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Device-funded vs Ad-funded Platforms

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Device-funded vs Ad-funded Platforms

by Federico Etro[1]

Abstract

We analyze device-funded and ad-funded platforms with differentiated ecosystems supporting apps provided under monopolistic competition. The incentives of a device-funded platform in investing in app curation, introducing and pricing its own apps and setting commissions on in-app purchases of external apps are largely aligned with those of consumers, while this is not necessarily the case for the ad-funded platform. In particular, consumers gain from a positive commission set by the device-funded platform because this implies a comparatively lower price of the device, and platform's apps are introduced and priced internalizing the impact on consumer welfare, perfectly in models of horizontal differentiation and partially in models of vertical differentiation.

Key words: Platforms, business models, monopolistic competition, horizontal differentiation, vertical differentiation.

JEL Code: L1, L4.

[1] Florence School of Economics and Management, Florence and Charles River Associates, London. I am extremely grateful to Cristina Caffarra who provided the original intuition and motivation for this analysis, and to Fiona Scott-Morton for fundamental insights and comments. I am also indebted with Benno Buehler for important discussions and Paolo Bertoletti, Greg Crawford, Oliver Latham, Samuel Marden, Bob Stillman, Alessandro Tampieri and Helen Weeds for useful comments. I am currently consulting Apple in an ongoing antitrust investigation. However, this work reflects only my own opinions. *Correspondence*: Federico Etro: Florence School of Economics and Management, Via delle Pandette 32, Florence, 50127. Phone: 055-2759603. Email: *federico.etro@unifi.it.*

1 Introduction

Some of the most innovative companies around the world provide digital platforms generating market transactions through apps, sales and ads. While their contribution to create a large surplus for consumers is well recognized, these platforms have been under antitrust scrutuny for allegations relating to their double role as marketplaces and downstream players, as well as for exploitative interactions with third party apps and sellers.[2] A crucial differentiation between them is in terms of business models, with some platforms monetizing through sales of devices (as Apple with its smartphones and tablets), or payments per service use and commissions (as Amazon with its cloud services and marketplace) and others monetizing through ad revenues from search advertising (as Google with its search engine) and display advertising (as Facebook with its social network). This work argues that this differentiation of business models is crucial for the mentioned antitrust concerns.[3]

The main motivation of this work is the comparison of the device-funded platform built by Apple for the iPhone and the ad-funded platform built by Google for Android devices. Both these platforms host a variety of apps on their app stores (respectively the App Store and Google Play), but have evolved in opposite directions, with Apple developing a more quality-oriented integrated platform which establishes more requirements toward app developers, for instance in terms of standards on privacy protection, and Google developing an open source OS available to manufacturers with a free app store running an unmatched number of apps.[4] While Apple monetizes its platform mainly through the sale of devices, it has started collecting additional revenues from other sources, trying also to introduce cheaper devices to expand sales toward less demanding customers. Instead, Google mainly monetizes through ad revenues generated by its search engine aggregator and by traffic originated on other apps. Both platforms have been introducing their own apps, often competing with incumbent apps by external app developers, and both platforms have been collecting commissions on in-app purchases of digital services provided by external apps (at rates of 30% on revenues reduced to 15% for subscription payments after a year). The combination of these strategies has raised antitrust concern because the platforms act at the same time as marketplaces for app developers and players with their own apps, and they enforce a commission on rivals that they do not pay. Google has been at the center of various antitrust cases focused on its treatment of rival apps on the Android platform and more generally on self-preferencing for its search engine. Apple is currently under investigation in the EU to assess whether the restrictions aimed at raising the commission on in-app purchases violate competition rules (with particular reference to apps for

[2] The debate culminated in the Hearing of the CEOs of Google, Amazon, Facebook and Apple in front of the U.S. Congress on July 29, 2020.

[3] See also Caffarra (2019) and Scott Morton (2019) for related policy discussions.

[4] After the Android case in the EU, Google announced a fee for the Google app suite on devices shipped to the EU, but this would only apply to manufacturers that do not install Chrome and Google Search. The suite is free in the rest of the world. For a related discussion of that case see Etro and Caffarra (2017) and Choi and Jeon (2021).

music and e-books that are also provided by Apple's own apps). In August 2020, the leading videogame developer Epic Games was banned by the app stores of Google and Apple after bypassing their payment systems, starting a legal battle against the commissions that is likely to extend to other app developers. Other platforms face similar antitrust and regulation debates.[5] We develop a simple model that sheds light on these issues and, more generally, on the strategies adopted by different platforms and their impact on consumers.

Our benchmark model has heterogeneous consumers purchasing a device with an app store and a variety of apps priced under monopolistic competition *à la* Spence (1976). The device-funded platform sets the price of its integrated device (the iPhone) monetizing on sales and possibly on additional revenues generated on the device, while the ad-funded platform makes freely available its software and app store to competitive producers of devices (the Android devices) and monetizes only through additional revenues, primarily from ads. The choice of consumers depends on the expected values of the app stores, which is a function of the number of apps (as in two-sided markets *à la* Rochet and Tirole, 2003, and Armstrong, 2006) as well as of their varieties and prices. We consider both horizontal differentiation, where consumers differ in the relative preference for the two platforms, and vertical differentiation, where consumers with high valuation of app store's quality prefer the high quality device-funded platform sold at a higher price (Gabszewicz and Wauthy, 2014). In this simple environment, the ad-funded platform pockets all the additional revenues generated on its devices, while the device-funded platform tends to redistribute part of them to consumers through lower prices of its devices aimed at expanding sales.[6] This basic difference between business models is at the heart of our extensions endogenizing the sources of revenues of the platforms.

Our first result captures the basic difference between device-funded and ad-funded plaftforms as those of iPhones and Android devices. Platform owners invest in app curation, for instance enhancing privacy protection, restricting collection and use of data, and setting high quality standards for the apps, which creates gains for consumers but sacrifices revenues generated from ads, data trade and payments from app developers. We show that a device-funded platform tends to make efficient choices on app curation because it shares the generated surplus with consumers through the price of devices, while the ad-funded platform tends to underprovide app curation because it does not properly internalize the benefits of consumers. This reflects the opposite strategies of Apple and Google toward privacy protection and quality standards for app

[5] The ongoing EU investigation on Amazon is largely about whether the marketplace should be allowed to sell on its platform using sellers' data (see Hagiu *et al.*, 2020, and Etro, 2020, for a recent assessment). Facebook has been also investigated for the way it collects and monetizes users' data to foster its own advertising.

[6] Ad-funded platforms whose ads create nuisance to consumers (as TV platforms) can increase consumers'utility by lowering the number of ads, which generates a similar, albeit limited, mechanism as the one based on lowering the price of device (as in Gabszewicz *et al.*, 2004, and Casadesus-Masanell and Zhu, 2010). We abstract from this to emphasize the main differences between business models, and because digital platforms are perceived as making strategic commitments on advertising intensity rather than changing it as frequently as prices.

developers.

Our next result concerns the direct provision of apps. Both platforms have incentives to introduce apps at lower prices than external providers, but in the case of the device-funded platform the purpose is to monetize through higher prices and sales of devices and in the case of the ad-funded platform to expand sales and ad revenues. Moreover, in the horizontal differentiation model the interest of the device-funded platform and consumers in both selecting and pricing the apps are aligned, while in the vertical differentiation model a misalignment emerges because the platform has an incentive to price discriminate on its customers due to their higher preference for app services.

Finally, we consider a uniform commission rate on in-app purchases, which has an impact on app prices (and possibly on their selection). We show that consumers benefit always from a positive commission of the device-funded platform because its revenues are in part shifted back through a lower price of the device. Under horizontal differentiation the profit-maximizing commission is actually the optimal one for consumers because it maximizes the joint surplus generated on the platform and split through the price of the device. Under vertical differentiation, instead, the device-funded platform selects an excessive commission to discriminate on its high demand customers. On the other side, consumers are made worse off by the commission of the ad-funded platform, whose profit-maximizing level is decreasing in its ad revenues and in the commission of the rival platform. This can explain why, in a Nash equilibrium, the commission rates set by the platforms can be similar in spite of different business models.

These insights can shed light on the ongoing debate on the commissions on in-app purchases by Apple and other digital platforms. First, notice that we depart from a benchmark case with competitive apps where the *One Monopoly Profit* (OMP) theorem would hold and a device-funded platform would not gain from either introducing its own apps (foreclosing more efficient rival apps) or setting a positive commission. Due to the market power of app providers the OMP theorem fails and the platform has an incentive to enter and set a positive commission, but taking in consideration the impact on the endogenous surplus of consumers. The reason is that there is a fundamental link between the value generated by the app store for consumers and the price of devices, and the platform tends to internalize the impact of its strategies on consumer welfare, perfectly in the horizontal differentiation model, and only imperfectly in the vertical differentiation model.[7] This is not the case for ad-funded platforms, which create large benefits for consumers by providing cheaper devices, but lose the incentive to internalize the interest of consumers on their subsequent strategies.

The analysis is related to the literature on two-sided platforms monetizing

[7] Similar "waterbed effects" are quite common in markets where firms can monetize on multiple sides (see for instance Shapiro, 1994, and Inderst and Valletti, 2011). Of course, these channels do not exclude that device-funded platforms could be engaged in abusive conducts through margin squeeze or predatory pricing, but they suggest only that this cannot be assumed without specific investigations.

on different sides (Caillaud and Jullien, 2003; Anderson and Gabszewicz, 2006; Belleflamme and Toulemonde, 2016; Belleflamme and Peitz, 2019) and on one side only due to zero price commitments (Amelio and Jullien, 2012; Choi and Jeon, 2021). The monopolistic competition framework builds on recent works by Melitz and Ottaviano (2008) and Bertoletti and Etro (2016, 2017, 2018). The analysis of strategic app curation is inspired by models of platform competition in advertising by Gabszewicz *et al.* (2004) and strategic choice of business models by Casadesus-Masanell and Zhu (2010). Related models of pricing on trade platforms are in Anderson and Bedre-Defolie (2020) and Etro (2020) focusing on marketplaces monetizing on both their own sales and commissions on third party sales. The main insights on the difference from an ad-funded business model and its antitrust implications have been pointed out by Caffarra (2019).

The rest of the work is organized as follows. Section 2 presents the general model. Section 3 endogenizes app curation. Section 4 explores the introduction of new apps by the platforms. Sections 5 investigates the role of commissions. Section 6 concludes. The Appendix present more technical extensions including the joint analysis of entry and commissions by a device-funded platform.

2 The model

We consider two platforms built on a device (hardware with essential functionalities) and an app store hosting services provided by independent apps. Devices are produced at the marginal cost h independently from the platform. One platform is mainly monetized through sales of devices produced by the same platform. The other platform is instead mainly monetized through ad revenues generated on devices produced by a competitive sector.[8]

Consumers adopt either the device-funded platform A or the ad-funded platform G. If they purchase a device based on platform $i = A, G$ they pay the price of the device P_i. All devices provide a basic value $u > h$ which is augmented by the value of the app store and its apps. Platform i provides a set of apps Ω_i and consumers purchase their services (subscriptions or in-app purchases) at prices p_{ji} for any $j \in \Omega_i$, obtaining the following additive surplus function:[9]

$$V_i(\mathbf{p}_i) = \sum_{j \in \Omega_i} v_{ji}(p_{ji}) \tag{1}$$

where each $v_{ji}(p)$ function is decreasing and convex in the price, generating a well-behaved demand of the app. The surplus functions and the sets of apps are taken as given (but see the Appendix A for the extension to endogenous entry

[8] The business models are taken as given here, assuming that the ad-funded platform has developed an app store that generates more surplus than alternative ones. In practice, business models can change (as confirmed by startups such as Patreon and Masterclass offering subscription alternatives to previously ad-funded businesses) before stabilizing. For a formalization of the endogenous selection of business models see Casadesus-Masanell and Zhu (2010).

[9] This is an additive indirect utility function. Most of our results extend to non-additive functions generating demand system with a price aggregator where one can isolate the incremental surplus of an app (as in Melitz and Ottaviano, 2008, and Bertoletti and Etro, 2021).

of apps in the presence of fixed entry costs). The preferences over devices and outside goods are quasi-linear and heterogeneous. Each consumer has income E, assumed large enough to allow purchases of the outside goods, and a preference parameter x, assumed uniformly distributed on $[0, 1]$. We will consider two classic models of consumer's heterogeneity and product differentiation with heterogeneous consumers, though hybrids could be considered as well.[10]

Horizontal differentiation In a model of horizontal differentiation (Hotelling, 1929) the indirect utility of consumer x is:

$$U(x) = \max_i (u + V_i(\mathbf{p}_i) - |l_i - x| - P_i) + E \tag{2}$$

where l_i is the position of platform i at an extreme of the unit interval, with $l_G = 0$ and $l_A = 1$, and $|l_i - x|$ is the cost of distance for consumer x from platform i. In this case consumers are differentiated only for their relative preferences of the two platforms, and the valuation of app stores is the same for each consumer and depends on the number of apps (as in Armstrong, 2006), as well as on their varieties and prices. This model reproduces a basic form of product differentiation between platforms where each platform increases its own attractivity when it provides more surplus to its customers. By Roy's identity, the demand of services j on platform i is:

$$q_{ji}(p_{ji}) = \left|v'_{ji}(p_{ji})\right| \tag{3}$$

for any consumer, independently from which platform is adopted.

Vertical differentiation In a model of vertical differentiation (Gabszewicz and Thisse, 1979) we have the following utility:

$$U(x) = \max_i (u + xV_i(\mathbf{p}_i) - P_i) + E \tag{4}$$

where the valuation of the app store depends on the types of consumers, who are therefore differentiated for the relative preference for high quality app stores. This model reproduces situations where consumers give different value to the price-quality ratios of the platforms, and is typical of competition for top quality platforms, where more demanding consumers select the high quality and expensive platform (see Gabszewicz and Wauthy, 2014). By Roy's identity, the demand of services j on platform i is:

$$q_{ji}(p_{ji}) = x\left|v'_{ji}(p_{ji})\right| \tag{5}$$

for a consumer of type x. Accordingly, agents who care more about the quality of apps purchase also more of their services in this model (or, with a slight

[10] Our baseline assumption is that consumers are rational and understand that their utility derives from both the device and the apps. This captures the ability of consumers to appreciate the general quality and the lifetime cost of an ecosystem (as in case of aftermarkets, with the crucial difference that devices are frequently changed).

reinterpretation of the heterogeneity parameter x, have a higher probability of purchasing each service).[11]

Timing The common timing of the baseline model is the following:

1) Platform A and competitive manufacturers for platform G set the prices of the devices P_i;

2) External app developers of each platform set the prices of their apps p_{ji} under monopolistic competition;[12]

3) Consumers purchase a device and the services from the apps available on their device.

2.1 Prices on the platforms

Consumers decide which device to purchase knowing all the prices. In both models of horizontal and vertical differentiation there is a cut-off agent $\hat{x}(P_A - P_G, \Delta(\mathbf{p}))$ who is indifferent between platforms, where $\Delta(\mathbf{p}) \equiv V_A(\mathbf{p}_A) - V_G(\mathbf{p}_G)$ is defined as the differential surplus between the app stores in function of the vector $\mathbf{p}$ of all app prices. This cut-off determines the fraction of agents purchasing the ad-funded platform, which will be defined here as its market share. In the horizontal differentiation model the cut-off can be derived as $\hat{x} = (1 + P_A - P_G - \Delta)/2$ and in the vertical differentiation model as $\hat{x} = (P_A - P_G)/\Delta$ as long as they are in the unit interval.

Each active app j bears a marginal cost c_j. The gross profits of an app j on the two platforms are:

$$\Pi_{jA} = \int_{\hat{x}}^{1} (p - c_j) q_{jA}(p) dx \quad \text{and} \quad \Pi_{jG} = \int_{0}^{\hat{x}} (p - c_j) q_{jG}(p) dx \tag{6}$$

with demand given by either (3) or (5) depending on the model. Monopolistic competition implies that each app sets its price taking as given the set of consumers and neglecting its impact on the choice of devices and therefore on the price aggregator Δ and on $\hat{x}$. Therefore, all apps are priced according to a rule $p_{ji} = p_{ji}(c_j)$ which maximizes the "unitary" profits $\pi_{ji}(p) = \left|v'_{ji}(p)\right| (p - c_j)$ and satisfies the standard condition:

$$p_{ji} = \frac{c_j \varepsilon_{ji}(p_{ji})}{\varepsilon_{ji}(p_{ji}) - 1} \tag{7}$$

where $\varepsilon_{ji}(p) \equiv -v''_{ji}(p)p/v'_{ji}(p)$ is the demand elasticity assumed higher than unitary in equilibrium. It can be verified that the elasticity of price with respect

[11] Applications include TV platforms: consumers who care more about the quality of content tend to adopt the high quality platform (as PayTV platforms by Sky or Netflix). See the classic work by Spence and Owen (1977) on monopolistic competition on these platforms and the more recent ones by Crawford (2016) and Weeds (2016).

[12] Each app developer considers as negligible the impact of its price choice on the demand of devices of the platform (as in standard models of monopolistic competition *à la* Spence, 1976), even if the aggregate impact of the price choices of the app developers is *not* negligible. This is a natural assumption since the number of apps on App Store and Google Play is by now in the order of millions.

to cost $\eta_{ji} = p'_{ji}(c)c/p_{ji}(c)$ is positive and smaller than unitary if and only if $\varepsilon'_{ji}(p) \geqslant 0$, which implies incomplete pass-through (with important consequences for our future analysis of commissions on apps).[13] This price rule is the same in both models of horizontal and vertical differentiation and independent from the price of other apps and of the same device. This highlights a Cournot complementarity problem which is pervasive on the platforms: the prices of the apps are too high because they are set without internalizing the impact on the profits of the platform owner (as the price of the device-funded platform is set without internalizing the impact on the profits of the app developers), which inefficiently reduces the total profits of platform and app developers, as well as the endogenous total surplus. Notice that the market power of app developers breaks the conditions for the OMP theorem to hold for the device-funded platform, which will drive its incentives to enter with its apps and set a commission on rival apps.

Given the set of apps and the prices on each platform we can compute the surplus obtained by consumers on each platform and the differential surplus:

$$\Delta = \sum_{j \in \Omega_A} v_{jA}(p_{jA}(c_j)) - \sum_{j \in \Omega_G} v_{jG}(p_{jG}(c_j)) \tag{8}$$

The device-funded platform bears the marginal cost of production of hardware h obtaining profits:

$$\Pi_A = [1 - \hat{x}(P_A - P_G, \Delta)]\,(P_A - h + R_A) \tag{9}$$

where $P_A - h$ is the markup on sales and $R_A > 0$ represents the additional revenues per device. These revenues may derive from advertising choices, profits of own apps or commissions from app developers, and we will endogenize all these alternatives sources of revenues in later sections. However, in this section we consider these revenues per device as exogenous, for instance due to exogenous ad revenues or to sales of additional products and devices (as the iPods or the Apple Watch for Apple).

The ad-funded platform has profits:

$$\Pi_G = \hat{x}(P_A - P_G, \Delta)R_G \tag{10}$$

where $R_G > 0$ represent its revenues per device. Also in this case various sources of revenues will be considered in later sections, including endogenous advertising, profits from apps and commission revenues, but in this section we consider an exogenous flow of advertising revenues per device. In our main application this is clearly associated with the market power of Google on search

[13] The example of isoelastic demand functions is generated by power functions as $v(p) = p^{1-\varepsilon}$ with $\varepsilon > 1$, and implies full pass-through of cost changes. Translated power functions as $v(p) = (a-p)^{1+\gamma}/(1+\gamma)$ with a, $\gamma \geq 0$, generate incomplete pass-through (with limit cases of a perfectly rigid demand for $\gamma \to 0$, a linear demand for $\gamma = 1$ and a perfectly elastic demand for $\gamma \to \infty$).

advertising.[14]

Our assumptions are aimed at capturing the impact of different business models for platforms with market power respectively on high quality devices and search advertising.[15] Both platforms could invest in the quality of the platform and decide how much revenues to collect through ads and collection of consumers' data creating advertising nuisance and losses of privacy for consumers: since competition in this strategic dimension takes place at the foundation of the respective business models, we will consider it separetely in Section 3.[16] We will then consider revenues from platform apps in Section 4 and from commissions on external apps in Section 5.

The price of the devices for the ad-funded platform is set at the marginal cost by competitive manufacturers, namely $P_G = h$, but our subsequent discussion will show that assuming some form of imperfect competition would not affect the substance. Instead the device-funded platform selects the price P_A to maximize its profits. We now solve both models for the equilibrium price, profits and utility of consumers. The latter includes a basic utility $\bar{U} = u - h + E$ and an additional surplus depending on prices of devices and apps.

2.2 Equilibrium under horizontal differentiation

Under horizontal differentiation the price of the device of platform A is set to maximize (9) with $\hat{x} = (1 + P_A - h - \Delta)/2$, which implies:

$$P_A = h + \frac{1 + \Delta - R_A}{2} \tag{11}$$

This generates an equilibrium market share $\hat{x} = (3 - \Delta - R_A)/4$ for the ad-funded platform, which is in the unit interval if $\Delta + R_A \in (-1, 3)$.[17] Assuming that this is the case the respective profits are:

$$\Pi_A = \frac{(1 + \Delta + R_A)^2}{8} \quad \text{and} \quad \Pi_G = \frac{(3 - \Delta - R_A)\, R_G}{4} \tag{12}$$

[14] The commitment not to monetize the app store on Android devices could be rationalized as a consequence of the market power on advertisers: if the ad-funded platform could ask a non-negative price per device to manufacturers which is fully shifted on P_G, the Bertrand equilibrium between platforms would deliver a corner solution with a free app store when R_G is large enough. We could also model ad revenues per device as increasing in the market share of the ad funded platform due to the improvement of search algorithms and targeted advertising with the scale of activity, but this would not change the main results.

[15] In practice, Apple monetizes ads generated on its devices through an exclusivity contract with Google, and Google commercializes its in-house Pixel handset, however, taking into account these factors cannot overturn our main insights as long as most of the profits derive from sales of iPhones for Apple and ads generated on Android devices for Google.

[16] In case of simultaneous choices of the price of the device for platform A and the number of ads creating nuisance to consumers for platform G, both platforms would have tools to redistribute additional revenues to consumers, which would reduce differences between business models. This maybe relevant for TV platforms, but less for other digital platforms, whose strategic choices on advertising and investment in quality in general are typically taken at a preliminary stage.

[17] Notice that this allows for either $\Delta > 0$ or $\Delta < 0$, though the markup of the device-funded platform is positive only for Δ large enough.

The equilibrium profits of each platform increase in the surplus generated by its app store compared to the rival one, and in its additional revenues per device.[18]

The gross profits of the apps (6) in equilibrium become:

$$\Pi_{jA}(\Delta) = \frac{(1+\Delta+R_A)\pi_{jA}}{4} \quad \text{and} \quad \Pi_{jG}(\Delta) = \frac{(3-\Delta-R_A)\pi_{jG}}{4} \tag{13}$$

with the former increasing and the latter decreasing in $\Delta + R_A$: higher revenues for the device-funded platform increase the profits of its app developers.

In equilibrium, users of platform A gain from an increase of its quality V_A because this is associated with a less than proportional increase of the price. They also gain from an increase of the quality of rival devices V_G, because this leads to reduce the price of their devices. Finally, they gain when revenues from other sources R_A increase because this induces the device-funded platform to reduce the price of its devices, so that part of those revenues are shifted back to consumers. Instead, users of platform G gain from an increase of the quality of their devices V_G but not of the revenues of the ad-funded platform R_G. Using the equilibrium market shares we can compute for future reference the expected utility of all consumers as:

$$\mathbb{E}[U] = \bar{U} + V_G + \frac{(1+\Delta+R_A)^2 - 8}{16} \tag{14}$$

Consumers' welfare increases in $\Delta + R_A$, just like the profits of the device-funded platform in (12): this will be at the basis of the alignment of the interests of each consumer and the device-funded platform.[19]

2.3 Equilibrium under vertical differentiation

Under vertical differentiation the price of the device A is set to maximize profits (9) with $\hat{x} = (P_A - h)/\Delta$, which implies:

$$P_A = h + \frac{\Delta - R_A}{2} \tag{15}$$

This generates a market share $\hat{x} = (\Delta - R_A)/2\Delta$ for the ad-funded platform. This and the markup are positive under the condition $\Delta > R_A$. Assuming that this is the case requires that the device-funded platform is the high quality one. Moreover, it implies that the market share of the ad-funded platform $\hat{x}$ is decreasing in the quality of its app store (increasing in Δ) as long as there are

[18] Notice that the marginal profitability of improving the app store for a platform ($|\partial\Pi_i/\partial\Delta|$) depends on the business model: for the device-funded platform it depends on the consumer benefits because they determine the gains in sales and margins that are made possible, while the marginal profitability for the ad-funded platform depends uniquely on its ad revenues per device. For this reason, the platform with largest marginal profitability would tend to invest more in the quality of its app store.

[19] The alignment does not hold for the ad-funded platform due to its business model. Similar results apply in a different context analyzed by Buehler (2015).

additional revenues R_A for the device-funded platform.[20] The reason for this surprising effect is that a smaller differential surplus between platforms enhances their substitutability and induces the device-funded platform to reduce its price, which reduces the sales of the fixed-price devices of the ad-funded platform. As a consequence, the profits of the platforms become:

$$\Pi_A = \frac{(\Delta + R_A)^2}{4\Delta} \quad \text{and} \quad \Pi_G = \frac{(\Delta - R_A)\, R_G}{2\Delta} \tag{16}$$

The device-funded platform gains from a more valuable app store, while the ad-funded platform does not, because a more valuable app store strengthens price competition without having a price to adjust (and for the same reason the device-funded platform has higher incentives to invest more in the quality of its app store).[21]

The gross profits of the apps (6), after integrating, can be computed as:

$$\Pi_{jA}(\Delta) = \frac{(3\Delta^2 - R_A^2 + 2\Delta R_A)\pi_{jA}}{8\Delta^2} \quad \text{and} \quad \Pi_{jG}(\Delta) = \frac{(\Delta - R_A)^2\, \pi_{jG}}{8\Delta^2} \tag{17}$$

where the former is decreasing and the latter increasing in Δ/R_A: in particular, the impact of new revenues for the device-funded platform is always positive for sales and profits of its app developers.

Users of platform A with a high preference for quality (high x) gain from a larger Δ, but all the others lose due to an increase of the price of the device that is not compensated enough by better quality. Nevertheless, using the equilibrium prices we can compute the expected utility of all consumers as:

$$\mathbb{E}[U] = \bar{U} + \frac{V_G}{2} + \frac{(\Delta + R_A)^2}{8\Delta} \tag{18}$$

which is increasing in Δ. It is also an increasing function of $(\Delta+R_A)^2/\Delta$ exactly as the profits of the device-funded platform in (16): in this case, the alignment of interests concerns the average consumer and the device-funded platform.

2.4 Discussion

The minimalistic framework developed in this section suggests that an increase in the additional revenues of the device-funded platform reduces the price of its

[20] When $R_A = 0$ the market shares are independent from surplus differential. Such neutrality relies on the competitive provision of ad-funded platforms but extends to a general distribution of types $G(x)$, in which case the price becomes $P_A = h + \hat{x}\Delta$, where $\hat{x}$ satisfies $\hat{x} = \frac{1-G(\hat{x})}{G'(\hat{x})}$ and depends on the hazard rate of the distribution. Conditions for the existence of equilibria of vertical differentiation with general distributions have been analyzed by Benassi *et al.* (2019).

[21] Introducing an outside option of fixed value $\bar{u}$ available at marginal cost h, the comparison with (4) implies that consumers with $x < \bar{x} \equiv \bar{u}/V_G$ select this option. Then, the fraction of consumers of the ad-funded platform becomes:

$$\hat{x} - \bar{x} = \frac{1}{2} - \frac{R_A}{2(V_A - V_G)} - \frac{\bar{u}}{V_G}$$

which is now maximized when the surplus from its app store is $V_G = V_A/(1 + \sqrt{R_A/\bar{u}})$, that is a fraction of the surplus of the rival app store.

devices with benefits for consumers and its app developers, while this is not the case for the revenues of the ad-funded platform. The pass-through of revenues into device prices is 1/2 in this model with platform A setting prices and a linear demand. Introducing Bertrand competition with a manufacturer of devices for platform G would increase the pass-through to 2/3 due to strategic complementarities in prices, and departing from a uniform distribution of types would change the shape of demand affecting further the pass-through, but without qualitatively changing the results. These apply for a given set of apps on each platform determing the differential surplus Δ, but in the Appendix A we extend the model to endogenous entry of apps facing fixed entry costs on each platform, so that in equilibrium both sets Ω_i include all the apps whose profits $\Pi_{ji}(\Delta)$, from (13) or (17), cover the fixed costs, and the surplus differential satisfies (8) for these sets. In this environment, an increase of the additional revenues of the device-funded platform exerts an additional effect by increasing also the equilibrium surplus differential Δ between platforms, with further feedback on the price of devices.

Our results resonate well with the recent trend of increasing revenues generated on the Apple platform from its app store and with the introduction of new cheaper devices as the iPhone XR or the new iPhone SE along with devices of higher price and quality. The rationale appears to be expanding sales of devices with a sacrifice of margins to obtain additional revenues from collateral business activities. In the next sections we will endogenize various sources of revenues to investigate the different incentives emerging under the two business models.

3 App curation

Building a digital platform involves preliminary strategic choices on how to organize the app store, how to select apps, which restrictions must be imposed on the app developers and what are the quality standards for their services. All this goes under the label of "app curation", and is vital for the generation of both consumers' benefits and platform's revenues from the app store. For instance, by setting higher standards for privacy protection of personal (and payment) data, a platform provides services of higher perceived quality for consumers, who typically value their privacy, but at the same time reduces the ad revenues that can be generated on the device due to less efficient behavioral advertising.[22] By setting restrictive conditions on the collection of consumers' data, the platform can attract more customers but gives up to revenues from data brokering. By limiting the number of ads per device a platform reduces advertising nuisance attricting more customers, but loses ad revenues per device.[23] Finally, by requiring app developers to make investments to insure appropriate interoperability and security (protection from malware), the platform provides a better ecosystem for its consumers, but limits the number of apps that qualify for the

[22] For related analyses of privacy protection in online markets see Norman *et al.* (2016) and Montes *et al.* (2019).

[23] See Gabszewicz *et al.* (2004) and Casadesus-Masanell and Zhu (2010).

app store or can cover entry costs, which reduces revenues from commissions on in-app purchases and other potential sources. Our question is how platforms deal with these trade-offs and what are the implications for consumers.

To augment our model with app curation in the simplest way, we introduce its utility gains assuming that the app store $i = A, G$ provides the effective surplus $V_i + B_i(R_i)$, where the additional benefits from app curation $B_i(R_i)$ are a function, *inter alia*, of the revenues per device of the platform $R_i \in [0, \bar{R}_i]$, which can be governed for instance through the frequency of ads or the rate of collection of users' data, with an upper bound $\bar{R}_i$. We assume non-monotonic benefits, with $B_i'(R) \gtrless 0$ for $R \lesseqgtr R_i^*$ and $B_i''(R) < 0$, where $R_i^* > 0$ defines the revenues and the level of app curation that maximize the surplus from the app store i. Given this, we consider a preliminary stage where the two platforms decide simultaneously on the quality of app curation, setting R_A and R_G, and the rest of the pricing game is as before.

The Nash equilibrium, analyzed in the Appendix B, implies that the device-funded platform selects either the optimal app curation from the point of view of consumer welfare (in the horizontal differentiation model) or even more than that (in the vertical differentiation model), while the ad-funded platform always underprovides app curation. Possibly more important, the following result establishes the welfare impact of changes in each strategy:

PROPOSITION 1. *In a Nash equilibrium for the choice of app curation, consumer welfare cannot be increased by changes in the app curation of the device-funded platform but is increased by more app curation of the ad-funded platform.*

In practice, the device-funded platform equates the marginal benefits of app curation to the marginal cost of lost revenues exactly as consumers do: the reason is that the same benefits and costs are shared between platform and consumers through the endogenous pricing of the device. The ad-funded platform, instead, internalizes all the costs of app curation but only part of the benefits, and therefore underinvests. Strategic interactions explain why both equilibrium strategies can deviate from the optimal ones, but the choice of the device-funded platform is efficient conditional to the choice of the rival.

Our results resonate well with the stricter requirements adopted by Apple for its app store, where app developers must insure not ony interoperability and app security, but also high privacy protection, giving up to revenues from data collection in the interest of consumers' privacy. Instead Google sets lower standards on privacy protection for Android devices, and indeed promotes and monetizes data collection on its platform, effectively charging its customers through the cost of a suboptimal privacy protection.

Two remarks are in order. First, we can use this framework to evaluate the impact of the revenue sharing agreement between Google and Apple for the promotion of Google Search as its default search engine: this would not affect the incentives of Apple, but would reduce further the incentives of Google to sacrifice revenues and invest in app curation, confirming the spirit of our conclusions above. Second, assuming fixed rather than variable costs would generate suboptimal choices for both platforms, but preserve the tendency for the device-funded platform to invest more in app curation.

A similar logic applies to other environments. Cloud platforms such as Microsoft's Azure or Amazon Web Services charge enterprise users for services insuring high levels of data security. Instead, an ad-funded social network as Facebook has lower standards on privacy protection to foster data collection and overprovides ads: this tendency is strengthened by its market power, and would be limited in a more competitive environment.

4 Introduction of platform apps

In this section we consider the incentives for each platform to introduce a newly developed app exclusively for its own ecosystem. Since this is an extraordinary event where a platform internalizes the impact of the app on its overall profits, we focus separately on each platform.[24] We modify the game assuming that in the first stage a platform sets the price of the new app simultaneously with the prices of the devices, in the second stage all the external developers set prices under monopolistic competition, and in the third stage consumers purchase their favorite device. Our interest is on which prices are adopted by the platforms and which services are more likely to be introduced (see the Appendix C for an extension taking into account direct competition between platform apps and external apps providing imperfectly substitutable services).

4.1 Apps by the device-funded platform

Let us consider new apps developed by a device-funded platform for exclusive use on its devices.[25] We start from the horizontal differentiation model and then verify how its insights change with vertical differentiation. For simplicity we abstract from other revenues setting $R_A = 0$.

Horizontal differentiation Platform A considers whether to introduce its app j and at which price $\bar{p}$. Upon entry, its profits are amended as:

$$\Pi_A = (1 - \hat{x})[P_A - h + \pi_{jA}(\bar{p})] \quad \text{with } \hat{x} = \frac{1 + P_A - P_G - \Delta - v_{jA}(\bar{p})}{2}$$

where $v_{jA}(\bar{p})$ and $\pi_{jA}(\bar{p}) = \left|v'_{ji}(\bar{p})\right| (\bar{p} - c_j)$ are the incremental surplus and the incremental profits per device when the new app is introduced at price $\bar{p}$. Solving the maximization problem with respect to P_A and $\bar{p}$ with $P_G = h$ provides:

$$P_A = h + \frac{1 + \Delta + v_{jA}(c_j)}{2} \quad \text{and} \quad \bar{p}_{jA} = c_j \tag{19}$$

[24] In a game of simultaneous introduction of apps creating the same surplus, it is easy to verify that in our framework introducing the app would be the dominant strategy for both platforms.

[25] This analysis applies for instance to Apple Book which is only available on Apple's devices. We focus on apps with positive marginal costs of provision, with the understanding that under zero or low marginal costs, free provision can be optimal for both platforms.

The app is priced at marginal cost to maximize the total surplus generated and the price of the device is increased by half of the incremental surplus expanding sales of the upgraded devices. This has a variety of implications. First, app provision is monetized through sales of devices. Second, entry would not be profitable for the platform if the same app was already supplied by competitive providers at marginal cost (in which case the OMP theorem would set in), but it would be profitable if it was supplied by providers with market power, and in such a case entry would increase consumer welfare. Third, entry benefits the other independent app developers because they keep earning the same profits per device on an increased number of customers. The extreme result of marginal cost pricing holds also under imperfect substitutability between the app of the platform and an external app providing the same service (Appendix C), but a positive markup for the platform app would emerge when price discrimination is possible (in the vertical differentiation model below) and in the presence of a commission on external apps (Appendix C).

A last implication of this analysis concerns which apps should be introduced by the platfom. The expected profits of the platform from adding app j are:

$$\Pi_A = \frac{(1 + \Delta + v_{jA}(c_j))^2}{8}$$

so one can order apps in terms of profitability such that $v_{1A}(c_1) \geq v_{2A}(c_2) \geq$ ... The ranking of the device-funded platform is the same as the ranking of consumers, with apps generating the largest surplus (at marginal cost) having priority.[26] Nevertheless, if there are fixed costs of production F_j for app j, the platform would only introduce the most valuable apps for consumers, as long as the incremental profits cover the fixed costs:

$$\frac{(1 + \Delta + v_{jA}(c_j))^2}{8} - \frac{(1 + \Delta)^2}{8} \geqslant F_j \tag{20}$$

which is more easily satisfied when Δ is large because a larger market share allows to monetize the app on more consumers. As we will see, this logic does not apply to the ad-funded platform, whose incentives depend on direct profitability of the app and on the contribution to increase search traffic, which generates a bias compared to the ranking of consumers.[27] This suggests that a device-funded platform can correct market distortions on the app store and provide valuable services that are not profitably provided by external developers.[28]

[26] This resonates well with empirical findings by Rietveld *et al.* (2019) on video game platforms, showing that platforms give priority and support to complementary apps that increase the value of their ecosystem.

[27] Spence (1976) has been the first to point out divergence between equilibrium and optimal product selection. See also Bertoletti and Etro (2018) for further related discussion.

[28] In the case of the iPhone, new generation devices have been provided at increasing prices with new or improved functionalities (as for touch screen, camera, Siri) and free apps (Safari, Face Time, Wallet or iCloud). According to Wen and Zhu (2019) between 2007 and 2015 Apple introduced more than thirty apps or features in competition with third party apps and was followed by Android in 80% of the cases.

Vertical differentiation In the vertical differentiation model the profits of the device-funded platform must take into account that its customers have different demands of the in-app services and, on average, higher demands compared to the customers of the ad-funded platform. Total profits can be computed as follows:

$$\begin{aligned}\Pi_A &= (1-\hat{x})(P_A - h) + \int_{\hat{x}}^{1} x\pi_{jA}(\bar{p})dx \\ &= (1-\hat{x})(P_A - h) + \frac{(1-\hat{x}^2)\pi_{jA}(\bar{p})}{2} \quad \text{with } \hat{x} = \frac{P_A - P_G}{\Delta + v_{jA}(\bar{p})}\end{aligned}$$

Maximization with respect to P_A and $\bar{p}$ with $P_G = h$ provides:

$$P_A = h + \frac{\Delta + v_{jA}(\bar{p}_{jA})}{2 + \alpha_j(\bar{p}_{jA})} \quad \text{and} \quad \bar{p}_{jA} = \frac{c_j}{1 - \frac{1+\alpha_j(\bar{p}_{jA})}{(3+\alpha_j(\bar{p}_{jA}))\varepsilon_{jA}(\bar{p}_{jA})}}$$

where $\alpha_j(\bar{p}) \equiv \frac{\pi_{jA}(\bar{p})}{\Delta + v_{jA}(\bar{p})}$ and $\varepsilon_{jA}(\bar{p})$ is always the relevant demand elasticity. The price of the device is affected by the new app in two ways: on one side, there is a tendency to reduce it with the purpose of attracting new customers, but taking into account that newly attracted customers spend less and therefore generate lower incremental profits, and on the other side, there is a tendency to increase the price due to the additional surplus which can be extracted from consumers. The net impact is ambiguous, but the market share of the device-funded platform is unambiguously increased in equilibrium from the introduction of a new app if this is priced above marginal cost (again with benefits for the other apps). The price of the app is again lower compared to the price adopted by an external app developer (7) because the platform internalizes the impact on consumer surplus. However, the price is now above marginal cost: the reason is that the average user of the device-funded platform has a higher and more rigid demand than the marginal user, and this difference can be monetized setting a positive markup. Such a choice is not perfectly aligned with the one that would maximize average consumer welfare (subject to the equilibrium price of the device). In particular, the expected utility of all consumers can be computed as:

$$\mathbb{E}[U] = \bar{U} + \frac{V_G}{2} + \frac{\Delta + v_{jA}(\bar{p})}{2}\left[\frac{\Delta + v_{jA}(\bar{p}) + \pi_{jA}(\bar{p})}{2(\Delta + v_{jA}(\bar{p})) + \pi_{jA}(\bar{p})}\right]^2$$

which is still maximized by marginal cost pricing.[29] Nevertheless, also a price above marginal cost insures that the introduction of the new app increases this expected utility ($\mathbb{E}[U]$ increases in both v_{jA} and π_{jA}) because the benefits of the additional surplus more than compensate the potential losses from a higher price of the device.

[29] The FOCs can be rearranged as $\alpha_j(\bar{p})(1+\alpha_j(\bar{p}))v_j'(\bar{p}) = 2v_j''(\bar{p})(\bar{p}-c_j)$, and since $\alpha_j(\bar{p}) \gtrless 0$ for $\bar{p} \gtrless c_j$ the solution is marginal cost pricing.

4.2 Apps by the ad-funded platform

Moving to the introduction of a new app j by platform G, it is natural to allow this to monetize the app either through its price for in-app purchases $\bar{p}_{jG}$ or through additional ad revenues r_G generated on the quantity of new services provided by the app thanks to its market power in online advertising.[30]

Horizontal differentiation In the horizontal differentiation model the introduction of a new app j at price $\bar{p}$ would increase profits to:

$$\Pi_G = \frac{(3 - \Delta + v_{jG}(\bar{p}))\,(R_G + \tilde{\pi}_{jG}(\bar{p}))}{4}$$

augmented for the impact of the additional surplus $v_{jG}(\bar{p})$ on demand and of the additional profits $\tilde{\pi}_{jG}(p) = \left|v'_{jG}(p)\right|(p + r_G - c_j)$ on revenues per device, including in-app advertising. It can be verified that this platform sets the app price to satisfy:

$$\bar{p}_{jG} = \frac{c_j}{1 - \frac{1-\beta_j(\bar{p}_{jG})}{\varepsilon_{jG}(\bar{p}_{jG})}} - r_G \quad \text{with } \beta_j(\bar{p}) \equiv \frac{R_G + \tilde{\pi}_{jG}(\bar{p})}{3 - \Delta + v_{jG}(\bar{p})} \tag{21}$$

where $\varepsilon_{jG}(p)$ is the relevant demand elasticity and additional ad-revenues r_G perfectly crowd out app revenues. Entry is always profitable because the app store is imperfectly monetized by an ad-funded platform (the OMP theorem fails due to zero price constraint as in Choi and Jeon, 2021), and also in this case, the platform has an incentive to set a lower price than the one of external providers (7), but the purpose is to expand sales of devices and apps to foster ad revenues.

Vertical differentiation The vertical differentiation model generates similar results. The ad-funded platform expects profits:

$$\Pi_G = \hat{x}R_G + \int_0^{\hat{x}} x\tilde{\pi}_{jG}(\bar{p})dx = \frac{R_G}{2} + \frac{\tilde{\pi}_{jG}(\bar{p})}{8}$$

since $\hat{x} = 1/2$ under our assumption that $R_A = 0$, and the optimal price can be computed as:

$$\bar{p}_{jG} = \frac{c_j}{1 - \frac{1}{\varepsilon_{jG}(\bar{p}_{jG})}} - r_G \tag{22}$$

where it is only the substitutability between profits and ad revenues from apps that disciplines pricing compared to rule (7) followed by the external app developers.

Summing up, the incentives to introduce apps by an ad-funded platform are based on the ability of the apps to generate profits or search traffic, which may or

[30] We take ad revenues per device and per app as exogenous. In case of endogenous advertising intensity affecting consumer utility, further interactions with the prices of the apps would emerge.

may not be aligned with the interests of consumers (the incremental surplus of a good differs in general from its incremental profit under monopolistic pricing). For instance, YouTube and Google Maps are highly complementary with the search advertising business of Google and also likely to generate high surplus for consumers, but this does not apply to all the apps by ad-funded platforms.

4.3 Implications

While the source of product differentiation leads to somewhat different results on the incentives to introduce and price new apps, we can summarize the main differences between business models as follows:

PROPOSITION 2. *Both a device-funded and an ad-funded platform have an incentive to introduce apps at lower prices than external app providers, because the former internalizes the impact of its choices on consumer welfare and the latter internalizes the impact of app usage on in-app ad revenues.*

Analogous considerations shed light on other markets. For instance, Microsoft monetizes its operating system Windows with a payment for license agreement and bundles a variety of apps for free (as browsers, media players and firewalls): as complement services with zero marginal cost of provision, these apps increase the surplus obtained by final users allowing Microsoft to monetize through a higher price of Windows.

Finally, notice that many platforms have been engaged in acquisitions of firms that offer apps for their ecosystems, as in the prominent cases involving Skype and Linkedin for Microsoft, YouTube for Google or Instagram and WhatsApp for Facebook. In our framework these are clearly mergers of complements, but their implications can be slightly different depending on the business model of the platform. A device-funded platform would tend to purchase apps that provide high surplus to consumers and distribute their services at no charge with the purpose of increasing consumer welfare and extract only part of it through the price of the device (or the proprietary software). Instead, an ad-funded platform would tend to purchase apps that complement its business fostering online traffic and increasing the willingness to pay for ad revenues. Our model suggests that the impact on consumers should be more beneficial in the former case compared to the latter.[31]

5 Commissions on in-app purchases

We now exploit our baseline framework to verify what are the incentives to set a commission on services provided by external apps. We focus on a uniform commission rate which is typically applied by both Apple and Google on in-app purchases made through their app stores, as well as by other app stores (as the

[31] See also Prat and Valletti (2019) for an interesting perspective on the impact of these mergers.

Samsung Galaxy Store), video game digital marketplaces (as PlayStation and Nintendo), digital content platforms and e-Commerce marketplaces, typically in the 15%-30% range. The impact of this commission is at the center of the ongoing dispute between Epic Games and both Apple and Google. For simplicity, here we do not consider competition with the apps of the platform, which is at the core of the EU antitrust cases involving Apple, but in Appendix C we extend the analysis to the case of imperfect substitutability between internal and external apps and a commission set by the device-funded platform. In general, we show that both platforms tend to set a positive commission whose level is limited because on the one hand the device-funded platform internalizes the impact on consumers and on the other hand the ad-funded platform has an interest in fostering sales and ad revenues. However, the incentives of the device-funded platform are largely aligned with those of its customers because the commission revenues are shared through a lower price of the device, while the incentives of the ad-funded platform are not.

We assume that the platforms pre-commit to uniform commissions on app revenues at rates τ_i for all the external apps of platform $i = A, G$. The new timing is the following. In a preliminary stage platforms A and G simultaneously set their commissions τ_A and τ_G. Then the prices of devices are set and finally the price of apps are set. We first describe how the commissions affect the pricing stages and how each platform selects its commission unilaterally, and then we conclude by discussing the nature of the Nash equilibrium for the commission levels.

Under commissions τ_i the "unitary" profits on platform j become $\pi_{ji}(p) = \left|v'_{ji}(p)\right| (p(1-\tau_i) - c_j)$ and the price rules (7) are amended as:

$$p_{ji} = \frac{c_j \varepsilon_{ji}(p_{ji})}{(1-\tau_i)\left[\varepsilon_{ji}(p_{ji}) - 1\right]}$$

so that the price depends on the effective marginal cost $\tilde{c}_j(\tau_i) = c_j/(1-\tau_i)$, and the revenues per unit of demand of platform i are:

$$T_i(\tau_i) = \tau_i \sum_{j \in \Omega_i} \left|v'_{ji}(p_{ji}(\tilde{c}_j(\tau_i)))\right| p_{ji}(\tilde{c}_j(\tau_i))$$

The surplus differential can be expressed as:

$$\Delta(\tau_A, \tau_G) = \sum_{j \in \Omega_A} v_{jA}(p_{jA}(\tilde{c}_j(\tau_A))) - \sum_{j \in \Omega_G} v_{jG}(p_{jG}(\tilde{c}_j(\tau_G)))$$

which is decreasing in τ_A and increasing in τ_G. Both platforms have incentives to use a positive commission due to the market power of app developers and imperfect monetization of the app store (breaking the OMP theorem respectively for the device-funded platform and the ad-funded platform). But, as we will see, both platforms have incentives to set a commission below the revenue maximizing level, with crucial differences depending on the source of platform differentiation.

5.1 Commissions under horizontal differentiation

Under horizontal differentiation, for given commissions, the profits of the two platforms are:

$$\Pi_A = [1 - \hat{x}(\tau_A, \tau_G)][P_A - h + T_A(\tau_A)]$$
$$\text{and} \quad \Pi_G = \hat{x}(\tau_A, \tau_G)[R_G + T_G(\tau_G)] \tag{23}$$

where $\hat{x}(\tau_A, \tau_G) = \frac{1+P_A-h-\Delta(\tau_A,\tau_G)}{2}$ is the equilibrium market share of the ad-funded platform for given commission rates. This implies the profit-maximizing price of the device-funded platform:

$$P_A = h + \frac{1 + \Delta(\tau_A, \tau_G) - T_A(\tau_A)}{2} \tag{24}$$

and the equilibrium profits of platform A:

$$\Pi_A = \frac{(1 + \Delta(\tau_A, \tau_G) + T_A(\tau_A))^2}{8}$$

Accordingly, platform A sets the commission to maximize $\Delta(\tau_A, \tau_G) + T_A(\tau_A)$, which is exactly what a social planner would do to maximize consumer welfare: to verify this compare the expected utility (14) with $R_A = T_A(\tau_A)$. The intuition for the perfect alignment of the interest of the device-funded platform and its customers is that they both agree on the level of commission that maximizes the total value of the platform, being aware that the platform will select the price of the device to extract the maximum profits out of this value. The crucial implication of this model for the Apple case is that consumers would be worse off if Apple was forced to reduce the commission from its profit-maximizing level, because they would expect this reduction to be associated with an increase in the price of the iPhone that goes well beyond the gains in surplus from the apps.[32]

We can proceed noticing that the optimal commission on app revenues for platform A solves the problem:

$$\max \textstyle\sum_j \left[v_{jA}(p_{jA}(\tilde{c}_j(\tau_A))) + \tau_A \left|v'_{jA}(p_{jA}(\tilde{c}_j(\tau_A)))\right| p_{jA}(\tilde{c}_j(\tau_A))\right]$$

The first order condition:

$$\textstyle\sum_j \left\{ \frac{\left[v'_{jA}(p_{jA}) - \tau_A \left(v''_{jA}(p_{jA})p_{jA} + v'_{jA}(p_{jA})\right)\right] p'_{jA}\tilde{c}_j}{1-\tau_A} - v'_{jA}(p_{jA})p_{jA} \right\} = 0$$

[32] This result is reminiscent of what emerges in Buehler (2015). It can be also extended to the case of *myopic consumers* internalizing only a fraction of the future surplus from app stores (as in Gabaix and Laibson, 2006), in which case the device-funded platform sets a higher commission than the one set by a paternalistic planner (which however remains positive for a low enough pass-through). The result can be extended also to repeated purchases of devices with *switching costs* between platforms for a fraction of consumers (as in Klemperer, 1987), which instead does not affect the incentives to set commissions. I am thankful to Benno Buehler for precious suggestions on all these issues.

can be rearranged as:

$$\tau_A^* = \frac{\sum_j s_{jA}\left(1-\eta_{jA}\right)}{\sum_j s_{jA}[1+\eta_{jA}(\varepsilon_{jA}-1)]} \tag{25}$$

where $s_{jA} \equiv \left|v'_{jA}(p_{jA})\right| p_{jA}$ are the sales of app j and η_{jA} its pass-through elasticity. When the pass-through is on average incomplete this commission rate is positive.[33] Moreover, it is smaller than the revenue maximizing commission and independent from the commission of the ad-funded platform. As a back of the envelope computation, in case of fully symmetric apps, a demand elasticity $\varepsilon = 2$ with a pass-through elasticity $\eta = 3/4$ would deliver an optimal commission of almost 15%; lower demand elasticities and pass-through rates would tend to increase the optimal commission rate. We have also considered a total surplus standard finding that the commission that maximizes $\mathbb{E}[U] + \Pi_A + \sum_{j\in\Omega_A} \Pi_{jA}(\Delta)$ is lower, but still positive when the pass-through is low enough. The intuition is that a small commission shifts profits per device from app developers to the platform, but expands sales of devices (through its lower prices), which creates net benefits for all players when the impact of the commission on the prices of the apps is not too large.

The role of the commission on in-app purchases by platform G is radically different. A positive commission by the ad-funded platform harms its customers because they cannot be compensated through changes in the price of devices. It also harms the customers of the rival platform because it increases its quality advantage and therefore the price of its devices. Nevertheless, the ad-funded platform has an interest in setting a positive commission to maximize the profits from the app store taking into account ad revenues. Using (23) and (24), we can compute the profits of platform G in function of its commission as:

$$\Pi_G = \frac{(3-\Delta(\tau_A,\tau_G)-T_A(\tau_A))}{4}(R_G + \tilde{T}_G(\tau_G))$$

where we assume that $\tilde{T}_G(\tau) = T_G(\tau) + r_G \sum_{j\in\Omega_G} \left|v'_{jG}(p_{jG}(\tilde{c}_j(\tau)))\right|$ can also include ad-revenues r_G generated on the external apps and proportional to usage. The profit-maximizing commission rate can be computed after some manipulation of the FOC as:

$$\tau_G^* = \frac{\sum_j s_{jG}\left\{1-\eta_{jG}\left[\beta(\tau_A,\tau_G^*)+r_G\right]\right\}}{\sum_j s_{jG}[1+\eta_{jG}(\varepsilon_{jG}-1)]} \tag{26}$$

where $s_{jG} \equiv \left|v'_{jG}(p_{jG})\right| p_{jG}$ are sales per device, η_{jG} the pass-through elasticity and we defined $\beta(\tau_A,\tau_G) \equiv \frac{R_G+\tilde{T}_G(\tau_G)}{3-\Delta(\tau_A,\tau_G)-T_A(\tau_A)}$ as an index of profitability per device. There are two reasons why the platform sets a commission lower than

[33] When the commission is fully shifted on all prices (as under isoelastic demands or perfectly competitive apps) it is optimal to monetize the platform only through the price of devices (a version of the OMP theorem). As mentioned, the pass-through is incomplete if and only if $\varepsilon'_{ji}(p) > 0$.

the revenue maximizing one. The first is that such a high commission reduces its market share and the total ad revenues. The second is that a high commission reduces purchases of in-app services and the associated revenues from ads generated within apps. Last, notice that the commission is not independent from the one set by the rival platform: since $\beta(\tau_A, \tau_G)$ is maximized by τ_A^* the optimal commission τ_G^* is decreasing (increasing) for $\tau_A < (>) \tau_A^*$.

Having established the unilateral incentives to set commissions, we can comment on the nature of a Nash equilibrium in commissions for the two platforms. As we have seen, the optimal commission of platform A is independent from the one of platform G, while the optimal commission of platform G is minimized in correspondence of the optimal commission of platform A. This implies a unique equilibrium in commissions (τ_A^*, τ_G^*) satisfying (25)-(26). While further results would require a quantitative analysis, the different reasons for the two platforms to set positive but moderate commissions may explain why Apple and Google have converged toward a common system, with a 30% headline fee for new business and 15% for ongoing subscriptions.[34]

5.2 Commissions under vertical differentiation

Our final investigation is on commissions with vertical differentiation. In this case, one must take into account that the demand of services increases in the preference of consumers for quality, and therefore also the revenues from the commission and the profits of the apps change across consumers. More precisely, the profits of the platforms can be computed as:

$$\Pi_A = [1 - \hat{x}(\tau_A, \tau_G)](P_A - h) + \frac{[1 - \hat{x}(\tau_A, \tau_G)^2]T_A(\tau_A)}{2}$$

$$\text{and} \quad \Pi_G = \hat{x}(\tau_A, \tau_G)R_G + \frac{\hat{x}(\tau_A, \tau_G)^2 T_G(\tau_G)}{2} \tag{27}$$

where $\hat{x}(\tau_A, \tau_G) = \frac{P_A - h}{\Delta(\tau_A, \tau_G)}$. This generates the equilibrium price of the device of platform A:

$$P_A = h + \frac{\Delta(\tau_A, \tau_G)}{2 + \alpha(\tau_A, \tau_G)} \quad \text{with } \alpha(\tau_A, \tau_G) \equiv \frac{T_A(\tau_A)}{\Delta(\tau_A, \tau_G)} \tag{28}$$

which is reduced due to commission revenues with the purpose of expanding sales, but taking into account that newly attracted consumers spend less in the apps and therefore generate lower revenues. The equilibrium profits of platform A become:

$$\Pi_A = \frac{[\Delta(\tau_A, \tau_G) + T_A(\tau_A)]^2}{2\,[2\Delta(\tau_A, \tau_G) + T_A(\tau_A)]}$$

Also in this case the profit-maximizing choice of the device-funded platform takes in consideration the impact of the commission on both surplus and revenues, but with a lower weight on the former than the latter. The optimality

[34] With fully symmetric apps on both platforms, $\tau_G^* \gtrless \tau_A^*$ if $\beta + r_G \lessgtr 1$.

condition provides:

$$\tau_A^* = \frac{\sum_j s_{jA}\left(1 - \frac{2\eta_{jA}}{3+\alpha(\tau_A^*,\tau_G)}\right)}{\sum_j s_{jA}[1+\eta_{jA}(\varepsilon_{jA}-1)]} \tag{29}$$

Since $\alpha(\tau_A, \tau_G)$ decreases in τ_G, also τ_A^* decreases when the rival platform sets a higher commission, implying strategic substitutability. In an example with fully symmetric apps, a demand elasticity $\varepsilon = 2$ and a pass-through elasticity $\eta = 3/4$ would deliver an optimal commission above 28%.

Contrary to the earlier model, the commission has a different impact on different consumers. The introduction of a positive commission increases the utility of consumers with a low preference for quality (i.e. with low x) either because they keep purchasing this device but at a lower price and do not purchase much from the apps, or because they switch from the ad-funded platform to the device-funded one exactly because of its lower price. However, consumers with high preference for quality (i.e. with high x) can be harmed by higher prices of the apps generated by the introduction of the commission. To make further progress on the welfare implications, we can compute the expected utility of all consumers as:

$$\mathbb{E}[U] = \bar{U} + \frac{V_G}{2} + \frac{\Delta(\tau_A,\tau_G)}{2}\left[\frac{\Delta(\tau_A,\tau_G)+T_A(\tau_A)}{2\Delta(\tau_A,\tau_G)+T_A(\tau_A)}\right]^2$$

Also from their point of view the optimal commission should not simply maximize $\Delta(\tau_A, \tau_G)$, but take into account also the revenues of the platform $T_A(\tau_A)$, part of which is rebated to consumers through a lower price of the device. Since one can verify that the expected utility is increasing in the commission at $\tau_A = 0$ under incomplete pass-through, the optimal commission from the point of view of consumers must be strictly positive. Accordingly, even in this model there is no basis to argue that a ban on commission should be optimal or even that it should increase consumer welfare.[35]

Finally, also the ad-funded platform has an interest in setting a positive commission, though this is always detrimental to consumer welfare. Using (27) and (28), we can compute the profits of platform G as:

$$\Pi_G = \frac{\Delta(\tau_A,\tau_G)}{2\Delta(\tau_A,\tau_G)+T_A(\tau_A)}\left[R_G + \frac{\Delta(\tau_A,\tau_G)\tilde{T}_G(\tau_G)}{2\left[2\Delta(\tau_A,\tau_G)+T_A(\tau_A)\right]}\right]$$

[35] More precisely, we can compute the optimal commission formula as:

$$\tau_A^o = \frac{\sum_j s_{jA}\left[1-\left(1+\frac{\alpha(1+\alpha)}{2}\right)\eta_{jA}\right]}{\sum_j s_{jA}[1+\eta_{jA}(\varepsilon_{jA}-1)]}$$

which is lower than the equilibrium one (and null only with full pass-through). Considering the expected utility of initial or final customers of the device-funded platform the optimal commission from their point of view would be lower, but still positive. Also in this case we could consider a total surplus standard confirming the optimality of a positive commission if the pass-through rate is small enough.

which is maximized by:

$$\tau_G^* = \frac{\sum_j s_{jG}\left\{1 - \eta_{jG}\left[\delta(\tau_A, \tau_G^*) + r_G\right]\right\}}{\sum_j s_{jG}[1 + \eta_{jG}(\varepsilon_{jG} - 1)]} \tag{30}$$

where $\delta(\tau_A, \tau_G) \equiv \frac{T_A(\tau_A)}{\Delta^2}\left[R_G + \frac{2\Delta \tilde{T}_G}{2\Delta + T_A(\tau_A)}\right]$ is a coefficient proportional to $T_A(\tau_A)$ and decreasing in it. When the device-funded platform does not raise revenues from commissions ($\tau_A = 0$), the ad-funded platform simply sets the revenue maximizing commission, but an increase of τ_A reduces the market share of the ad-funded platform (due to the reduction of the price of devices) and reduces commission of the ad-funded platform τ_G^* implying, again, strategic substitutability in commissions.

The nature of a Nash equilibrium in commissions is more complex. Since we have shown that both response functions for the commission rates are downward sloping, equilibrium uniqueness is not granted. However, assuming a unique interior and stable equilibrium (τ_A^*, τ_G^*) satisfying (29)-(30), strategic substitutability implies that an increase of the ad revenues of the ad-funded platform leads to a reduction of τ_G^* and an increase of τ_A^*. Also this may contribute to explain why Apple and Google have reached the same commissions in spite of business models that internalize differently their impact on consumer welfare.

5.3 Implications

Focusing on common findings across models we can state the following result on the incentives to set commissions and their relation with consumer welfare:

PROPOSITION 3. *Under incomplete pass-through of commission rates on app prices, consumers benefit from a positive commission set by the device-funded platform through lower prices of its devices, while consumers do not benefit from a positive commission by the ad-funded platform.*

In the Appendix C we extend the analysis to the case where the device-funded platform can jointly set a commission on external apps and introduce its own apps competing with external ones under imperfect substitution. The OMP theorem fails whenever some of the competing apps have market power. In this case a device-funded platform has incentives to set a positive markup on its own apps. In the model of horizontal differentiation the optimal price of the platform app ranges between marginal cost in case of independent apps (as in the earlier section) and limit pricing slightly below the cost of the rival (inclusive of the commission) in case of perfectly substitutable apps. The price is lower than the price of the rival app and increasing in the commission because losses from demand diversion are recovered through commission revenues obtained on the demand of the rival. The platform adjusts the commission to account for the substitutability between apps, but the spirit of our main results goes through: the entry decision and the decision on the commission are aligned with the interest of consumers, maximizing the sum of consumer surplus, commission revenues and profits from platform's apps, and sharing them through the choice of the price of the device. Instead, in the model of vertical differentiation, the device-funded platform sets higher markups softening competition with the rival app and possibly a higher commission. Nevertheless, it still internalizes in part the interest of consumers in its entry decisions, which makes it unlikely that a full ban of the commission on in-app purchases can make consumers better off.[36]

While all these results suggest that consumers benefit from moderate commissions on in-app purchases by a device-funded platform, we should remark that alternative monetization schemes may have different welfare properties. Due to monopolistic competition between heterogeneous apps and the constraint of a uniform tool for all app developers, a specific commission on app usage (analyzed in the Appendix C) would be less efficient than the *ad valorem* commission analyzed here, which is consistent with the widespread adoptionof the latter. However, profit-sharing commissions or fixed access fees bargained with app developers would avoid double marginalization and generate higher revenues to be shared with consumers.[37] Their limited adoption is probably due to the lack of verifiable information on app profits and administrative costs of individual bargaining with a large number of app developers.

At last, we should remark that the spirit of these results applies also to other platforms. For instance, online marketplaces are mainly monetized through commissions on sales by third party sellers, and competition with alternative shopping channels limits the commission rates with the purpose of attracting more buyers (and sellers).[38] Amazon has also introduced a subscription based service, Amazon Prime, aimed at customer fidelization. This contributes to align the interests of the platform with those of consumers leading to further reductions in commission rates as well as reductions in prices of products by Amazon (as a private label distributor or first party retailer): not by chance, the expansion of the Prime membership has been accompanied by free delivery services, new promotions and also a gradual increase of the Prime fee.

6 Conclusion

We have studied competition between device-funded and ad-funded platforms emphasizing that different business models can have deep consequences on their strategies. Our claim is not that one of the two business models is conducive

[36] It is important to remark that in the case of rivals of apps by Apple, the commission on in-app purchases can be avoided because customers can directly purchase on the website of the provider and use the app on the device as a *reader app*.

[37] We have also considered a commission on downloads of each app in a model with endogenous entry of a continuum of app providers with marginal costs drawn from a Pareto distribution (as in Bertoletti *et al.*, 2018), which generates a highly skewed distribution of downloads, revenues and profits across apps. Such a commission can be neutral on prices, but induces exit of the least efficient providers reducing surplus through this selection effect (which reduces its optimal level).

[38] See Etro (2020) and Hagiu *et al.* (2020) for discussions of other aspects of the economics of online marketplaces.

to larger benefits for consumers: ad-funded business models do generate huge gains for consumers by providing devices at competitive prices and free services as much as device-funded business models generate high quality devices and services. Instead, our claim is that different business models generate different incentives to adopt strategies for the platform with important consequences on consumers. In particular, the incentives of a device-funded platform in setting commissions on external apps and providing its own apps are largely aligned with those of consumers, while this is not generally the case for the ad-funded platform. Of course, we do not exclude that device-funded platforms could be engaged in abusive conducts through other restrictive practices or that some reduction of their commissions could create benefits, but this cannot be assumed without specific investigations.

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Appendix A: Endogenous entry of external apps

In this Appendix we show how the sets of active apps Ω_i provided on platforms $i = A, G$ can be endogenized in the presence of entry costs in the spirit of the theory of platform competition *à la* Armstrong (2006). With entry costs F_{ji} for app j on platform i, a free entry equilibrium implies that: 1) Ω_A and Ω_G include all the apps whose profits satisfy $\Pi_{ji}(\Delta) \geqslant F_{ji}$, which defines the sets:

$$\Omega_A = \Omega_A(\Delta) \quad \text{and} \quad \Omega_G = \Omega_G(\Delta) \tag{31}$$

and 2) the surplus differential satisfies the equilibrium condition $\Delta = Z(\Omega_A, \Omega_G)$, where the correspondence Z is defined by (8), for the sets $\Omega_A(\Delta)$ and $\Omega_G(\Delta)$. In practice, a free entry equilibrium is determined by a fixed point Δ of the surplus differential such that:

$$\Delta = Z(\Omega_A(\Delta), \Omega_G(\Delta)) \tag{32}$$

which defines the equilibrium price aggregator and therefore all the equilibrium demands, prices and profits. In general, this can give raise to tipping equilibria or multiple equilibria, but also to "normal" equilibria where apps populate both platforms and consumers purchase both kinds of devices.

We first provide an example and then briefly analyze the general case. Let us consider apps that differ in terms of fixed costs of development, but are otherwise symmetric on each platform. The fixed cost of production of app j is assumed $F_{ji} = jf$ for a fixed parameter $f > 0$ on both platforms, so that the apps are ordered by increasing size of the fixed cost. The incremental surplus is given by $v(p)$ on the ad-funded platform and $dv(p)$ on the device-funded platform, assuming $d \geqslant 1$ to focus on a quality advantage of the latter (due for instance to higher quality standards). With a common marginal cost c for all apps, prices $p(c)$ are the same for all apps on both platforms according to rule (7) and the unitary profits are $\pi(p(c))$ for the ad-funded platform and $d\pi(p(c))$ for the device-funded platform. With a slight abuse of notation, the differential surplus between platforms (8) can be rewritten as:

$$\Delta = Z(n_A, n_G) = n_A dv(p(c)) - n_G v(p(c)) \tag{33}$$

where n_i is the number of apps on platform i which fully describes the set Ω_i. If there is an interior equilibrium with entry on each platform (neglecting integer constraints), it must satisfy the free entry conditions:

$$\Pi_{n_i i}(\Delta) = n_i f$$

for $i = A, G$. For simplicity we assume $R_A = 0$ in what follows.

Under horizontal differentiation we can use the equilibrium gross profits of the apps (13) to rewrite the free entry conditions as:

$$n_A(\Delta) = \frac{(1+\Delta)d\pi(p(c))}{4f} \quad \text{and} \quad n_G(\Delta) = \frac{(3-\Delta)\pi(p(c))}{4f} \tag{34}$$

where the number of apps on each platform depends on the differential surplus Δ. The free entry equilibrium is a fixed point Δ of the differential surplus function such that $\Delta = Z(n_A(\Delta), n_G(\Delta))$. Using (33) we can solve it for:

$$\Delta = \frac{\left(d^2 - 3\right) k}{4 - (1 + d^2)k} \quad \text{with } k \equiv \frac{\pi(p(c))v(p(c))}{f} \tag{35}$$

where we assume $k < 1$ and $d < \sqrt{3/k}$ to avoid tipping equilibria, i.e. the marginal gains from entry parametrized by k (in terms of profits and surplus relative to cost) are not too large and the quality advantage d of the device-funded app store is not too large. This implies $\Delta > 0$ if $d > \sqrt{3}$, and we can determine the endogenous numbers of apps as:

$$n_A = \frac{(1-k)d\pi(p(c))}{4[4 - (1 + d^2)k]f} \quad \text{and} \quad n_G = \frac{(3 - kd^2)\pi(p(c))}{4[4 - (1 + d^2)k]f} \tag{36}$$

which are both positive under our assumptions. Moreover n_A (n_G) increases (decreases) in k and d. Recovering earlier results we can now conclude that in a free entry equilibrium with a device-funded platform of higher quality, an increase of the marginal gains from entry k or of the quality gap d do attract more app developers to the device-funded platform and less to the rival platform, amplify the surplus differential between platforms, and induce an increase in the price of its devices, as implied by (11), but this ultimately benefits all consumers, as implied by consumer welfare in (14).

Under vertical differentiation the analysis is simpler because the selection of the device-funded platform by high spending consumers delivers automatically higher profits for the apps on this platform and fosters entry rationalizing the positive surplus differential. Using the equilibrium gross profits (17), the free entry conditions provide the number of apps:

$$n_A = \frac{3d\pi(p(c))}{8f} \quad \text{and} \quad n_G = \frac{\pi(p(c))}{8f} \tag{37}$$

whose combination with (33) delivers the surplus differential:

$$\Delta = \frac{\left(3d^2 - 1\right) k}{8} > 0 \tag{38}$$

which is always positive (even if the platforms provide identical apps) because larger profits on the device-funded platform attract more apps. Also in this case, either an increase in the marginal gains from entry k or in the quality advantage of the app store of the device-funded platform d increase the surplus differential and the price of its devices, with benefits for consumers according to its measure (18).

Let us return to the general environment with asymmetries between apps. In the horizontal differentiation model the set Ω_A weakly expands and the set Ω_G weakly shrinks when Δ increases, therefore $Z(\Omega_A(\Delta), \Omega_G(\Delta))$ either is constant or jumps upward when Δ increases (it was increasing in our example above), defining an equilibrium when it satisfies (32). In the vertical differentiation model the set Ω_A weakly shrinks and the set Ω_G weakly expands when Δ increases, therefore $Z(\Omega_A(\Delta), \Omega_G(\Delta))$ is either constant or jumps downward when Δ increases (it was constant in our example above) which defines a unique equilibrium satisfying (32). Finally, assuming a unique interior equilibrium, an increase in the additional revenues R_A of the device-funded platform increases the surplus differential between app stores. The proof follows from the fact that in both models the set Ω_A weakly expands and the set Ω_G weakly shrinks when R_A increases, which weakly increases the equilibrium value of Δ. This attracts new apps on the platform whose market size expands.[39]

Appendix B: App curation

In this Appendix we provide details of the Nash equilibrium with endogenous app curation described in the text. In the model of horizontal differentiation the profit functions (12) amended for app curation become:

$$\Pi_A = \frac{\left[1 + \tilde{\Delta}(R_A, R_G) + R_A\right]^2}{8} \quad \text{and} \quad \Pi_G = \frac{[3 - \tilde{\Delta}(R_A, R_G) - R_A]R_G}{4}$$

where $\tilde{\Delta}(R_A, R_G) \equiv \Delta + B_A(R_A) - B_G(R_G)$. Assuming satisfied the relevant second order conditions, the Nash equilibrium satisfies:

$$B'_A(R^e_A) + 1 = 0 \quad \text{and} \quad B'_G(R^e_G) + \frac{3 - \tilde{\Delta}(R^e_A, R^e_G) - R^e_A}{R^e_G} = 0 \qquad (39)$$

Both platforms provide less app curation than ideal (less than the levels satisfying $B'_i(R^*_i) = 0$) with the purpose of raising more revenues. However, the expected consumer welfare (14) is now:

$$\mathbb{E}[U(R_A, R_G)] = \bar{U} + V_G + B_G(R_G) + \frac{\left[1 + \tilde{\Delta}(R_A, R_G) + R_A\right]^2 - 8}{16}$$

which is maximized by $B'_A(R^e_A) + 1 = 0$ and $B'_G(R^o_G) = 0$. It is immediate to verify that $\partial\mathbb{E}[U(R^e_A, R^e_G)]/\partial R_A = 0$ and $\partial\mathbb{E}[U(R^e_A, R^e_G)]/\partial R_G < 0$, implying that the device-funded platform provides the optimal level of app curation from the point of view of consumers, while app curation is underprovided by the ad-funded platform.

The results are more drastic in the model of vertical differentiation, where the profit functions (16) become:

$$\Pi_A = \frac{[\tilde{\Delta}(R_A, R_G) + R_A]^2}{4\tilde{\Delta}(R_A, R_G)} \quad \text{and} \quad \Pi_G = \frac{[\tilde{\Delta}(R_A, R_G) - R_A]R_G}{2\tilde{\Delta}(R_A, R_G)}$$

[39] Extending our example with horizontal differentiation, the equilibrium differential (35) becomes:

$$\Delta = \frac{\left(d^2 - 3 + (1 + d^2)R_A\right)k}{[4 - (1 + d^2)k]}$$

which is increasing in R_A.

While the device-funded platform gains from app curation and is therefore available to sacrifice some revenues to improve the quality of the app store, the ad-funded platform now does not gain anymore from app curation because this strengthens platform competition with a reduction in the price of rival devices and a loss of market share. Accordingly, the Nash equilibrium satisfies:

$$B'_A(R^e_A) + \phi(R^e_A, R^e_G) = 0 \quad \text{and} \quad R^e_G = \bar{R}_G \tag{40}$$

where $\phi(R^e_A, R^e_G) \equiv 2/[1 - \frac{R^e_A}{\tilde{\Delta}(R^e_A, R^e_G)}]$ decreasing in R^e_G. This implies strategic substitutability for the device-funded platform (since by total differentiation $dR^e_A/dR^e_G < 0$). Accordingly, this analysis provides endogenous foundations for the device-funded platform being the high quality platform and the ad-funded platform being the low quality one. The aggregate consumer welfare (18) becomes:

$$\mathbb{E}[U(R_A, R_G)] = \bar{U} + \frac{V_G + B_G(R_G)}{2} + \frac{\left[\tilde{\Delta}(R_A, R_G) + R_A\right]^2}{8\tilde{\Delta}(R_A, R_G)}$$

whose maximization requires $B'_A(R^o_A) + \phi(R^o_A, R^o_G) = 0$ and $B_G(R^o_G) = 0$. Since $R^o_A > R^e_G = \bar{R}_G$ and $R^o_A < R^e_A$, this implies that the ad-funded platform underprovides app curation and the device-funded platform actually overprovides it compared to the choices that maximize consumer welfare. Nevertheless, in equilibrium $\partial\mathbb{E}[U(R^e_A, R^e_G)]/\partial R_A = 0$ and $\partial\mathbb{E}[U(R^e_A, R^e_G)]/\partial R_G < 0$, therefore consumer welfare cannot be increased by changes in the app curation of the device-funded platform but increases in the app curation of the ad-funded platform.

Appendix C: Entry and commission with imperfectly substitutable apps

In this Appendix we explore the incentives of a device-funded platform to introduce and price apps while simultaneously setting the commission on services provided by external and rival apps. This is at the basis of the EU antitrust case on whether Apple has been using its apps as Apple Book and Apple Music and the commission on in-app purchases to try to foreclose rivals as respectively Kobo or Spotify from the Apple ecosystem. Similar reasoning could apply to other services by Apple and by other platforms.

We drop platform subscripts and (for simplicity and comparison purposes) we adopt a specific commission on app usage.[40] We assume that in a first stage the device-funded platform sets a uniform commission t on quantity purchased of all external apps $j \in \Omega$ and selects the set $\bar{\Omega}$ of apps that it directly provides, with $\bar{\Omega} \subseteq \Omega$. In a second stage the prices of devices are set and, since we want to consider Bertrand competition between imperfectly substitutable apps for

[40] Similar qualitative results apply with an *ad valorem* commission as the one analyzed in the text.

the same service, also the prices of the apps are set, with each app developer j chosing p_j and the platform chosing the price vector $\bar{\mathbf{p}}$ of its own apps, with $\bar{p}_j$ for app $j \in \bar{\Omega}$.

We assume a common marginal cost c_j for rival apps providing the same service j. Defining $v_j(p, \bar{p})$ as the surplus from a service j provided by an external app and an internal app with prices p and $\bar{p}$, we denote its derivatives as $v_p < 0$, $v_{\bar{p}} < 0$, $v_{pp} > 0$, $v_{\bar{p}\bar{p}} > 0$ and $v_{p\bar{p}} \leqslant 0$ for prices below the choke prices. The last assumption implies imperfect substitutability, with the limit cases of independent goods for a null cross derivative $v_{p\bar{p}} = 0$, as in the main text, and perfectly substitute goods when $v_{p\bar{p}} \to -v_{pp}$. This generates a surplus differential $\Delta(\bar{\mathbf{p}}) = \sum_{j\in\Omega} v_j(p_j, \bar{p}_j) - V_G$, with revenues per unit of demand $T(t, \bar{\mathbf{p}}) = t \sum_{j\in\Omega} \left| v_{p_j}(p_j, \bar{p}_j) \right|$, and platform profits from apps per unit of demand $\pi(\bar{\mathbf{p}}) = \sum_{j\in\bar{\Omega}} \left| v_{\bar{p}_j}(p_j, \bar{p}_j) \right| (\bar{p}_j - c_j)$.

Horizontal differentiation Let us consider the model of horizontal differentiation. Given a commission t, each external app j sets its price p_j to maximize its profits:

$$\Pi_{jA} = (1 - \hat{x}) \left| v_{p_j}(p_j, \bar{p}_j) \right| (p_j - c_j - t)$$

taking $\hat{x}$ and the price of the rival app as given. The platform selects the price of each internal app $\bar{p}_j$ and simultaneously or sequentially the price of the device P_A to maximize profits:

$$\Pi_A = (1 - \hat{x}) \left[P_A - h + T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}}) \right]$$

internalizing the impact of its choices on $\hat{x} = \frac{1+P_A - P_G - \Delta(\bar{\mathbf{p}})}{2}$ and taking the price of the external apps as given.

The app developer selects a price rule:

$$p_j = \frac{c_j + t}{1 - \frac{1}{\varepsilon_j(p_j, \bar{p}_j)}} \quad \text{with } \varepsilon_j(p, \bar{p}) \equiv \frac{v_{p_j p_j}(p, \bar{p}) p}{-v_{p_j}(p, \bar{p})} \tag{41}$$

where the relevant elasticity $\varepsilon_j(p_j, \bar{p}_j) > 1$ is typically decreasing in $\bar{p}_j$ under strategic complementarity.

The platform, sets the equilibrium price of its devices as:

$$P_A = h + \frac{1 + \Delta(\bar{\mathbf{p}}) - T(t, \bar{\mathbf{p}}) - \pi(\bar{\mathbf{p}})}{2}$$

and the price vector $\bar{\mathbf{p}}$ for each internal app $j \in \bar{\Omega}$ such that:[41]

$$\bar{p}_j = c_j + b_j(p_j, \bar{p}_j) t \quad \text{with } b_j(p, \bar{p}) \equiv \frac{-v_{p_j \bar{p}_j}(p, \bar{p})}{v_{\bar{p}_j \bar{p}_j}(p, \bar{p})} \in [0, 1) \tag{42}$$

These rules simplify to marginal cost pricing $\bar{p}_j = c_j$ in case of independent apps ($b_j = 0$), as we have seen in the main analysis in the text, and to limit pricing

[41] In case of an *ad valorem* commission as in the text, this rule would simply become $\bar{p}_j = c_j + b_j(p_j, \bar{p}_j) p_j \tau \leqslant p_j$ since $p_j \geqslant c_j/(1 - \tau)$.

$\bar{p}_j = c_j + t$ in case of perfectly substitute apps ($b_j \to 1$). Otherwise the price is smaller than the one of the rival, since $\bar{p}_j = c_j + b_j(p_j, \bar{p}_j)t = c_j + t \leqslant p_j$, and increasing in the commission because losses from demand diversion are recovered through commission revenues on the demand of the rival.

For each service, the Bertrand equilibrium between the rival apps provided by an external app developer and the platform solves the system of the two pricing rules, and determines the equilibrium pass-through rates of the commission on the prices of the external apps, which is crucial for setting the optimal commission. As an example, consider the linear demand system emerging from the quadratic surplus function:

$$v_j(p, \bar{p}) = \frac{(a_j - p)^2}{2} + \frac{(a_j - \bar{p})^2}{2} - bp\bar{p}$$

where the parameter $b \in [0, 1)$ is inversely related to app differentiation. The profits of an external app are $\Pi_{jA} = (1 - \hat{x})(a_j - p_j + b\bar{p}_j)(p_j - c_j - t)$, so that its best response function can be derived as $p_j = \frac{1}{2}(a_j + b\bar{p}_j + c_j + t)$. In this example $b_j(p_j, \bar{p}_j) = b$ implies that the price selected by the device-funded platform for its app is independent from the external one. The system of the two pricing rules delivers a Bertrand equilibrium with prices:

$$p_j(t) = \frac{a_j + (1 + b)c_j + (1 + b^2)t}{2} \quad \text{and} \quad \bar{p}_j = c_j + bt$$

The equilibrium price of the external app is higher and increases in the commission with incomplete pass-through since $p'_j(t) \in [1/2, 1)$. A higher commission softens price competition in the sense that it increases both prices, especially if these are poorly differentiated, but of course it reduces the margins of the external app provider.

Going back to the general model, for a given set of apps, the commission must be set at the initial stage by the platform to maximize the profits:

$$\Pi_A = \frac{[1 + \Delta(\bar{\mathbf{p}}) + T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}})]^2}{8}$$

taking into account the impact on the prices of the external apps (since the impact through the platform prices is null by the envelope theorem). This provides an optimal commission satisfying:

$$t^* = \frac{\sum_j |v_{p_j}| (1 - p'_j)}{\sum_j (v_{p_j p_j} + b_j v_{p_j \bar{p}_j}) p'_j} \tag{43}$$

This is positive under an incomplete pass-through rate $p'_j(t) \in (0, 1)$ rather than an incomplete pass-through elasticity (as for the *ad valorem* commission). Only full pass-through generates $t^* = 0$ and $\bar{p}_j = c_j$: remarkably, this would apply under competitive apps (pricing at $p_j(t) = c_j + t$) so that the conditions for the OMP logic would hold in that case and the platform could not gain from either foreclosing rival apps or using a commission. Under market power of app developers, instead, the OMP theorem does not apply, and incomplete pass-through and imperfect substitutability deliver a positive commission and positive markups on the apps provided by the platform. For instance, assuming common costs and linear demand functions as above for all the apps ($\bar{\Omega} = \Omega$), the optimal commission can be computed explicitly as:[42]

$$t^* = \frac{a - (1-b)c}{3 + b^2}$$

The most important result is that the equilibrium commission and prices for the platform apps correspond to those selected by a social planner to maximize consumer welfare under the constraint that the price of the device and of the external apps are chosen respectively by the platform and the external app developers - compare (14) after setting $\Delta = \Delta(\bar{\mathbf{p}})$ and $R_A = T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}})$. The same decision to introduce an app, and to adjust the commission after its introduction is done to maximize the total welfare generated for platform and consumers, which is then split between them. Under endogenous entry of external apps, the algorithm to identify the optimal sets is intuitive: one should compare the optimal commission and prices for any set of apps consistent with positive profits for the external apps and then select the set that maximizes $\Delta(\bar{\mathbf{p}}) + T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}})$. Such a choice must trade off the benefits of allowing entry of more apps and the costs of raising lower revenues from the commission, which leads to select apps that generate high surplus. Summing up, strategies adopted by the device-funded platform cannot harm consumers in this model.[43]

Vertical differentiation Let us finally move to the vertical differentiation model. The pricing rules for the external app developers are the same as before. The profits of the device-funded platform are:

$$\Pi_A = (1 - \hat{x})(P_A - h) + \frac{(1 - \hat{x}^2)[T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}})]}{2}$$

where $\hat{x} = \frac{P_A - h}{\Delta(\bar{\mathbf{p}})}$. This generates the equilibrium price of the device:

$$P_A = h + \frac{\Delta(\bar{\mathbf{p}})}{2 + \alpha(t, \bar{\mathbf{p}})} \quad \text{with } \alpha(t, \bar{\mathbf{p}}) \equiv \frac{T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}})}{\Delta(\bar{\mathbf{p}})} > 0$$

As usual, this price is reduced in the presence of additional revenues with the purpose of expanding sales. The price of the apps by the platform are selected

[42] This is ambiguously dependent on the substitutability parameter b: higher substitutability increases the pass-through rate, which pushes for a smaller commission, but also increases the demand of external apps and the associated revenues, which pushes for a higher commission (with the former effect prevailing for low marginal costs).

[43] It has been argued that foreclosure can emerge in a dynamic environment due to opportunistic behavior toward old customers (as in Borenstein *et al.*, 2000). However, this cannot be profitable and cannot even emerge as an equilibrium outcome when the platform sets profit-maximizing commissions. I am thankful to Benno Buehler for useful discussions on these points.

to maximize equilibrium profits:

$$\Pi_A = \frac{\left(\Delta(\bar{\mathbf{p}}) + T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}})\right)^2}{2\left(2\Delta(\bar{\mathbf{p}}) + T(t, \bar{\mathbf{p}}) + \pi(\bar{\mathbf{p}})\right)}$$

Assuming an interior solution, the optimal prices of the apps of the platform satisfy the following rules:

$$\bar{p}_j = \frac{c_j + b_j(p_j, \bar{p}_j)t}{1 - \frac{1}{\bar{\varepsilon}_j(p_j, \bar{p}_j)}} \quad \text{with } \bar{\varepsilon}_j(p, \bar{p}) \equiv \frac{v_{\bar{p}_j \bar{p}_j}(p, \bar{p})\bar{p}}{-v_{\bar{p}_j}(p, \bar{p})} \left(\frac{3+\alpha}{1+\alpha}\right) \tag{44}$$

for any $j \in \bar{\Omega}$. The equilibrium prices tend to be higher than the prices emerging in the earlier model for given conditions because the platform gives a lower weight to consumer surplus. However, the price tends to remain below the price of external apps because the relevant demand elasticity is higher and the commission is only partially shifted on prices.[44]

Given the equilibrium app prices, the platform selects the profit maximizing commission taking into account its direct impact on revenues and its indirect impact on consumer surplus and profits through the external prices. The optimal level satisfies:

$$t^* = \frac{\sum_j \left[\left| v_{p_j} \right| \left(1 - \frac{2p_j'}{3+\alpha}\right) - v_{\bar{p}_j p_j} \frac{c_j p_j'}{\bar{\varepsilon}_j - 1} \right]}{\sum_j \left(v_{p_j p_j} + b_j v_{p_j \bar{p}_j} \frac{\bar{\varepsilon}_j}{\bar{\varepsilon}_j - 1} \right) p_j'} \tag{45}$$

The policies of the device-funded platform now have a different impact on different consumers. The introduction of a positive commission increases the utility of consumers with a low preference for quality either because they keep purchasing this device but at a lower price and do not purchase much from the apps, or because they switch from the ad-funded platform to the device-funded one exactly because of the price reduction. However, consumers with high preference for quality are now penalized by the higher prices of the apps generated by the commission. As before, the commission that maximizes expected utility is positive, though lower than the equilibrium one.

[44] For instance, the earlier example with linear demand provides the pricing rules:

$$\bar{p}_j = \frac{(a_j + bp_j)(1+\alpha) + (c_j + bt)(3+\alpha)}{2(2+\alpha)}$$

increasing in the rival price. Using the pricing rules for the external apps, one can find the Bertrand equilibrium prices.