late period. In period $t = 1$ of the game, there is no other app with the same functionality. In period $t = 2$, the platform may enter its own version of the app (first-party app). Two groups of consumers who have so far not used the platform and would not derive any utility from any other apps are potentially interested in downloading C's app, or P's app if and when it will be available.

In our analysis with reduced-form profit functions, we express equilibrium profits in the product market depending on the availability of apps in the two periods (gross of any payment from the complementor to the platform). In period 1, only C may be active in the app market and we write its profit π_C^1 as a function of its app being available on the platform in this period. An app is only available on the platform in a given period it has been developed *and* if it is admitted. The complementor makes monopoly profit $\pi_C^1(1) > 0$ if it is available ($x = 1$), while it makes zero profit otherwise ($\pi_C^1(0) = 0$ if $x = 0$). We denote period-2 profits as $\pi_j^2(x, y_C, y_P)$, $j \in \{C, P\}$, where again $x = 1$ means that the third-party app was available on the platform in period 1 and $x = 0$ that it was not; $y_C = 1$ means that the third-party app is available on the platform in period 2 and $y_C = 0$ that it is not; $y_P = 1$ means that the first-party app is available in period 2 and $y_P = 0$ that it is not. Thus, second-period profits depend on which apps are available on the platform and on the availability of the entrant's app in the first period. The availability of a competing app clearly affects the profits made from the app, but so may the availability of the complementor's app in the first period. This is motivated by data-induced network effects exerted from period-1 participation on period-2 attractiveness of the app.[8] Developing an app is costly; denote the entrant's cost by F_C and the incumbent's cost by F_P.

Period-2 profits in the app market are assumed to satisfy the following properties: (i) $\pi_C^2(1, 1, y_P) > \pi_C^2(0, 1, y_P)$ because data collected from usage in period 1 positively affects the performance of the third-party app in period 2; (ii) $\pi_P^2(1, 1, 1) < \pi_P^2(0, 1, 1)$ and $\pi_P^2(1, 0, 1) = \pi_P^2(0, 0, 1)$ because

[8] This can be seen as learning by doing which positively affects the inclination of consumers to use the app.

the third-party app's superior performance harms the platform's profits made from its first-party app in case the third-party app remains available in period 2; (iii) $\pi_C^2(x,1,1) < \pi_C^2(x,1,0)$ and $\pi_P^2(x,1,1) < \pi_P^2(x,0,1)$ as competition from the competing app reduces profit.

Property (i) is a shortcut for network effects that period-1 consumers exert on period-2 consumers.[9] We spell them out in our two examples below. Network effects capture the idea that while using the app, individuals' attention and usage are converted into data which can improve the experience of future app users: think for instance of a searchable GIF app which can better predict which GIFs users prefer, or a marketplace which learns from richer consumer data accumulated over time leading to a better consumer experience, or a navigation app which can offer better solutions as it gathers information about how users move and how traffic is likely to develop.[10]

We assume that the platform has two sources of profits: profits from the first-party app and a fraction $\beta \in (0,1)$ of third-party profit. The exogenous profit sharing is a shortcut for a revenue share (say 30 %) to be extracted from the third-party app developer and negligible variable costs. We develop a simple analysis of the platform's incentives to deny third-party interoperability with its platform.

The game is as follows.

(1.1) Firm C decides whether to develop in period 1 at cost F_C. It will then ask for interoperability with the platform.

(1.2) Firm P decides whether to allow period-1 interoperability between its platform and the third-party app, or deny it.

(1.3) Period-1 profits realize.

(2.1) Firm P decides whether to spend F_P to create its first-party app.

(2.2) Period-2 profits realize.

We solve for the subgame perfect Nash equilibrium in the following section. For simplicity, in period 1, firms maximize the undiscounted sum of period-1 and period-2 profits.

In the base model, we assume that the platform has to provide interoperability to the third-party app if it offers a competing first-party app. This is clearly the case if discriminating against the third-party app is not permitted thanks to regulation or intervention by an antitrust authority (which can

[9]Our two-period model can be interpreted as a model with two markets, one for period-1 consumers and one for period-2 consumers. These markets are linked through cross-market network effects as data collected from period-1 consumers affect the period-2 consumers benefit of the complementor's product. Thus, our model fits within the framework of de Cornière and Taylor (2020).

[10]Alternatively, one may have traditional network effects where the utility of users increases directly with the number of users joining in the other period, provided that period-1 users stay around for two periods, do not care about period 2-users, and do not reconsider their period-1 decision in period 2; for example, period-1 users are experts who improve the experience of period-2 consumers who lack expertise. Ad revenues collected from users who make the app installation decision encompass ad revenues in both periods from these consumers.

be seen as an act of self-preferencing).[11] We analyze the issue of period-2 interoperability in Section 5.1. In the base model, we also take platform entry with its first-party app in period 1 for granted; in other words, F_P is sufficiently small that it always enters in period 2, and thus the platform does not make any effective decision at stage (2.1). We analyze the case of substantial costs and the platform's entry decision in Section 5.2. Note also that according to our timing, the platform cannot commit to deny interoperability prior to the complementor's entry decision; see Section 5.4 for the analysis under this alternative timing.

To evaluate consumer harm, we assume a partial ordering of consumer surplus. Consumer surplus in period 1 depends on x, consumer surplus in period 2 depends on (x, y_C, y_P). As long as consumer surplus is not fully extracted in the first period, $CS^1(1) > CS^1(0)$, which is what we assume. For period-2 consumer surplus we assume that $CS^2(1,1,1) > CS^2(0,1,1) > CS^2(0,0,1)$; that is, given that the first-party app is available in period 2, consumers prefer the third-party app being available in both periods to it being available in period 2 only, which in turn is preferred to it not being available at all. In our two examples below, we confirm this consumer surplus ranking.

Example 1: Horizontally differentiated apps and monetisation through advertising *To provide a concrete setting, we derive reduced profit as a function of users in a simple differentiated product model in which apps compete for consumer attention and monetise through advertising. Denote with* N_C^1, N_C^2, *and* N_P^2 *the number of consumers (to be endogenously determined) who will download the apps in respectively period* 1 *and period* 2*. For simplicity, we assume that the* N_1^C *consumers use the app only in period 1 and then disappear (or base their decision on whether to download only on the utility derived in period 1). Downloading an app has a positive but arbitrarily small cost,* ϵ*, which can be thought of as the opportunity cost of time for installing the app or the opportunity cost of storage space. The utility of one consumer (directly or indirectly) increases with the number of all other individuals who used the app in the past:* $U_j^t = v - \tau \mid \omega - l_j \mid + \gamma N_j^{t-1}$*, with* $t = 1, 2$*, and* $j \in \{C, P\}$*.* N_j^t *represents the number of users of app* j *at time* t*;* $N_j^0 = 0$ *because any app cannot be available before time* $t = 1$*;* $N_P^1 = 0$ *because the first-party app can only be introduced in* $t = 2$*. Note that at time* $t = 2$ *consumers may use the app by either C or P if both are made available;* v *is the stand-alone utility of the app (that consumers experience under zero participation in the previous period),* τ *is a disutility parameter that measures how much consumers suffer from a mismatch (also called the transport cost parameter). The consumer type* ω *represents the preferred specification of the app for a consumer,* $l_C = 0$ *and* $l_P = 1$ *are respectively the "product specification" of the complementor's and the platform's version of the app,* γ *is a parameter which measures the strength of network effects (for simplicity, we assume linear network effects). We assume that consumer preferences* ω *are uniformly distributed on the unit interval; there is mass* M^1 *of period-1 consumers and mass* M^2 *of period-2 consumers. Without loss of generality, we set* $M^2 = 1$*. Regarding the parameter values, we assume (in this and the following example) that* $v \geq 2$ *and* $\gamma < \tau \leq 1$*.*

All firms monetise through advertising; thus, both apps are available for free and so is the use of

[11] A related setting is one in which the platform cannot give access in period 1 and then deny it in period 2. This is in line with current case law in most jurisdictions, where *withdrawing* access is typically considered a violation of the law even if denying access may otherwise not be unlawful.

the platform. Each user brings an advertising revenue of a. Platform and apps have zero variable costs (zero marginal cost for operations and maintenance). At the end of each period, advertiser revenues are realized. The complementor has to pay a fraction β of its ad revenue to the platform.[12]

This simple specification allows us to express profits as a function of primitives of the model (reported here gross of any payment from third-party developer to platform). Let us start with $\pi_C^1(1)$. *In this case, C serves all period-1 consumers since* $v - \tau > 0$ *and its (gross) profit is* $\pi_C^1(1) = M^1 a$. *In period 2, if C entered and interoperability was denied in period 1, profits are* $\pi_C^2(0,1,1) = \pi_P^2(0,1,1) = a/2$*; if C did not enter, C makes zero profit and P makes* $\pi_P^2(0,0,1) = a$. *The remaining case is that C has entered and interoperability was allowed in period 1. In this case, C's app was installed by all period-1 consumers. Thus, in period 2, the indifferent consumer satisfies* $\gamma - \tau\hat{\omega} = -\tau(1-\hat{\omega})$ *and, thus,* $\hat{\omega} = (\tau + \gamma)/(2\tau) \in (1/2, 1)$ *under our assumption that* $\gamma < \tau$. *Hence,* $\pi_C^2(1,1,1) = a(1/2 + \gamma/(2\tau))$ *and* $\pi_P^2(1,1,1) = a(1/2 - \gamma/(2\tau))$.

Consumer surplus is expressed as follows. If all consumers use the same app, the average mismatch generated disutility $\tau/2$. *Thus,* $CS^1(1) = M^1(v - \tau/2)$ *and* $CS^2(0,0,1) = v - \tau/2$. *If half of all consumers choose either app in the second period (apps are symmetric because the third-party app was not available on the platform in period 1), we have* $CS^2(0,1,1) = v - \tau/4$. *In the situation in which the first-party app was available on the platform in period 1 and both apps are available in period 2, the fraction* $\hat{\omega}$ *of consumers benefits from data-induced network benefits and obtains a surplus of* $v + \gamma$ *gross of the disutility from mismatch. The average disutility from mismatch across all consumers is* $\hat{\omega}\tau\hat{\omega}/2 + (1-\hat{\omega})\tau(1-\hat{\omega})/2 = (\tau/2)(\hat{\omega}^2 + (1-\hat{\omega})^2) = (1/(8\tau))((\tau+\gamma)^2 + (\tau-\gamma)^2) = (\tau^2 + \gamma^2)/(4\tau)$. *Thus,* $CS^2(1,1,1) = v + \gamma\hat{\omega} - (\tau^2+\gamma^2)/(4\tau) = v + \gamma(\tau+\gamma)/(2\tau) - (\tau^2+\gamma^2)/(4\tau) = v - (\tau^2 - \gamma^2 - 2\gamma\tau)/(4\tau)$.

The assumed partial orderings of profits and consumer surplus are all satisfied. In particular, we have that $CS^2(1,1,1) > CS^2(0,1,1)$. *In the example this means that we must have* $v - (\tau^2 - \gamma^2 - 2\gamma\tau)/(4\tau) > v - \tau/2$, *which is equivalent to* $\tau^2 - \gamma^2 - 2\gamma\tau < 2\tau^2$, *which is clearly satisfied. The reason is that one of the apps is of higher quality (thanks to data-induced network effects) and nothing else has changed; therefore, consumer surplus must be higher.*

Example 2: Horizontally differentiated apps and subscription pricing. *We use the same setting as in Example 1 with the only difference that apps do not make revenues from advertising but charge users a subscription price. In this case, the timing of the game with reduced profit function is augmented by a price-setting stage in each period that is introduced after entry and interoperability decisions have been made. The app market then becomes a (possibly asymmetric) Hotelling model with linear transport costs in which users have to pay prices* p_C^t *and* p_P^t *to use the apps offered by C and P, respectively, in period t. The utility is written as* $U_j^t = v - \tau \mid \omega - l_j \mid + \gamma N_j^{t-1} - p_j^t,\ j \in \{C, P\}$. *App profit is thus* $p_j^t N_j^t(p_C^t, p_P^t)$.

Equilibrium profits are as follows: If only one app is available in a given period t, under our parameter assumption, the app will be sold to all period-t consumers at the price which makes

[12] Alternatively, when thinking about an ad-funded website being accessed through a search engine, the search engine may be able to directly monetise through advertising such that total ad spending is split between the search engine and the website.

the consumer whose preferred specification is furthest away from the available specification just indifferent between buying and not buying. If the third-party app developer enters and the app is made available on the platform, it will thus sell at price $v-\tau$ and make a profit $v-\tau$ (before sharing those profits with the platform). This means that $\pi_C^1(1) = M^1(v-\tau)$. If the third-party app is not available, then the first-party app generates profit in the second period of $\pi_P^2(0,0,1) = v-\tau$. If instead the third-party app is available but does not enjoy an advantage in data-induced network effects (because interoperability was denied in period 1), this is the symmetric Hotelling model with equilibrium prices equal to τ. Thus, profits are $\pi_C^2(0,1,1) = \pi_P^2(0,1,1) = \tau/2$, as demand for each app is $1/2$. If first-party and third-party apps are available in period 2 and the platform allowed interoperability in period 1, the third-party app gives stand-alone utility $r+\gamma$ in period 2 (since all consumers in period 1 used the app), while the first-party app gives only v. Equilibrium prices are easily calculated as $p_C^2(1,1) = \tau+\gamma/3$ and $p_P^2(1,1) = \tau-\gamma/3$. In equilibrium, the fraction $(\tau+\gamma/3)/(2\tau)$ subscribe to C's app and $(\tau-\gamma/3)/(2\tau)$ of consumers to P's app. Equilibrium profits are $\pi_C^2(1,1,1) = (\tau+\gamma/3)^2/(2\tau)$ and $\pi_P^2(1,1,1) = (\tau-\gamma/3)^2/(2\tau)$. We note that the third-party app developer obtains a higher profit in period 2 if the platform granted period-1 interoperability, $\pi_C^2(1,1,1) > \pi_C^2(0,1,1)$ (since $(\tau+\gamma/3)^2/(2\tau) > (\tau+\gamma/3)/2 > \tau/2$). The assumption on the profit ranking in the model with reduced-form profits is satisfied.

We now report consumer surplus in this example and show that the partial ordering assumed in the model with reduced-form profits is also satisfied. We have $CS^1(1) = M^1\tau/2$ and $CS^2(0,0,1) = \tau/2$. Under symmetric competition, each app is made available at price τ and, on average, consumers incur a disutility from the mismatch of $\tau/4$. Thus, $CS^2(0,1,1) = v-(5/4)\tau$, which is larger than $CS^2(0,0,1)$. Under asymmetric competition in period 2, $CS^2(1,1,1) = v-\pi_C^2(1,1)-\pi_P^2(1,1)-N_C^2(\tau N_C^2)/2-N_P^2(\tau N_P^2)/2$, where the last two terms in absolute value capture the average cost of mismatch. Substituting for the equilibrium values, we obtain $CS^2(1,1,1) = v-(5/8)\tau(\tau^2+(\gamma/3)^2)$. It is easy to check that $CS^2(1,1,1) > CS^2(0,1,1)$ (since τ and γ are less than 1, $CS^2(1,1,1)$ is bounded below by $v-(25/36)\tau$ which is greater than $v-(5/4)\tau$). The surplus ordering also follows from the observation that with interoperability in period 1, each app offers a higher net surplus to period-2 consumers than without interoperability in period 1.[13]

4 Denial of interoperability as raising-the-rival's-cost strategy

If the platform can deny interoperability only in the first period, the following outcomes are possible: (i) the third-party developer invests, the platform approves the request for interoperability and develops its own app, which it introduces in period 2; (ii) the third-party developer invests, the platform denies the request for interoperability and develops its own app, which it introduces in period 2; (iii) the third-party developer does not invest and the platform introduces its own app in period 2; (iv) the third-party developer invests, the platform approves the request for interoperability and does not develop its own app; (v) neither the third-party developer nor the platform invests. All other possible

[13] Consumer ω obtains $v-(\tau-\gamma/3)-\tau(1-\omega) > v-\tau-\tau(1-\omega)$ when choosing P's app and $v+\gamma-(\tau+\gamma/3)-\tau\omega > v-\tau-\tau\omega$ when choosing C's app.

outcomes are dominated. To reduce the number of possible outcomes, we assume in this section that F_P is sufficiently small that the platform will always develop the first-party app in period 2. Thus, we can focus on outcomes (i)-(iii).

Outcome (i) implies profits for the third-party developer of $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1))-F_C$ and for the partially integrated platform of $\pi_P^2(1,1,1)+\beta(\pi_C^1(1)+\pi_C^2(1,1,1))-F_P$. Outcome (ii) implies profits for the third-party developer of $(1-\beta)\pi_C^2(0,1,1)-F_C$ and for the platform of $\pi_P^2(0,1,1)+\beta\pi_C^2(0,1,1))-F_P$. Outcome (iii) implies profits for the third-party developer of 0 and for the platform of $\pi_P^2(0,0,1)-F_P$.

Suppose that the third-party developer invested. The platform then decides whether to deny interoperability. Denial is preferred by the platform if

$$\pi_P^2(0,1,1))+\beta\pi_C^2(0,1,1))>\pi_P^2(1,1,1)+\beta(\pi_C^1(1)+\pi_C^2(1,1.1)),$$

which is equivalent to

$$\pi_P^2(0,1,1)-\pi_P^2(1,1,1)>\beta(\pi_C^1(1)+\pi_C^2(1,1,1)-\pi_C^2(0,1,1)). \tag{1}$$

The advantage of denial for the platform is that it faces a weaker competitor in period 2 and will thereby obtain a higher profit with its first-party app; this is the term on the left-hand side of the inequality. The countervailing effect is that it makes a lower profit from its share in the third-party developer's gross profit: the platform's share in the third-party developer's gross profits amounts to zero in period 1 since the third-party developer will not make profits in the first period and it receives also a lower payment in the second period since the third-party developer does not benefit from network effects from first-period usage; this is the term on the right-hand side of the inequality. If β is sufficiently small, the platform denies interoperability in the first period.

What will the third-party developer do? If inequality (1) holds, it will invest provided that $(1-\beta)\pi_C^2(0,1,1)>F_C$. If inequality (1) does not hold, it will invest if $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1))>F_C$.

Thus, the equilibrium outcome under laissez-faire is characterized as follows:

Proposition 1. *When the platform has to provide compulsory period-2 access, the following holds:*

- *If* $\pi_P^2(0,1,1)-\pi_P^2(1,1,1)\leq\beta(\pi_C^1+\pi_C^2(1,1,1)-\pi_C^2(0,1,1))$ *and* $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1))\geq F_C$, *in equilibrium, the third-party app enters and the platform approves the request for period-1 interoperability.*
- *If* $\pi_P^2(0,1,1)-\pi_P^2(1,1,1)>\beta(\pi_C^1(1)+\pi_C^2(1,1,1)-\pi_C^2(0,1,1))$ *and* $(1-\beta)\pi_C^2(0,1,1)\geq F_C$, *in equilibrium, the third-party app enters and the platform denies the request for period-1 interoperability.*
- *If either* $\pi_P^2(0,1,1)-\pi_P^2(1,1,1)\leq\beta(\pi_C^1+\pi_C^2(1,1,1)-\pi_C^2(0,1,1))$ *and* $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1))<F_C$ *or* $\pi_P^2(0,1,1)-\pi_P^2(1,1,1)>\beta(\pi_C^1(1)+\pi_C^2(1,1,1)-\pi_C^2(0,1,1))$ *and* $(1-\beta)\pi_C^2(0,1,1)<F_C$, *in equilibrium, the third-party app does not enter and the platform's own app has a monopoly position in period 2.*

Under inequality (1), the platform will always deny interoperability. This reduces the third-party developers profit and makes the developer a weaker competitor in case it entered. Denial thus is a way for the platform to make the first-party app relatively more attractive compared to the third-party app (because it deprives the third-party app from the increased attractiveness thanks to data-induced network effects); since the complementor's profit decrease, the parameter range for which the third-party app will not be developed becomes larger.

Compulsory access What happens if the antitrust authority intervenes and forces the platform to allow interoperability in period 1 (compulsory period-1 access)? Then, the third-party developer knows that, with entry, it will make profit $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1))$. The third-party developer thus enters if this profit is larger than the entry cost.

Lemma 1. *Consider compulsory period-1 access. If* $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1)) \geq F_C$*, the platform makes equilibrium profit* $\pi_P^2(1,1,1)+\beta(\pi_C^1(1)+\pi_C^2(1,1,1))$ *and the complementor* $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1))$*, and consumer surplus is* $CS^1(1)+CS^2(1,1,1)$*. By contrast, if* $(1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1)) < F_C$*, the platform makes equilibrium profit* $\pi_P^2(0,0,1)$ *and the complementor zero, and consumer surplus is* $CS^2(0,0,1)$.

The comparison between laissez-faire and policy intervention then plays out as follows:

Proposition 2. *The introduction of compulsory period-1 access can change the market outcome in either one of two ways*

- *If* $\pi_P^2(0,1,1)-\pi_P^2(1,1,1) > \beta(\pi_C^1(1)+\pi_C^2(1,1,1)-\pi_C^2(0,1,1))$ *and* $(1-\beta)\pi_C^2(0,1,1) > F_C$*, the third-party party app will be available on the platform in period 2 and but not in period 1. Consumer surplus increases as a result of this policy as* $CS^1(1)+CS^2(1,1,1) > CS^2(0,1,1)$.
- *If* $\pi_P^2(0,1,1)-\pi_P^2(1,1,1) > \beta(\pi_C^1(1)+\pi_C^2(1,1,1)-\pi_C^2(0,1,1))$ *and* $(1-\beta)\pi_C^2(0,1,1) < F_C < (1-\beta)(\pi_C^1(1)+\pi_C^2(1,1,1))$*, the third-party app will be available in both periods instead of not being developed. Consumer surplus increases as a result of this policy as* $CS^1(1)+CS^2(1,1,1) > CS^2(0,1,0)$.

In all other cases, the policy is neutral.

We illustrate the findings of this proposition with our two examples.

Example 1 continued *In this example, the inequality* $\pi_P^2(0,1,1)-\pi_P^2(1,1,1) > \beta(\pi_C^1(1)+\pi_C^2(1,1,1)-\pi_C^2(0,1,1))$ *becomes* $a\gamma/(2\tau) > \beta a(M^1+\gamma/(2\tau))$ *or, equivalently,*

$$\beta < \frac{\gamma}{2\tau M^1+\gamma}. \tag{2}$$

If inequality (2) is satisfied and $(1-\beta)a/2 > F_C$*, the prohibition of denying interoperability implies that the complementor's app is available in both periods and not only in period 2. For consumers, this has two benefits: benefits in period 1 and an improved app by the complementor thanks to data-induced network effects in period 2.*

If inequality (2) is not satisfied and $(1-\beta)a/2 < F_C < (1-\beta)(a/2+aM^1+a\gamma/(2\tau))$*, the prohibition of denying interoperability implies that the complementor's app is available in both periods and not only in period 2. For consumers, this has two benefits: benefits in period 1 and the availability of both apps and not just the platform's own app in period 2 (where the complementor's app is improved thanks to data-induced network effects).*

Note that the inequality is more likely to be satisfied, other things being equal, the lower β *(that is, the lower the appropriability of rents by the platform), the lower* M^1 *(that is, the less weight for period-1 demand), the lower* τ *(that is, the lower the transport cost, namely the more competitive the market), and the higher* γ *(that is, the more important the network effect).*

Example 2 continued *The inequality* $\pi_P^2(0,1,1) - \pi_P^2(1,1,1) > \beta(\pi_C^1(1) + \pi_C^2(1,1,1) - \pi_C^2(0,1,1))$ *becomes*

$$\beta < \frac{2\tau - \frac{\gamma}{3}}{2\tau + \frac{\gamma}{3} + \frac{6\tau}{\gamma}M^1(v-\tau)}. \tag{3}$$

If inequality (3) is satisfied and $(1-\beta)\tau/2 > F_C$*, the prohibition of denying interoperability implies that the complementor's app is available in both periods and not only in period 2. For consumers, this has two benefits: benefits in period 1 and an improved app by the complementor thanks to data-induced network effects in period 2.*

If inequality (3) is not satisfied and $(1-\beta)\tau/2 < F_C < (1-\beta)(M^1(v-\tau) + (\tau+\gamma/3)^2/(2\tau))$*, the prohibition of denying interoperability implies that the complementor's app is available in both periods and not only in period 2. Consumers benefit from the availability of the third-party app in period 1 and the availability of both apps and not just the platform's own app in period 2 (where the complementor's app is improved thanks to data-induced network effects).*

As in Example 1, the inequality is more likely to be satisfied, other things being equal, the lower β *(that is, the lower the appropriability of rents by the platform), the lower* M^1 *(that is, the less weight for period-1 demand). The additional parameter* v *plays the same role as* M^1 *as a higher stand-alone value leads to a higher price in period 1 and does not affect the price in period 2 and, thus, makes period 1 a more imporant source of profits. Also because of price competition, the effects of* γ *and* τ *are ambiguous.*

As a side remark: we note that the platform may not be satisfied with the outcome under laissez-faire because the third-party developer does not invest fearing that it will be denied interoperability. If the platform denies interoperability and this triggers no entry, it will make profit $\pi_P^2(0,0,1)$. Suppose that the platform is better off under compulsory period-1 access. This requires that the following inequality holds: $\pi_P^2(1,1,1) + \beta(\pi_C^1(1) + \pi_C^2(1,1,1)) > \pi_P^2(0,0,1)$ or, equivalently, $\pi_P^2(0,0,1) - \pi_P^2(1,1,1) < \beta(\pi_C^1(1) + \pi_C^2(1,1,1))$. The condition that the platform denies interoperability after C's entry is $\pi_P^2(0,1,1) - \pi_P^2(1,1,1) > \beta(\pi_C^1(1) + \pi_C^2(1,1,1) - \pi_C^2(0,1,1)$. Thus, a necessary condition for both inequalities to be simultaneously satisfied is $\pi_P^2(0,0,1) < \pi_P^2(0,1,1) + \beta\pi_C^2(0,1,1)$. In principle, this is possible as duopoly industry profits may exceed monopoly profits under sufficient differentiation and then the inequality holds for sufficiently large β. In addition, it must hold that complementor entry is not profitable when interoperability is denied, but profitable when allowed – that is, $(1-\beta)\pi_C^2(0,1,1) < F_C < (1-\beta)(\pi_C^1(1) + \pi_C^2(1,1,1))$.[14] Under these conditions, compulsory period-1 access leads to a Pareto improvement: the partially integrated platform, the third-party developer and consumers are better off after the intervention.

5 Extensions

5.1 Denial of interoperability

In the main model, we did not allow for denial of interoperability in period 2. In this subsection, we show that it may be the preferred strategy by the platform, and then argue that given the legal risks this involves the platform may find it a better option to deny interoperability in the first period. Under laissez-faire, the platform can allow interoperability in period 1, but deny it in period 2.

The platform has no reason to deny interoperability in period 1 if it has the option to deny in period 2 since this generates additional profit $\beta\pi_C^1(1)$. Suppose that the third-party app has entered in period 1. If the platform denies interoperability in period 2 it will make period-2 profit $\pi_P^2(1,0,1)$, which is equal to $\pi_P^2(0,0,1)$. If it allows interoperability it will make period-2 monopoly profit $\pi_P^2(1,1,1) + \beta\pi_C^2(1,1,1)$. As long as monopoly profits are larger than industry duopoly profits $\pi_P^2(1,1,1) + \pi_C^2(1,1,1)$, if the platform can deny interoperability in period 2, it will always do so. The following result holds:

Lemma 2. *Suppose that monopoly profits $\pi_P^2(x,0,1)$ are larger than industry duopoly profits $\pi_P^2(1,1,1)+\pi_C^2(1,1,1)$ and the platform can deny interoperability in any periods.*

If period-1 profits accruing to the complementor are sufficient to cover its entry cost, i.e. $(1-\beta)\pi_C^1(1) \geq F_C$, then the complementor enters with a third-party app and the platform allows interoperability in period 1, but denies it in period 2. In equilibrium, the platform makes profit $\pi_P^2(1,0,1) + \beta\pi_C^1(1)$ and the complementor $(1-\beta)\pi_C^1(1)$ (gross of entry costs), and consumer surplus is $CS^1(1) + CS^2(1,0,1)$, corresponding to two successive monopolies.

If the reverse inequality $(1-\beta)\pi_C^1(1) < F_C$ holds, the complementor does not enter and the platform is a monopolist with its first-party app in period 2. The platform makes equilibrium profit $\pi_P^2(0,0,1)$ and the complementor zero, and consumer surplus is $CS^2(0,0,1)$.

Compulsory access What are the effects of compulsory period-2 access (when access can always be denied in period 1) compared to this outcome? Let us continue to suppose that monopoly profits are larger than industry duopoly profits. The answer then follows from Proposition 1 and Lemma 5.1.

As stated in Proposition 1, if $\pi_P^2(0,1,1) - \pi_P^2(1,1,1) \leq \beta(\pi_C^1 + \pi_C^2(1,1,1) - \pi_C^2(0,1,1))$ and $(1-\beta)(\pi_C^1(1) + \pi_C^2(1,1,1)) \geq F_C$ the third-party app enters and the platform approves the request for period-1 interoperability. Thus, under period-2 compulsory access, consumer surplus

[14] Here we do not return to our examples because in our examples product differentiation is insufficient to generate this outcome. However, if we were to allow for lower v in Example 2, the inequality can be satisfied.

will be $CS^1(1) + CS^2(1,1,1)$. By contrast, absent period-2 compulsory access, consumer surplus will be $CS^1(1) + CS^2(1,0,1)$ if $(1-\beta)\pi_C^1(1) \geq F_C$ and $CS^2(0,0,1)$ otherwise, which is less than $CS^1(1)+CS^2(1,0,1)$. Since $CS^1(1)+CS^2(1,1,1) > CS^1(1)+CS^2(1,0,1)$, consumers are better off under period-2 compulsory access.

If $\pi_P^2(0,1,1) - \pi_P^2(1,1,1) \leq \beta(\pi_C^1 + \pi_C^2(1,1,1) - \pi_C^2(0,1,1))$ and $(1-\beta)(\pi_C^1(1) + \pi_C^2(1,1,1)) < F_C$ there is no complementor entry with and without compulsory period-2 access. Thus, only the first-party app will be provided in period 2 and consumer surplus is $CS(0,0,1)$.

Consider instead situations under inequality $\pi_P^2(0,1,1) - \pi_P^2(1,1,1) > \beta(\pi_C^1(1) + \pi_C^2(1,1,1) - \pi_C^2(0,1,1))$. If $(1-\beta)\pi_C^2(0,1,1) < F_C$, under compulsory period-2 access, the third-party app does not enter and the platform's own app has a monopoly position in period 2. This generates consumer surplus $CS^2(0,0,1)$. Absent compulsory period-2 access, the complementor would not enter either if $(1-\beta)\pi_C^1(1) < F_C$. Thus, for $(1-\beta)\min\{\pi_C^2(0,1,1), \pi_C^1(1)\} < F_C$ there is no third-party app entering with or without compulsory period-2 access. Only the first-party app will be provided in period 2 and consumer surplus is $CS(0,0,1)$. If instead $(1-\beta)\max\{\pi_C^2(0,1,1), \pi_C^1(1)\} > F_C$ there is complementor entry with and without compulsory period-2 entry. With compulsory period-2 access, the platform denies period-1 interoperability and consumer surplus is $CS^2(0,1,1)$. Without compulsory period-2 access, the platform allows period-1 interoperability, but denies it in period 2; the ensuing consumer surplus is $CS^1(1)+CS^2(1,0,1)$, which may be larger than $CS^2(0,1,1)$. This is the case if consumers are better to be in a monopoly market for both periods instead of a symmetric duopoly market in period 2 only.

In other words, knowing that it cannot deny interoperability in period 2, the platform denies it in period 1. This leads the third-party app to enter only in period 2. The resulting outcome may be inferior for consumers relative to the one arising without compulsory period-2 access, when C enters in period 1, and P enters in period 2 (and it is the only available app because it would deny interoperability

The remaining situation depends on whether or not the complementor's symmetric period-2 duopoly profit is larger than the period-1 monopoly profit, $\pi_C^2(0,1,1) > \pi_C^1(1)$. If this is the case, the complementor's entry cost can satisfy $(1-\beta)\pi_C^1(1) < F_C \leq (1-\beta)\pi_C^2(0,1,1)$. Then, there is no complementor entry without compulsory period-2 access and consumer surplus is $CS^2(0,0,1)$, while there is complementor entry with compulsory period-2 entry and consumers obtain $CS^2(0,1,1)$, which is larger. Hence, consumers are better off under period-2 compulsory access. If instead $\pi_C^2(0,1,1) < \pi_C^1(1)$ the complementor's entry cost can satisfy $(1-\beta)\pi_C^1(1) \geq F_C > (1-\beta)\pi_C^2(0,1,1)$. Then, there is complementor entry without compulsory period-2 access and consumer surplus is $CS^1(1) + CS^2(1,0,1)$, while there is no entry with compulsory period-2 access and consumer surplus is $CS^2(0,0,1)$. Hence, consumers are worse off under period-2 compulsory access.

We summarize our findings in the following proposition.

Proposition 3. *Compulsory period-2 access (but no period-1 restriction) affects consumers as follows:*

- *Suppose that* $\pi_P^2(0,1,1) - \pi_P^2(1,1,1) \leq \beta(\pi_C^1 + \pi_C^2(1,1,1) - \pi_C^2(0,1,1))$. *If* $(1-\beta)(\pi_C^1(1) +$

$\pi^2_C(1,1,1)) \geq F_C$, *compulsory period-2 access leads to an increase of consumer surplus.*

- *Suppose that* $\pi^2_P(0,1,1) - \pi^2_P(1,1,1) > \beta(\pi^1_C(1) + \pi^2_C(1,1,1) - \pi^2_C(0,1,1))$.
  - *If* $(1-\beta)\max\{\pi^2_C(0,1,1), \pi^1_C(1)\} > F_C$, *compulsory period-2 access leads to an increase of consumer surplus if and only if* $CS^1(1) + CS^2(1,0,1) < CS(0,1,1)$.
  - *If* $\pi^2_C(0,1,1) > \pi^1_C(1)$ *and* $(1-\beta)\pi^1_C(1) < F_C \leq (1-\beta)\pi^2_C(0,1,1)$, *compulsory period-2 access leads to an increase of consumer surplus.*
  - *If* $\pi^2_C(0,1,1) < \pi^1_C(1)$ *and* $(1-\beta)\pi^1_C(1) \geq F_C > (1-\beta)\pi^2_C(0,1,1)$, *compulsory period-2 access leads to a decrease of consumer surplus.*
- *In all other cases, the policy is neutral.*

In our examples, the respective conditions take the following form:

Example 1 continued *As shown above, the condition* $\pi^2_P(0,1,1) - \pi^2_P(1,1,1) > \beta(\pi^1_C(1) + \pi^2_C(1,1,1) - \pi^2_C(0,1,1))$ *becomes inequality (2) in the example. For* $\max\{a/2, M^1 a\} > F_C$, *compulsory period-2 access leads to an increase of consumer surplus if and only if* $M^1(v - \tau/2) + v - \tau/2 < v - \tau/4$, *which is equivalent to* $M^1(v - \tau/2) < \tau/4$. *The condition* $\pi^2_C(0,1,1) > \pi^1_C(1)$ *becomes* $a/2 > M^1 a$ *or, equivalently,* $M^1 < a/2$.

Hence, if the number period-1 of consumers is relatively small compared to the number of period-2 consumers, compulsory period-2 access always leads to an increase of consumer surplus whenever the policy has any impact. Only in the opposite case can the policy be consumer surplus decreasing.

Example 2 continued *As shown above, the condition* $\pi^2_P(0,1,1) - \pi^2_P(1,1,1) > \beta(\pi^1_C(1) + \pi^2_C(1,1,1) - \pi^2_C(0,1,1))$ *becomes inequality (3). For* $\max\{\tau/2, M^1(v-\tau)\} > F_C$, *compulsory period-2 access leads to an increase of consumer surplus if and only if* $M^1\tau/2 + \tau/2 < v - (5/4)\tau$, *which is equivalent to* $M^1\tau/2 + (7/4)\tau < v$. *The condition* $\pi^2_C(0,1,1) > \pi^1_C(1)$ *becomes* $\tau/2 > M^1(v - \tau)$. *As in Example 1, we have that if the number period-1 of consumers is relatively small compared to the number of period-2 consumers, compulsory period-2 access leads to an increase of consumer surplus whenever the policy has any impact.*

Compulsory period-2 access (without any restriction in period 1) thus gives a somewhat ambiguous result. However, if the platform has to offer interoperability in both periods, such compulsory full access necessarily increases consumer surplus. To see this, we compare the outcome of Lemma with the one of Lemma 1. We immediately obtain the following result:

Proposition 4. *Compulsory full access (compared to the laissez faire in which the platform is not restricted at all) never decreases consumer surplus:*

- *If* $(1-\beta)\pi^1_C(1) \geq F_C$, *consumer surplus increases from* $CS^1(1) + CS^2(0,0,1)$ *to* $CS^1(1) + CS^2(1,1,1)$.
- *If* $(1-\beta)\pi^1_C(1) < F_C < (1-\beta)(\pi^1_C(1) + \pi^2_C(1,1,1))$, *consumer surplus increases from* $CS^2(0,0,1)$ *to* $CS^1(1) + CS^2(1,1,1)$.

Otherwise, the policy is neutral.

In the first case, the complementor enters with compulsory full access and without any obligation; with compulsory full access both apps will be available in period 2, and the third-party app is improved thanks to data-induced network effects. In the second case, the complementor does not enter when the platform is not subject to any obligation since the complementor does not make any profits in period 2.

5.2 Costly entry of the first-party app

In the main model, we assumed that the entry cost for the first-party app was sufficiently low such that entry occurred for sure in the second period. In this extension, we assume that entry costs can be substantial, so we have to analyze when the first-party app will be made available in period 2. We will analyze the implications for the platform's decision regarding interoperability and show that the policy which prohibits the denial of interoperability in period 1 may backfire.

To limit the number of comparisons, we follow the base model and we assume the platform cannot deny interoperability in period 2. The timing of the game is augmented by the decision of the platform whether to develop its own app at cost F_I at the beginning of period 2 (that is, we account for the decision at stage 2.1).

If the platform enters with its first-party app, its period-2 profit (for wholesale and retail activities) is $\pi_P^2(x,1,1) + \beta\pi_C^2(x,1,1) - F_I$, provided that the third-party app has been developed. Otherwise, it is $\beta\pi_P^2(x,1,0)$; that is, it obtains the fraction β of the complementor's period-2 monopoly profit. Given $x = 1$, the platform develops the first-party app if $\pi_P^2(1,1,1) - \beta(\pi_P^2(1,1,0) - \pi_C^2(1,1,1)) \geq F_I$. Given $x = 0$ and the development of the third-party app, the platform develops the first-party app if $\pi_P^2(0,1,1) - \beta(\pi_P^2(0,1,0) - \pi_C^2(0,1,1)) \geq F_P$.

The game can be analyzed as a two-stage game in which, at the first stage, the complementor decides whether to enter and, at the second stage, the platform decides whether or not to allow for interoperability and whether or not to enter with a first-party app in period 2. To show that compulsory period-1 access can harm consumers, let us consider the limit case in which $\beta = 0$.

Suppose first that the complementor entered. If the platform allows interoperability in period 1 and enters in period 2 it makes profit $\pi_P^2(1,1,1) - F_P$. If instead it does not allow interoperability and enters with its own app in period 2 it makes $\pi_P^2(0,1,1) - F_P$, which dominates the former option. If it does not enter, while the complementor does, its profit is zero. Thus, if the complementor enters and $\pi_P^2(0,1,1) \geq F_P$, the platform makes profit $\pi_P^2(0,1,1) - F_P$, the complementor $\pi_C^2(0,1,1) - F_C$, and consumer surplus is $CS^2(0,1,1)$.

Suppose second that the complementor did not enter. Then, the platform enters with its own app if $\pi_P^2(0,0,1) \geq F_P$.

Consider now compulsory period-1 access. In this case, the platform can only decide whether or not to enter in period 2. With first-party entry, the platform makes profit $\pi_P^2(1,1,1) - F_P$ and without it makes zero. Thus, it enters if and only if $\pi_P^2(1,1,1) \geq F_P$. If the inequality holds, first-party entry generates profits in excess of entry costs and consumer surplus is $CS^1(1) + CS^2(1,1,1)$;

if first-party entry is not profitable consumer surplus is $CS^1(1) + CS^2(1,0,1)$. This implies that, for $\pi_P^2(1,1,1) < F_P \leq \pi_P^2(0,1,1)$, the platform will enter and deny period-1 interoperability if it is allowed to do so, but it will not enter under compulsory period-1 access. The former triggers competition in period 2, while the latter leads to monopoly in both periods. Consumer surplus then changes from $CS^2(0,1,1)$ to $CS^1(1) + CS^2(1,1,0)$. Thus, we have shown the following result:

Proposition 5. *Provided that $CS^2(0,1,1) > CS^1(1) + CS^2(1,1,0)$, compulsory period-1 access reduces consumer surplus if and only if $\pi_P^2(1,1,1) < F_P \leq \pi_P^2(0,1,1)$.*

This result is robust to introducing $\beta > 0$ as long as β this is not too large. The condition on consumer surplus says that consumer surplus under monopoly over both periods is less than consumer surplus under symmetric competition in period 2 only. We illustrate that this condition can hold by taking a look at Example 2.

Example 2 continued *In the example, the condition $\pi_P^2(1,1,1) < F_P \leq \pi_P^2(0,1,1)$ is $(\tau-\gamma/3)^2/(2\tau) < F_P \leq \tau/2$. Under this condition, when does the prohibition decrease consumer surplus (for F_C sufficiently small such that third-party entry always takes place)? As explained above, we have that $CS^2(0,1,1) = v - (5/4)\tau$ and $CS^1(1) + CS^2(1,1,0) = (1 + M^1)\tau/2$ (noting that $CS^2(1,1,0) = \tau/2$ because the utility increment γ due to data-induced network effects is fully extracted through the subscription pice). Hence, the prohibition reduces consumer surplus if $v > \frac{7+2M^1}{4}\tau$.*

The message from this extension is that there is a possible downside of compulsory period-1 access if the platform's first-party entry is at stake. Here the tradeoff is between early availability of an app and competition between apps at a later point in time. Looking beyond our duopoly model our results suggests that caution is warranted when considering compulsory period-1 access if a platform's cost to enter the app market at a later stage are substantial and if there are no other important competitive constraints on the complementor's pricing in period 2 if the platform does not enter with a first-party app.

5.3 Spillovers from data-induced network effects

In our main model, we assumed that network effects are app-specific. However, the platform may have partial access to the data generated by third-party app in the first period and use it for its own purposes. In this extension we allow for such partial spillovers and explore what this means for the platform's strategy regarding interoperability.

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5.4 Commitment to deny interoperability

In the main model, we assumed that the platform can deny interoperability in period 1 after the third-party app developer has decided whether to enter. Over time, the platform may develop a reputation on how it deals with interoperability requests. In the extreme, it is able to fully commit to its interoperability. In this extension, we analyze how this affects the market outcome.

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6 Discussion and conclusion

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7 References

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