Mandated Platform Compatibility: Competition and Welfare effects

Shiva Shekhar* Georgios Petropoulos† Marshall Van Alstyne‡
Geoffrey Parker§

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Regulators have emphasized on mandating compatibility between competing platform ecosystems. In this paper, we study the welfare implications of compatibility by building a stylized model that reflects the competitive dynamics of the current mobile ecosystems market. We consider a device funded and an ad-funded platform that compete for attracting developers and consumers. If compatibility is mandated on the developer side in a way that eliminates the cost of developers to multi-home, then mandated compatibility reduces the welfare of both consumers and developers because it introduces strategic complementarities that limit platform competition for developers. As a result, developers are charged higher prices which through network externalities imply that also consumers are worse off. If compatibility is mandated on the consumer side, by allowing consumers to multi-home, then under strong network effects it can be a Pareto improvement and result in a win-win outcome for all market participants.

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*Tilburg School of Economics and Management (TiSEM), email: s.shekhar_1@tilburguniversity.edu, shiva.shekhar.g@gmail.com, CESifo Research Fellow and TILEC research fellow.
†MIT 100 Main St, Cambridge, MA 02142 , email: gpetrop@mit.edu
‡Boston University 595 Commonwealth Av., Boston, MA 02215, email: mva@bu.edu
§Dartmouth College 15 Thayer Dr, Hanover, NH 03755 , email: Geoffrey.G.Parker@dartmouth.edu

1 Introduction

The rise of giant platforms like Apple and Google has raised market power concerns. Their ability to serve as gatekeepers to multi-sided interactions allows them to capture a disproportionate share of value from their participation in and governance of online markets. Apple and Google, for example, have created and manage the two largest app stores, which "feed" device users with useful applications and content. Analysis of market power becomes complicated as they use different business models. Apple adopts a vertically integrated structure where it sells devices with exclusive access to its app store (device funded model). Google, on the other hand, licenses its applications to device manufacturers and finances its app store largely through targeted advertising instead of selling directly in the device market (ad-funded model).[1] Platforms now are in the eye of the storm with regulators working trying to enhance contestability as well as encouraging platforms to share a portion of the value with consumers and smaller firms on their ecosystem. These marketplaces represent the eye of the regulatory storm with legislators working to enhance contestability as well as prompt platforms to share more value with consumers and smaller firms.

A number of reports have argued for increasing interoperability in order to achieve contestability.[2] Interoperability, in turn, requires common compatibility standards. According to these reports, mandated compatibility would allow platform partners to multihome on different platforms with less cost. A dominant platform would then be unable to act as sole gatekeeper — businesses and consumers could find alternate paths to interacting. By this logic, interoperability would reduce platforms' abilities and incentives to abuse their market power. In other words, mandated compatibility could give rise to multihoming that reduced market power concerns.

Apple and Google are currently under regulatory scrutiny in several jurisdictions. The UK's Competition and Markets Authority suggests that both platforms should get a "strategic market status" designation that "will lead to these firms to face legally enforceable codes of conduct to govern their behaviour and to prevent them from exploiting their powerful positions".[3] This report calls for policy initiatives that increase compatibility between the two platforms such as interventions that are focused on "making it easier for users to switch between devices that come with different operating systems." Similarly, the EUâs Digital Markets Act considers these as "gatekeeper" platforms that should follow specific rules to ensure they do not abuse their power.[4] Moreover, a US proposal, the Open Markets Act aims at preventing Apple and Google from adopting anticompetitive strategies in their app stores.[5]

This paper considers the competition and welfare implications of a regulation that mandates compatibility across two competing platforms.[6] We further assume that these competing plat-

[1] Google also manufactures its own devices but it has a small share of the device manufacturing market and this share of its revenues is small. Its app store is also available for multiple device manufacturers.

[2] See for example Report (2020), Cabral et al. (2021), and Furman et al. (2019).

[3] See link for more details.

[4] See link for more details.

[5] See link for more details.

[6] Certainly, there are important security issues for opening up platforms to new apps and creating more compatible structures. Here, we focus on the economic effects of mandated compatibility.

forms employ different revenue generating models — ad-funded and device funded. In such a context, we try to understand how enforced compatibility of applications affects competition and its impact on consumers, developers and platform profits. We find that compatibility between platforms can benefit the platforms, leaving developers and consumers worse off. Under incompatibility, platforms compete to attract consumers. To make their ecosystems attractive, platforms must aggressively attract developers. This competition to attract a greater mass of developers makes the developer participation fees strategic complements and competition for developers is linked to competition for consumers. By contrast, mandated compatibility shuts down competition for developers as now application developers always multi-home and care about the total addressable demand across both platforms and the total participation fees. As a consequence, platforms become complementary to each other on the developer side and do not compete to attract more developers. This change in competitive dynamics due to compatibility can be observed by noticing that participation fees become strategic substitutes which results in fees being higher than under incompatibility. Reduced competition for developers lowers total developer surplus and, in some cases, also their participation across both platforms. Additionally, we find that consumers are unambiguously worse off under compatibility as increased participation (under compatibility) fees lower expectation of the value from interacting with developers and thus also their participation in the ecosystem. Finally, reduced competition (under compatibility) benefits platforms and their profits are higher. While our results are stark, in this paper, we try to show the existence of the negative welfare impact of compatibility and policy makers should be circumspect when designing such policies and bear in mind these unintended consequences of regulation.

The second modelling approach has to do with compatibility on the consumer side. Consumers of one platform can access apps that are in the rival platform. As a result, it is the consumer side that multi-homes in this case, while developers single-home. The two platforms compete more fiercely for developers and reduce the participation fees on the developer side to zero. We do not observe any strategic complementary in this case due to the increased competition. The welfare implications of compatibility are more nuanced in this case. While developer surplus is always higher under compatibility, consumer surplus only increases if cross-side network effects are significant. More importantly, for sufficiently high network effects, platforms also realize a higher payoff under compatibility, suggesting that adopting compatibility on the consumer side can be a Pareto improvement and result in a win-win outcome for all market participants.

2 Relevant literature

Our paper is contributing on three strands of the literature. First, our paper builds on classical works in two-sided markets such as (Rochet & Tirole 2003, 2006), Parker & Van Alstyne (2005), Armstrong (2006) and especially, Katz & Shapiro (1985*a*). Our motivation is somewhat different and we contribute to this literature by focusing on competition between platforms with different business models and understand how they compete. Further, we assess the economic implications of mandated compatibility vis-Ã -vis the status quo of incompatibility. Second, we also contribute to the nascent yet very relevant literature on competition between platforms employing asymmetric business models such as ad-funded and device funded models (Etro

(2021) and Zennyo (2021)). We add to this literature by trying to understand how mandated compatibility on the app developers' side can affect competitive and welfare dynamics, by introducing cross-sided network effects and adopting a two-sided markets framework. In addition to understanding competition between platforms employing different business models, we also try to understand how a policy regime that implements mandated compatibility on developers' side impacts consumers' surplus, developers' surplus and overall welfare. Third, the literature on the competitive effects of mandated compatibility has missed so far the implications of having two different platform funded models competing. Doganoglu & Wright (2006) consider competition between firms in a Hotelling product differentiation model where consumers can multi-home and firms can choose compatibility after incurring a fixed cost. Compatibility is modelled as access to consumers of another platform. Viecens (2011) builds a product differentiation platform competition model where platforms are asymmetric in terms of the utility apps generate and studies the implications of both platform and application compatibility. Maruyama & Zennyo (2013) deal with competition between systems that offer both hardware devices and content and study the incentives of each platform to make their content compatible with the hardware of the rival, while, Maruyama & Zennyo (2015)and Rasch (2017) endogenize content provision to identify when compatibility emerge in the equilibrium and to assess the welfare implications of compatibility. Furthermore, Adner et al. (2020) study compatibility decisions of two competing platform owners that generate profits through both hardware sales and royalties from content sales. To the best of our knowledge, compatibility has not been studied before in the context of asymmetric business models that resemble the app stores by Apple and Google.

3 Model

There are two ecosystem platforms A and B that compete with each other and manage a two-sided market. These two platforms differ in their business models where platform A is focused on a device based business model while platform B focuses on an advertising based business model. Towards this, we assume that platform A sells devices to consumers directly while platform B licenses its platform ecosystem to device manufactures (for *free*) and earns from advertising revenues. For simplicity, we assume that there are two competing device sellers on platform B denoted by D_1 and D_2 that compete in quantities.[7] The two sides of the market include consumers and developers who value the presence of each other on the platform.

Consumers. The demand side features direct network externalities and is modeled à la Katz & Shapiro (1985*b*). Consumers are heterogeneous in their basic willingness to pay and are homogeneous in their valuation for the network externality. We assume that the basic willingness to pay, denoted by r, is uniformly distributed over the support: $r \sim \mathcal{U}[0,1]$. The gross value of a consumer of type r from affiliating with platform i is given as

$$\mathcal{V}_i(\cdot) \triangleq v_i + \theta\Delta_i^e \quad i = A, B,$$

[7]We consider a duopoly only for illustrative purposes. It can be shown that our results remain true qualitatively with $N > 2$ device sellers active on platform B (proofs are available upon request).

where intrinsic value v_i invested by platform i, Δ_i^e is the aggregate mass of developers that consumers expect to interact with on platform i. The parameter $\theta \geq 0$ measures consumers' value for developers active on the platform — i.e., the more developers on the platform, the more likely is that other users will be interested in joining the network, as reflected by a higher willingness to pay (demand intercept as shown below).

The expected net utility of a consumer of type r affiliating with platform A is

$$u_A\left(r, \Delta_A^e, P_A\right) \triangleq r + \mathcal{V}_A(\cdot) - P_A,$$

where P_A is the price of the device that consumers pay to access the platform. The expected net utility of a consumers of type r affiliating with platform B is

$$u_B\left(r, \Delta_B^e, P_B, \alpha\right) \triangleq r + \mathcal{V}_B(\cdot) - P_B - \alpha,$$

where P_B is the price charged by competing device sellers on the platform and α is the advertising intensity set by platform B to consumers.

Under the above specification, consumers affiliate with platforms A and B only if the following *'no arbitrage condition'* on the hedonic prices holds

$$P_A - \mathcal{V}_A(\cdot) = P_B + \alpha - \mathcal{V}_B(\cdot). \tag{1}$$

Let the common reservation value be

$$r^\star \triangleq P_A - \theta\Delta_A^e - v_A = P_B + \alpha - \theta\Delta_B^e - v_B,$$

consumers buy the device of either platform if and only if $r \geq r^\star$. Hence, the aggregate demand in the market is

$$\Pr\left[r \geq r^\star\right] = X \triangleq \sum_{i=1,2} x_i + x_A,$$

where $x_B \triangleq \sum_{i=1,2} x_i$ is the sum of outputs x_1 and x_2 by device sellers D_1 and D_2 on platform B. Hence, the inverse demand function for the devices distributed within platform A's ecosystem is

$$P_A\left(\Delta_A^e, X\right) \triangleq \max\left\{0, 1 + v_A + \theta\Delta_A^e - X\right\}.$$

The inverse demand for devices affiliated with platform B's ecosystem is

$$P_B\left(\Delta_B^e, \alpha, X\right) \triangleq \max\left\{0, 1 + v_B + \theta\Delta_B^e - \alpha - X\right\}.$$

The impact of the different components of the inverse demand at platform i can be summarized as follows.

- **Market output:** $\frac{\partial P_i(\cdot)}{\partial X} < 0$ for $i = 1, 2$,
- **Developer Value:** $\frac{\partial P_i(\cdot)}{\partial \Delta_i^e} > 0$ for $i = 1, 2$,
- **Intrinsic Value:** $\frac{\partial P_i(\cdot)}{\partial v_i} > 0$ for $i = 1, 2$,
- **Advertising intensity:** $\frac{\partial P_B(\cdot)}{\partial \alpha} < 0$.

The first effect is straightforward and arises directly from the fact that an increase in market output increases competitive and thus lowers device margins at either platform. An increase in the number of developers on platform i increases the consumers' willingness to pay for accessing the developer ecosystem and thus platform i is able to charge a higher quality adjusted price. Similarly, investment in intrinsic value v_i at platform i also increases consumers' willingness to pay and thus platform i is able to charge a higher quality adjusted price. Finally, an increase in advertising intensity at platform i lowers the value of platform B's ecosystem and thus also lowers the margin of device makers affiliated with the platform.

Developers. Developers are heterogeneous in their cost of developing content and are distributed uniformly according to their development cost $m \sim U(0,1)$. We assume that if platforms are not compatible with each other platforms must duplicate investment each time they port their content on a platform. We discuss below developer payoff in the two compatibility regimes below.

Incompatible platforms: Suppose the platforms were incompatible, the payoff of a developer of type m for creating content or applications on platform i is given as

$$\pi_i^I(\cdot) \triangleq \phi x_i^e - l_i - m,$$

where x_i^e is the expectation on the total mass of consumers affiliating with the platform i, l_i is the access fee charged by platform i to developers. Developers affiliate with a platform only if they get positive utility and thus

$$\pi_i^I(m) > 0 \implies m < m_i^I(x_i^e, l_i) \triangleq \phi x_i^e - l_i.$$

This gives us the mass of developers active on platform i as $\Delta_i^I(x_i^e, l_i,) \triangleq m_i^\star(x_i^e, l_i)$. It is important to note that in the incompatibility case developers only care about the expected mass of consumers on each platform and the participation fee charged by each platform.

Compatible platforms: Suppose the platforms were mandated to be compatible, then developers need to incur development costs only once and then they port their content on both platforms. In such a case, the profit of a developer of type m which creates content is given as

$$\pi^C(\cdot) = \phi \underbrace{(x_A^e + x_B^e)}_{X^e} - l_A - l_B - m. \tag{2}$$

A developer produces content only if

$$\pi^C(m) > 0 \implies m < m^C(X^e, l_A, l_B) \triangleq \phi(X^e) - l_A - l_B.$$

The mass of active content providers (developers) is now

$$\Delta^C(X^e, l_A, l_B) \triangleq m^C(X^e, l_A, l_B). \tag{3}$$

Unlike the incompatibility case, under compatibility between platforms, developers now care about the total expected mass of consumers on both platforms and the sum of participation fees at the two platforms.

Platforms. Platform A's business model differs from the business model of platform B. While platform A is a device funded platform, platform B earns through advertisements. Specifically, platform A's profit is the sum of revenues from selling devices and charging developers a participation fee (l_A) and is given as follows

$$\underbrace{P_A(\cdot)x_A}_{\substack{\text{Revenue from}\\ \text{devices}}} + \underbrace{l_A\Delta_A.}_{\substack{\text{Revenue from}\\ \text{developers}}}$$

Revenues from the consumer side arises from device sales where platform A sets output x_A and earns margins commensurate to a quality adjusted price $P_A(\cdot)$. Further, platform A also earns from the presence of developers (denoted by Δ_A) through the participation fee it charges them l_A.

Different from platform A, platform B is an advertising funded platform and does not sell devices directly to consumers. Instead, platform B licenses for *free* access to its platform ecosystem to device sellers. Platform B's revenue streams through two channels — advertisements and from participation of developers. The payoff of platform B is then given as

$$\underbrace{R(\alpha)x_B}_{\substack{\text{Revenue from}\\ \text{advertising}}} + \underbrace{l_B\Delta_B.}_{\substack{\text{Revenue from}\\ \text{developers}}}$$

The first component is the advertising revenue stream where the per-consumer ad-revenue is $R(\alpha)$ where $R'(\cdot) > 0$ and $R''(\cdot) \leq 0$. For tractability, we assume $R(\alpha) \triangleq \alpha$. This revenue stream increases in the mass of consumers affiliating with platform B's ecosystem, $x_B = x_1 + x_2$. The second revenue stream arises from the presence of developers on the platform B's ecosystem (denoted by Δ_B) who are then changed participation fee l_B.

Device sellers on platform *B*. Device sellers on platform B denoted by $j = 1, 2$ compete by setting quantities. The profit of each retailer j is given as

$$P_B(\cdot)x_j \text{ for } j = 1, 2$$

where x_j is the output set by retailer j and $P_B(\cdot)$ is the market price. Note that the platform B does not charge device sellers any license fee for selling devices accessing the platform ecosystem. This is because platform B employs a different business model and earns revenues from advertisements.

Timing and equilibrium concept. We consider two market structures contingent on whether the two platforms are incompatible or compatible. Given platform compatibility, the timing of the game is as follows:

$t = 1$ Platform A sets l_A and platform B sets l_B and advertising intensity α.

$t = 2$ Consumers form expectations on the total mass of developers on a platform and developers form expectations on the total mass of consumers on a platform.

$t = 3$ Platform A sets output x_A and device sellers on platform B set outputs x_j for $j = 1, 2$. Profits materialize.

As in Katz & Shapiro (1985*b*), the solution concept in the downstream competition game is Fulfilled Expectations Cournot Equilibrium. Specifically, each seller (platform A and device sellers $j = 1, 2$) chooses in stage 3 its output level taking as given consumers' and (developers') expectations on the mass of developers (Δ_i^e) (consumers (x_i^e)) under the assumption that these expectations are consistent with the equilibrium outcome — i.e., rational expectations — and are formed at the interim stage after consumers and developers have observed participation fees set on each platform l_i for $i = A, B$ and advertising intensity on platform B but before output is set in stage 3.

Assumption 1. *Consumer value from the presence of developers is not very high —* $\theta < \overline{\theta} \triangleq \frac{6+7\phi^2-\sqrt{36+20\phi^2+17\phi^4}}{4\phi(2+\phi^2)}$.

This assumption ensures we are in an interior solution and the participation fees charged to developers are positive.

In the following, we first discuss the incompatibility benchmark framework and then present the outcome under mandated compatibility and then we compare the competitive and welfare implications of this policy regime. To focus on our main idea, we assume that platforms' additional investments v_i are symmetric and normalized to zero — $v_A = v_B = 0$.

4 Analysis:

4.1 Incompatibility.

Output setting stage. In the output setting stage, for given developer participation fees l_A, l_B and advertising intensity α, platform A and device sellers on platform B set outputs to maximize profits. Specifically, the maximization problem of platform A is given as

$$\max_{x_A} P_A(\Delta_A^e, X)x_A + l_A\Delta_A, \tag{4}$$

$$\max_{x_i} P_B(\Delta_A^e, \alpha, X)x_i. \tag{5}$$

Differentiating the profit of platform A and the profit of each retailer i with respect to their outputs yields the following set of first order conditions

$$P_A(\cdot) + \frac{\partial P_A(\cdot)}{\partial X}x_A = 0, \tag{6}$$

$$P_B(\cdot) + \frac{\partial P_A(\cdot)}{\partial X}x_i = 0, \text{ for } i = 1, 2. \tag{7}$$

Imposing rational expectations where consumers' and developers' respective beliefs on mass of developers and consumers affiliating with a platform are correct — i.e., $x_A^\star = x_A^e$, $x_B^\star = \sum_{i=1,2} x_i^\star = x_B^e$, $\Delta_i(x_i^\star, l_i) = \Delta_i^e$ — and solving the first order conditions yields outputs and mass of developers on each platform as functions of participation fees as presented below.

$$x_i^\star(l_B, l_A, \alpha) \triangleq \frac{1 - 2\alpha + \theta(l_A - 2l_B) - \theta\phi(1 - \alpha - l_B\theta)}{4 - \theta\phi(7 - 2\theta\phi)}, \; x_B^\star(l_B, l_A, \alpha) \triangleq \sum_{i=1,2} x_i^\star(l_B, l_A, \alpha) \tag{8}$$

$$x_A^\star(l_A, l_B, \alpha) \triangleq \frac{1 + 2\alpha + \theta(2l_B - 3l_A) - 2\theta\phi(1 - l_A\theta)}{4 - \theta\phi(7 - 2\theta\phi)} \tag{9}$$

$$\Delta_A^\star(l_A, l_B, \alpha) \triangleq \phi x_A^\star(l_A, l_B, \alpha) - l_A = \frac{\phi(1 + 2\alpha + 2\theta(l_B - \phi)) - 4l_A(1 - \theta\phi)}{4 - \theta\phi(7 - 2\theta\phi)}, \tag{10}$$

$$\Delta_B^\star(l_B, l_A, \alpha) \triangleq \phi x_B^\star(l_B, l_A, \alpha) - l_B = \frac{2\phi(1 - 2\alpha + \theta l_A - \theta\phi(1 - \alpha)) - l_B(4 - 3\theta\phi)}{4 - \theta\phi(7 - 2\theta\phi)}. \tag{11}$$

Consequently, the total output in the market as a function of participation fees and privacy setting are respectively given as $X^\star(l_A, l_B, \alpha) \triangleq x_A^\star(l_A, l_B, \alpha) + x_B^\star(l_B, l_A, \alpha)$.

Performing some quick comparative statics, we observe that the device output at each platform falls with an increase in the participation set by the platform and rises with an increase in the rival's participation fee. This result is straightforward and arises directly from the profitability of selling devices. An increase in the participation fee lowers the market price of a device as the consumers' expected value from developers is lower. This decrease in device margin makes it profitable to lower output. Since outputs are strategic substitutes an increase in the rival's participation fee lowers its output (by the same logic) which makes it profitable for platform i to raise its output. Total market output falls with an increase in the participation fee set by either platform. The direct negative effect of an increase in participation by platform i on its output is always greater than the indirect positive effect on the rival's output. Further, an increase in the participation fee lowers the mass of active developers as well through two reinforcing channels. First, a direct effect that lowers the profitability of each developer on the platform and encourages the marginal developer to exit the market. Second, an indirect effect arising from a reduction in expected consumer participation on the platform. Finally, an increase in the advertising intensity on consumers active on platform B lowers the output set by device makers, total market output and the mass of active developers on platform B. In contrast, the device output and the mass of active developers on platform A increases. The intuition for this result is similar in spirit to the previous discussion on the effect of participation fee and is omitted in favor of brevity. We summarize these comparative statics below.

$$\frac{\partial x_i^\star(\cdot)}{\partial l_A} > 0, \; \frac{\partial x_A^\star(\cdot)}{\partial l_A} < 0, \; \frac{\partial X^\star(\cdot)}{\partial l_A} < 0, \; \frac{\partial \Delta_A^\star(\cdot)}{\partial l_A} < 0, \; \frac{\partial \Delta_B^\star(\cdot)}{\partial l_A} > 0, \tag{12}$$

$$\frac{\partial x_i^\star(\cdot)}{\partial l_B} < 0, \; \frac{\partial x_A^\star(\cdot)}{\partial l_B} > 0, \; \frac{\partial X^\star(\cdot)}{\partial l_B} < 0, \; \frac{\partial \Delta_A^\star(\cdot)}{\partial l_B} > 0, \; \frac{\partial \Delta_B^\star(\cdot)}{\partial l_B} < 0, \tag{13}$$

$$\frac{\partial x_i^\star(\cdot)}{\partial \alpha} < 0, \; \frac{\partial x_A^\star(\cdot)}{\partial \alpha} > 0, \; \frac{\partial X^\star(\cdot)}{\partial \alpha} < 0, \; \frac{\partial \Delta_A^\star(\cdot)}{\partial \alpha} > 0, \; \frac{\partial \Delta_B^\star(\cdot)}{\partial \alpha} < 0. \tag{14}$$

The profit of each device seller on platform i is given as follows.

$$\pi_i^\star(l_B, l_A, \alpha) \triangleq P_B(\Delta_B^\star(\cdot), \alpha, X^\star(\cdot))x_i^\star(\cdot). \tag{15}$$

Advertising intensity and developer fee setting stage. In stage 1, while platform A sets participation fee l_A to developers to maximize profits, platform B sets participation fee l_B and advertising intensity α to maximize profit. Thus, their maximization problem is given as

$$\max_{l_A} \Pi_A^\star(l_A, l_B, \alpha) \triangleq \underbrace{P_A(\Delta_A^\star(\cdot), X^\star(\cdot))x_A^\star(\cdot)}_{\text{Device revenues}} + \underbrace{l_A \Delta_A^\star(\cdot)}_{\substack{\text{App store}\\ \text{revenues}}}, \tag{16}$$

$$\max_{l_B,\ \alpha} \Pi_B^\star(l_B, l_A, \alpha) \triangleq \underbrace{R(\alpha)x_B^\star(\cdot)}_{\substack{\text{Advertising}\\ \text{revenues}}} + \underbrace{l_B \Delta_B^\star(\cdot)}_{\substack{\text{App store}\\ \text{revenues}}}. \tag{17}$$

Differentiating the profit expression of the device funded platform as presented in equation (16) with respect to the developer fees l_A and employing the envelope theorem yields the following first order conditions

$$\begin{aligned}\frac{\partial \Pi_A^\star(l_A, l_B, \alpha)}{\partial l_A} &= \underbrace{\frac{\partial P_A(\cdot)}{\partial \Delta_A^e}\left(\underbrace{\frac{\partial \Delta_A(\cdot)}{\partial x_A^e}\frac{\partial x_A^\star(\cdot)}{\partial l_A} - 1}_{(-)}\right)}_{\text{Platform A value effect}} x_A^\star(\cdot) + \underbrace{\frac{\partial P_A(\cdot)}{\partial X}\frac{\partial x_B^\star(\cdot)}{\partial l_A}x_A^\star(\cdot)}_{\substack{\text{Device}\\ \text{margin effect}}\ (-)} \\ &+ \underbrace{\Delta_A^\star(\cdot)}_{\substack{\text{Developer}\\ \text{Margin effect}}(+)} + \underbrace{l_A\left(\frac{\partial \Delta_A(\cdot)}{\partial x_A^e}\frac{\partial x_A^\star(\cdot)}{\partial l_A} - 1\right)}_{\text{Developer volume effect}(-)} = 0.\end{aligned} \tag{18}$$

The first order condition of the device funded platform can be decomposed into different forces. First, the *Platform value effect* of an increase in l_A which lowers consumers' expectation on developer participation and thus also their willingness to pay for the device associated with the ecosystem. This lowers the marginal revenue per-device and thus negatively affects the incentive to raise the participation fee. Second, the *Device margin effect*, an increase in participation fee l_A increases consumer participation on the rival (ad-funded) platform's ecosystem which lowers the margin per-device for platform A. This negatively impacts the incentive to raise the participation fee. The latter two effects are just the classical trade-off between margin and volume effect on the developer side due to an increase in price incident on them. The sum of these opposing forces determines the optimal fee set by platform A. For brevity, we can rewrite the above first order condition as

$$\left(\frac{\partial P_A(\cdot)}{\partial \Delta_A^e}x_A^\star(\cdot) + l_A\right)\left(\underbrace{\frac{\partial \Delta_A(\cdot)}{\partial x_A^e}\frac{\partial x_A^\star(\cdot)}{\partial l_A} - 1}_{(-)}\right) + \underbrace{\frac{\partial P_A(\cdot)}{\partial X}\frac{\partial x_B^\star(\cdot)}{\partial l_A}}_{(-)} + \Delta_A^\star(\cdot) = 0. \tag{19}$$

Similarly, differentiating the profit expression of the ad-funded platform as presented in equation (17) with respect to l_B and the advertising intensity α while employing the envelope theorem yields the following first order conditions

$$\frac{\partial \Pi_B^\star(l_B, l_A, \alpha)}{\partial l_B} = \underbrace{R(\alpha)\frac{\partial x_B^\star(\cdot)}{\partial l_B}}_{\substack{\text{Advertising volume} \\ \text{effect of developer fees}}\ (-)} + \underbrace{\Delta_B^\star(\cdot) + l_B\left(\frac{\partial \Delta_B(\cdot)}{\partial x_B^e}\frac{\partial x_B^\star(\cdot)}{\partial l_B} - 1\right)}_{\text{Developer margin + volume effect on B } (+)} = 0, \tag{20}$$

$$\frac{\partial \Pi_B^\star(l_B, l_A, \alpha)}{\partial \alpha} = \underbrace{\frac{\partial R(\alpha)}{\partial \alpha}x_B^\star(\cdot) + R(\alpha)\frac{\partial x_B^\star(\cdot)}{\partial \alpha}}_{\substack{\text{Advertising volume} \\ \text{+ Margin effect}}\ (+)} + \underbrace{l_B\left(\frac{\partial \Delta_B(\cdot)}{\partial x_B^e}\frac{\partial x_B^\star(\cdot)}{\partial \alpha}\right)}_{\substack{\text{Developer volume effect} \\ \text{of increased advertising}}\ (-)} = 0. \tag{21}$$

The first order condition with respect to l_B as presented in equation (20) can be decomposed into different forces which determine the optimal fee l_B. Notice that the ad-funded platform does not earn revenue from the device market and thus there is no device margin effect. Instead, it earns revenues from advertising to consumers that buy devices connected to its platform ecosystem. The effect on advertising revenues due to an increase in the developer participation fee l_B manifests through the first term in equation (20) which exhibits the negative effect on the advertising revenues and thus is a dampening force on the incentives to raise l_B. The latter two terms present the classical margin and volume trade-off on the developer market on platform B from an increase in the participation fee l_B.

Similarly, the first order condition with respect to α as presented in equation (21) can be decomposed into different forces which determine the optimal advertising intensity α. The first two terms represent the classic ad-margin and volume trade-off on the consumer side that the ad-funded platform must consider when setting its advertising intensity level. Additionally, there is the *Developer volume effect of increased advertising* which characterizes the effect of an increase in the advertising on the developer participation on the platform B. Specifically, an increase in the advertising intensity on the platform lowers participation by developers as they expect a lower mass of consumers affiliating with the platform which lowers their participation and also the revenues earned from the developer side.

Before proceeding further, it is informative to consider how platform's best responses interact with a change in the rival's strategic choice. Let's denote the participation fee best responses as $l_i^{BR}(l_{-i}, \alpha)$ for $i = 1, 2$ and $\alpha^{BR}(l_B, l_A)$. Performing some comparative statics, we observe that participation fees are strategic complements — $\frac{\partial l_i^{BR}(\cdot)}{\partial l_{-i}} > 0$. The intuition for this result is that an increase in the rival's participation fee to developers lowers competitive intensity on platform i and thus it is profitable for platform i to raise the participation fee as well. Further, an increase in α shifts upwards the participation fee best response of the device funded platform while shifting downwards the participation fee best response of the ad-funded platform — $\frac{\partial l_A^{BR}(\cdot)}{\partial \alpha} > 0$ and $\frac{\partial l_B^{BR}(\cdot)}{\partial \alpha} < 0$. An increase in the advertising intensity on the ad-funded platform, makes the device funded platform relatively more attractive for consumers. This increases consumer demand on platform A increasing developer value on platform A making it profitable to set higher participation fees. On the contrary, an increase in α, all else equal, lowers consumer participation on platform B and thus lower developer value and participation on the platform. As a consequence, platform B finds it profitable to lower l_B to stem exit of developers from its ecosystem. Similarly, an increase in l_B shifts the advertising intensity response upwards and an increase in l_A shifts downwards the advertising intensity response — $\frac{\partial \alpha^{BR}(\cdot)}{\partial l_A} > 0$ and $\frac{\partial \alpha^{BR}(\cdot)}{\partial l_B} < 0$. Thus, we get the result that l_A and α are strategic complements to each other while l_B and α are strategic substitutes to each other.

Solving simultaneously the first order conditions as presented in equations (18), (20) and (21), we obtain the equilibrium participation fees and advertising intensity under incompatibility is given as

$$
\begin{aligned}
l_A^I &\triangleq \frac{(6+\theta^2(\phi-2(1-\phi^2))-2\phi^2-\theta\phi(8-\phi^2))(4\phi-\theta(6+7\phi^2-2\theta\phi(2+\phi^2)))}{\mathcal{X}}, \\
l_B^I &\triangleq \frac{(\phi-\theta)(2-\theta\phi)(8-15\theta\phi+4\theta^3\phi-6\theta^2(1-\phi^2))}{\mathcal{X}}, \\
\alpha^I &\triangleq \frac{(8-15\theta\phi+4\theta^3\phi-6\theta^2(1-\phi^2))(4-\phi(2\phi+\theta(5-\phi(\theta+\phi))))}{\mathcal{X}},
\end{aligned}
$$

where $\mathcal{X} \triangleq 128+4\theta^6\phi^2+16\theta^5\phi^3-14\theta^5\phi+20\theta^4\phi^4-94\theta^4\phi^2+12\theta^4+8\theta^3\phi^5-142\theta^3\phi^3+168\theta^3\phi-42\theta^2\phi^4+354\theta^2\phi^2-92\theta^2+68\theta\phi^3-360\theta\phi-32\phi^2 > 0$.
Performing some comparative statics, we present our results in the following lemma.

Lemma 1 (**Developer fees and advertising intensity**). *Under incompatibility, the equilibrium fee charged by platform A is higher than the fee charged by platform B if and only if $\theta < \theta^l$. The equilibrium developer fee set by both platforms falls with an increase in consumer value for developers (θ) and rises with an increase in developer value for the presence of consumers (ϕ) — $\frac{\partial l_i^I}{\partial \theta} < 0$ and $\frac{\partial l_i^I}{\partial \phi} > 0$. The equilibrium advertising intensity set by platform B falls with an increase in θ and ϕ — $\frac{\partial \alpha^I}{\partial \theta} < 0$ and $\frac{\partial \alpha^I}{\partial \phi} < 0$.*

The intuition for the above results are as follows. Platform A's developer fee is directly impacted by consumer's marginal value for developers. Observe that the *Platform value effect* in equation (18) directly affects device margins and profitability in the sales of devices. When consumer value of developers is high enough, then margins in the device market are high as well and platform A set lower fees to encourage entry on its platform. Note that this effect on the profitability of the device market is second order for platform B as it is not active in the device market and cares about advertising revenue. Therefore, its revenue is only indirectly impacted by an increase in θ and therefore affected to a much lower extent. Thus for large levels of consumer value for developers — $\theta > \theta^l$, the developer participation fee is higher on platform B than platform A. An increase in θ lowers l_i^I because consumers now value higher the presence of developers and are more sensitive to the presence of developers. This incentivizes platforms to compete by attracting a greater mass of developers on the platform by lowering the developer participation fees charged by them. Interestingly, an increase in developer value for consumers increases the developer participation fees. This is because an increase in ϕ increases the per-consumer value for a developer on the platform there is increased entry on the platform and this increases the developer margin effect as presented in equations (18) and (20) which encourages platforms to raise participation fees. Finally, the intuition for platform B lowering its advertising intensity as θ and ϕ increase is as follows. An increase in θ increases consumer value for developers which encourages platform i to attract more developers by positively affecting developers' expectation on the mass of consumers active on the platform. Platform B is able to favorably affect expectations of developers by lower advertising intensity on consumers. An increase in ϕ also lowers advertising intensity because it increases revenues from each developer and as a result platform B encourages developer entry by enhancing their expectations on the mass of consumers buying from platform B by reducing the advertising intensity.

Substituting these equilibrium platform choices into platform outputs yields the equilibrium outputs on each platform as

$$x_A^I \triangleq x_A^\star(l_A^I, l_B^I, \alpha^I) = l_A^I \frac{(8 - \theta\phi(11 - 2\theta\phi))}{(4\phi - \theta(6 + 7\phi^2 - 2\theta\phi(2 + \phi^2)))}, \tag{22}$$

$$x^I \triangleq x_i^\star(l_B^I, l_A^I, \alpha^I) = (\phi - \theta) l_B^I, \tag{23}$$

$$X^I \triangleq x_A^I + x_B^I = 2(\phi - \theta) l_B^I + l_A^I \frac{(8 - \theta\phi(11 - 2\theta\phi))}{(4\phi - \theta(6 + 7\phi^2 - 2\theta\phi(2 + \phi^2)))} \tag{24}$$

Performing some comparative statics, we present our results in the following proposition.

Lemma 2 (**Platform outputs and profits**). *The equilibrium output of platform A rises with consumer value for developers (θ) if and only if $\theta > \max\{0, \theta^b\}$ and unambiguously falls with developer value for consumers (ϕ). The equilibrium output by each device seller on platform B rises with θ and ϕ. The total market output rises with θ and ϕ. Profit of platform A rises with θ if and only if $\theta < \theta^h$ and rises with ϕ if and only if $\theta < \theta^k$ and $\phi < 0.685$. Profit of platform B rises with θ if and only if $\theta < \theta^g$ and always rises with an increase in ϕ.*

An increase in θ increases platform A's output when consumer value for developers is large. When θ is low, the positive effect of an increase in θ on the output through increased margin is lower than the negative effect of increased output of the competitive rival. As a result, in this case, platform A lowers its output with an increase in θ. Instead when θ is high, the positive effect of an increase in θ on device margins is larger than the response to output expansion by platform B's device sellers which results in higher output with an increase in θ. An increase in ϕ reduces output on platform A as the demand expansion by platform B's sellers outweighs any demand expansion incentive of platform A. Interestingly, the output of platform B rises with an increase in θ and ϕ. An increase in θ and/or ϕ positively affects the margins of the competing device makers who respond by raising outputs. Total output increases with an increase in θ and ϕ as the competitive output on platform B responds faster to an increase in θ and ϕ in comparison to platform A's output. An increase in θ increases platform A's profit only if θ is sufficiently low. This is because when θ is low competition for developers is lower and an increase in θ implies lower that developer fees fall slower while consumer value increases.[8] Further, an increase in ϕ increases the profit of platform A only if $\theta < \theta^k$ and $\phi < 0.685$. The intuition for this result is that the developer participation fee is increasing in ϕ and the rate of this increase falls in both θ and ϕ. Therefore, an increase in ϕ when ϕ has a greater larger positive effect on profitability when both θ and ϕ are sufficiently low. Interestingly, the profit of platform B always rises with an increase in ϕ and this result arises directly from the fact

[8] It is easy to verify that the second derivative of l_A^I with respect to θ is negative.

that an increase in ϕ increases l_B at an increasing rate along with an increase in the mass of developers active on its ecosystem. Any negative impact on consumer demand for platform B due to an increase in l_B^I is outweighed by the positive effect of an increase in developers on the platform. Finally, an increase in θ raises the profit of platform B if and only if θ is low. This is because advertising intensity falls at a faster rate with an increase in θ making profits concave in θ.[9]

An increase in θ and ϕ increases the output on the Substituting the equilibrium outcome into the expression for device seller profits yields

$$\pi^I \triangleq \pi_i^\star(l_A^I, l_B^I, \alpha^I) = (x^I)^2. \tag{25}$$

Performing some comparative statics, we present our results in the following corollary.

Corollary 1 (**Profit of device sellers on platform** B)**.** *The equilibrium profit of device sellers on platform B rises with θ and ϕ.*

The output and margin of each seller on platform B rises with θ and ϕ. A direct consequence of this result is that the profit of each device seller rises in consumer value for developers (θ) and developer value for consumers (ϕ).

4.2 Mandated compatibility

Under mandated compatibility, developers do not face duplication of development cost and need to invest only once. After development of the content, they are easily able to port on both platforms. As a result, the addressable market for them now are all active consumers in market X while facing participation fees from both platforms. The total mass of developers is then

$$\Delta_C(X^e, l_A, l_B) \triangleq m^C(X^e, l_A, l_B) = \phi \underbrace{(x_A^e + x_A^e)}_{X^e} - l_A - l_B.$$

Another aspect of compatibility is that developers always multi-home and thus the platforms face the same mass of developers on the two platforms. This is because once content is developed with a cost k, active developers affiliate with each platform if $\phi * x_i - l_i > 0$ for $i = 1, 2$. In the following, we conjecture that $\phi * x_i - l_i > 0$ and ex-post show this is indeed the case.

Output setting stage. In the output setting stage, for given developer participation fess l_A, l_B and advertising intensity α, platform A and device sellers on platform B set outputs to maximize profits.

$$\max_{x_A} P_A(\Delta_C^e, X)x_A + l_A \Delta_C, \tag{26}$$

$$\max_{x_i} P_B(\Delta_C^e, \alpha, X)x_i. \tag{27}$$

[9] It is easy to verify that $\frac{\partial^2 \alpha^I}{\partial \theta^2} < 0$.

Differentiating the profit of platform A and the profit of each retailer i with respect to their outputs yields the following set of first order conditions as presented in equations (6) and (7).

Imposing rational expectations where consumers' and developers' respective beliefs on mass of developers and consumers affiliating with a platform are correct — i.e., $\tilde{X} = \tilde{x}_A + \tilde{x}_B = X^e$, $\tilde{\Delta}_C(\tilde{X}, l_A, l_B) = \Delta_C^e$ — and solving the first order conditions yields outputs and mass of developers on each platform as functions of participation fees as presented below.

$$\tilde{x}_i(l_B, l_A, \alpha) \triangleq \frac{1 - \theta(l_A + l_B) - \alpha(2 - \theta\phi)}{4 - 3\theta\phi}, \ \tilde{x}_B(l_B, l_A, \alpha) \triangleq \sum_{i=1,2} \tilde{x}_i(l_B, l_A, \alpha) \tag{28}$$

$$\tilde{x}_A(l_A, l_B, \alpha) \triangleq \frac{1 - \theta(l_A + l_B) + 2\alpha(1 - \theta\phi)}{4 - 3\theta\phi} \tag{29}$$

$$\tilde{\Delta}_C(l_A, l_B, \alpha) \triangleq \phi\tilde{X}(l_A, l_B, \alpha) - l_A - l_B = \frac{\phi(3 - 2\alpha) - 4(l_A + l_B)}{4 - 3\theta\phi}. \tag{30}$$

The total market output is given as

$$\tilde{X}(l_A, l_B, \alpha) \triangleq \tilde{x}_A(l_A, l_B, \alpha) + \tilde{x}_B(l_B, l_A, \alpha) = \frac{3 - 2\alpha - 3\theta(l_A + l_B)}{4 - 3\theta\phi}. \tag{31}$$

Performing some quick comparative statics, we observe that under compatibility the response of device outputs to developer participation fees and advertising intensity differ significantly in comparison to the incompatibility case as presented in equations (12), (13) and (14). Notice that an increase in developer participation fee of either platform lowers demand at both platforms. This is because an increase in the developer participation fees lowers consumers' expectation on the value from each developer participation at both the platforms. This lowers the device margin for sellers on both platforms and thus also lower the output of each platform, total output and also the mass of developers active in the market. Interestingly, an increase in advertising intensity also lowers platform outputs, total outputs and the mass of active developers. The intuition for this result is similar in spirit to the previous discussion on the effect of participation fee and is omitted in favor of brevity. We summarize these comparative statics below.

$$\frac{\partial \tilde{x}_i(\cdot)}{\partial l_A} < 0, \ \frac{\partial \tilde{x}_A(\cdot)}{\partial l_A} < 0, \ \frac{\partial \tilde{X}(\cdot)}{\partial l_A} < 0, \ \frac{\partial \tilde{\Delta}_C(\cdot)}{\partial l_A} < 0, \tag{32}$$

$$\frac{\partial \tilde{x}_i(\cdot)}{\partial l_B} < 0, \ \frac{\partial \tilde{x}_A(\cdot)}{\partial l_B} < 0, \ \frac{\partial \tilde{X}(\cdot)}{\partial l_B} < 0, \ \frac{\partial \tilde{\Delta}_C(\cdot)}{\partial l_B} < 0, \tag{33}$$

$$\frac{\partial \tilde{x}_i(\cdot)}{\partial \alpha} < 0, \ \frac{\partial \tilde{x}_A(\cdot)}{\partial \alpha} > 0, \ \frac{\partial \tilde{X}(\cdot)}{\partial \alpha} < 0, \ \frac{\partial \tilde{\Delta}_C(\cdot)}{\partial \alpha} < 0. \tag{34}$$

In contrast to the incompatibility case, comparing these comparative statics with those in equations (12), (13) and (14), we observe a few differences. Under compatibility an increase in participation fee at platform i also lowers the output of the rival. Specifically, an increase in l_i negatively affects the output on a platform but also the output of the rival platform. Similarly, an increase in l_i lowers the mass of developers on both platforms.

The profit of each device seller on platform B is given as

$$\tilde{\pi}_i^C(l_B, l_A, \alpha) \triangleq P_B(\tilde{\Delta}_C(\cdot), \alpha, \tilde{X}(\cdot))\tilde{x}_i(\cdot). \tag{35}$$

Advertising intensity and developer fee setting stage. In stage 1, while platform A sets participation fee l_A to developers to maximize profits, platform B sets participation fee l_B and advertising intensity α to maximize profit. Thus, their maximization problem is given as

$$\max_{l_A} \tilde{\Pi}_A(l_A, l_B, \alpha) \triangleq P_A(\tilde{\Delta}_C(\cdot), \tilde{X}(\cdot))\tilde{x}_A(\cdot) + l_A\tilde{\Delta}_C(\cdot), \tag{36}$$

$$\max_{l_B,\alpha} \tilde{\Pi}_B(l_B, l_A, \alpha) \triangleq R(\alpha)\tilde{x}_B(\cdot) + l_B\tilde{\Delta}_C(\cdot). \tag{37}$$

Differentiating the profit expression of the device funded platform with respect to the developer fees l_A and employing the envelope theorem yields the following first order conditions

$$\begin{aligned}\frac{\partial\tilde{\Pi}_A(l_A, l_B, \alpha)}{\partial l_A} = {} & \underbrace{\frac{\partial P_A(\cdot)}{\partial \Delta_C^e}\underbrace{\left(\frac{\partial \Delta_C(\cdot)}{\partial X^e}\underbrace{\frac{\partial \tilde{X}(\cdot)}{\partial l_A}}_{(-)} - 1\right)}_{(-)}}_{\text{Platform A value effect}}\tilde{x}_A(\cdot) + \underbrace{\frac{\partial P_A(\cdot)}{\partial X}\frac{\partial \tilde{x}_B(\cdot)}{\partial l_A}}_{\substack{\text{Device} \\ \text{margin effect}}(+)} \\ & + \underbrace{\tilde{\Delta}_C(\cdot)}_{\substack{\text{Developer} \\ \text{margin effect}}(+)} + \underbrace{l_A\left(\frac{\partial \Delta_C(\cdot)}{\partial X^e}\underbrace{\frac{\partial \tilde{X}(\cdot)}{\partial l_A}}_{(-)} - 1\right)}_{\text{Developer volume effect}(-)} = 0.\end{aligned} \tag{38}$$

As in the incompatibility case, the first order condition of the device funded platform can be decomposed into different forces. First, the *Platform value effect* of an increase in l_A which lowers consumers' expectation on developer participation and thus also their willingness to pay for the device associated with the ecosystem A. This lowers the marginal revenue per-device and thus negatively affects the incentive to raise the participation fee. Note that the effect of an increase in the participation fee affects negatively the total output in market as consumers know that developers multi-home. This exacerbates the incentives to lower participation fee l_A in comparison to the incompatibility case. Second, in contrast to the incompatibility case, the *Device margin effect* positively affects the incentive to raise the developer participation fee. Specifically, an increase in developer participation fee l_A lowers output of the rival ecosystem as the mass of (multi-homing) developers also fall at the rival. This increases margin in the device market and positively affects the incentive to raise the participation fee. The latter two effects are just the classical trade-off between margin and volume effect on the developer side due to an increase in price incident on them. The sum of these opposing forces determines the optimal fee set by platform A. For brevity, we can rewrite the above first order condition as

$$\underbrace{\left(\frac{\partial P_A(\cdot)}{\partial \Delta_C^e}\tilde{x}_A(\cdot)+l_A\right)}_{(+)}\underbrace{\left(\frac{\partial \Delta_C(\cdot)}{\partial X^e}\frac{\partial \tilde{X}(\cdot)}{\partial l_A}-1\right)}_{(-)}+\underbrace{\frac{\partial P_A(\cdot)}{\partial X}\frac{\partial \tilde{x}_B(\cdot)}{\partial l_A}}_{(+)}+\underbrace{\tilde{\Delta}_C(\cdot)}_{(+)}=0. \tag{39}$$

Similarly, differentiating the profit expression of the ad-funded platform with respect to l_B and the advertising intensity while employing the envelope theorem yields the following first order conditions

$$\frac{\partial \tilde{\Pi}_B(l_B,l_A,\alpha)}{\partial l_B} = \underbrace{R(\alpha)\frac{\partial \tilde{x}_B(\cdot)}{\partial l_B}}_{\substack{\text{Advertising volume}\\ \text{effect of developer fees}}\ (-)} + \underbrace{\tilde{\Delta}_C(\cdot)+l_B\left(\frac{\partial \Delta_C(\cdot)}{\partial X^e}\underbrace{\frac{\partial \tilde{X}(\cdot)}{\partial l_B}}_{(-)}-1\right)}_{\text{Developer margin + volume effect on B }(+)}=0, \tag{40}$$

$$\frac{\partial \tilde{\Pi}_B(l_B,l_A,\alpha)}{\partial \alpha} = \underbrace{\frac{R(\alpha)}{\partial \alpha}x_B^\star(\cdot)+R(\alpha)\frac{\partial x_B^\star(\cdot)}{\partial \alpha}}_{\substack{\text{Advertising volume}\\ \text{+ Margin effect}}\ (+)} + \underbrace{l_B\frac{\partial \Delta_C(\cdot)}{\partial X^e}\underbrace{\frac{\partial \tilde{X}(\cdot)}{\partial \alpha}}_{(-)}}_{\substack{\text{Developer volume effect}\\ \text{of increased advertising}}\ (-)}=0. \tag{41}$$

The first order condition with respect to l_B and α can be decomposed into different effects as in the incompatibility case. Departing from the incompatibility case is the magnitude of the trade-off between developer margin and volume effect as the mass of addressable consumer demand they face increases and also therefore the effect of an increase in l_B affects the rival's output as well. A similar argument applies to the first order condition with respect to advertising intensity (α).

Before proceeding further, it is informative to consider how platform's best responses interact with a change in the rival's strategic choice. Let's denote the participation fee best responses as $l_i^{C,BR}(l_{-i},\alpha)$ for $i=A,B$ and $\alpha^{C,BR}(l_B,l_A)$. Performing some comparative statics, we observe that under compatibility participation fees are strategic substitutes — $\frac{\partial l_i^{BR}(\cdot)}{\partial l_{-i}}<0$. The intuition for this result is that an increase in the rival's participation fee to developers lowers developer participation on both the platforms and therefore the rival responds by lowering its participation fee to avoid further exit of developers in the market. Similarly, an increase in α shifts downwards the participation fee best response of both the device funded platform and the ad-funded platform — $\frac{\partial l_A^{C,BR}(\cdot)}{\partial \alpha}<0$ and $\frac{\partial l_B^{C,BR}(\cdot)}{\partial \alpha}<0$. An increase in the advertising intensity on the ad-funded platform lowers consumer participation on platform B. Since developers care about total market output, the mass of active developers falls. A direct consequence of this is that the device funded platform also becomes less attractive for consumers. This encourages platform A to set lower developer participation fee as α increases. Similarly, an increase in l_i lowers the advertising intensity response — $\frac{\partial \alpha^{C,BR}(\cdot)}{\partial l_i}<0$. Thus, we get the result that l_i and α are strategic substitutes.

Solving simultaneously the first order conditions as presented in equations (38), (40) and (41), we obtain the equilibrium participation fees and advertising intensity under incompatibility which is presented below.

$$l_A^C \triangleq \frac{\phi(20+\theta^2)-\theta(8+13\phi^2)}{96-10\theta^2-62\theta\phi-4\phi^2},\ l_B^C \triangleq \frac{\phi(20+\theta^2)-2\theta(1+6\phi^2)}{96-10\theta^2-62\theta\phi-4\phi^2},\ \alpha^C \triangleq \frac{6(4-\phi^2)-13\theta\phi}{96-10\theta^2-62\theta\phi-4\phi^2}.$$

Substituting these fees into outputs on both platforms and performing some comparative statics, we present our results in the following lemma.

Lemma 3 (**Developer fees and advertising intensity**). *The equilibrium developer fee set by platform B is always higher than the fee set by platform A.*
Under mandated compatibility, the equilibrium developer fee set by platform A falls with an increase in consumer value for developers θ and rises with an increase in developer value for consumers ϕ. The equilibrium developer fee set by platform B rises with θ if and only if $\theta > \theta^C \triangleq \frac{2\phi(26+\phi^2)-2\sqrt{5(2+\phi^2)(6+5\phi^2)(7\phi^2-4)}}{(10+29\phi^2)}$ and unambiguously rises with an increase in ϕ. The equilibrium advertising intensity set by platform B rises with θ if and only if $\theta > \theta^\alpha \triangleq \max\{0, \frac{\phi(24-6\phi^2)-2\phi\sqrt{144+6\phi^2-95\phi^4}}{13\phi^2}\}$ and unambiguously falls with an increase in ϕ.

The developer participation fees set by platform A are unambiguously lower than those set by platform B. This result implies that compatibility makes platform A more sensitive to the presence of developers than platform B in comparison to incompatibility. As in the incompatibility case, the equilibrium developer participation fee charged by platform A falls with an increase in consumer value for developers (θ) and rises with developer value for consumers. Further, developer participation fee charged by platform B also rises with an increase in ϕ. Interestingly and in contrast to the incompatibility case, an increase in θ increases the developer participation fees charged by platform B if and only if $\theta > \theta^C$. Similarly, an increase in ϕ increases the advertising intensity if and only if $\theta > \theta^\alpha$. The intuition for this result on the developer fee and the advertising intensity arises from the differences in business models. When θ is large platform A is more aggressive in its pricing to developers and lowers its price to developers faster with an increase in θ. This makes platform B's best response to a fall in l_A^C also quite strong and as a result both α^C and l_B^C rise with an increase in θ. This result stem from two mains facts. First, compatibility makes the platforms complementary to each other on the developer side. Second, the differences (asymmetry) in business models of the two platforms implies that they have asymmetric sensitivity to changes in network effects which provides insightful results.

Substituting these equilibrium outcomes into platform outputs and profits yields the equilibrium output at platform A and B and the total market output which are given as

$$x_A^C \triangleq \tilde{x}_A(l_A^C, l_B^C, \alpha^C) = \frac{4(9-\phi^2)-17\theta\phi}{96-10\theta^2-62\theta\phi-4\phi^2},\ x^C \triangleq \tilde{x}_i(l_B^C, l_A^C, \alpha^C) = \frac{6-2\theta\phi+\phi^2}{48-5\theta^2-31\theta\phi-2\phi^2},$$

$$x_B^C \triangleq \tilde{x}_B(l_B^C, l_A^C, \alpha^C) = \frac{2(6-2\theta\phi+\phi^2)}{48-5\theta^2-31\theta\phi-2\phi^2},\ X^C \triangleq x_A^C + x_B^C = \frac{60-25\theta\phi}{96-10\theta^2-62\theta\phi-4\phi^2}.$$

We perform some comparative statics and present our results in the following proposition.

Lemma 4 (**Platform outputs and profits**). *The individual output of each device seller on platform B increases with consumers value for developers on the ecosystem (θ) and in the developer value for the presence of consumers on platform B (ϕ). The output of platform A increases in consumer value for developers on the platform (θ) and falls with an increase in the developer value for the presence of consumers on platform A (ϕ). Total market output increases with an increase in θ and ϕ. The equilibrium profit of both platforms increases in θ and ϕ.*

The individual output of each device of platform B rises with both θ and ϕ. These sellers compete with each other by setting outputs and an increase in θ and ϕ increases their margins which drives them to set higher outputs. Similarly, an increase in θ increases the output of platform A as it directly and positively affects the margins which dominates any incentive to lower outputs due to rival sellers also expanding demand. Interestingly, in contrast to an increase in θ, an increase in ϕ lowers the output of platform A. This is because an increase in ϕ affects margins indirectly through an increase in the mass of developers while there is a stronger negative incentive to lower output as the rival platforms' competing sellers expand output. As a result, an increase in ϕ lowers the output of platform A. The intuition for total market output increasing in θ is obvious as both platform A's and platform B's outputs rise. Total output rising with an increase in ϕ is more nuanced and arises from the fact that output expansion by competing device sellers due to an increase in ϕ dominates any output reduction by the seller of platform A and thus total outputs rise. Finally, platform profits unambiguously rise with an increase in network effects θ or ϕ. An increase in θ increases margins of both firms who increase output. This increase in output by both firms increases the mass of active multi-homing developers and thus also increases profits of each firm. Similarly, an increase in ϕ increases the mass of developers on both platforms which increases their margins and thus also their profitability.

Substituting the equilibrium outcome into the expression for device seller profits yields the equilibrium profits The profit of device sellers on platform B are given as

$$\pi^C \triangleq \tilde{\pi}_i(l_A^C, l_B^C, \alpha^C) = \frac{(6 - 2\theta\phi + \phi^2)^2}{(48 - 5\theta^2 - 31\theta\phi - 2\phi^2)^2}. \tag{42}$$

We perform some comparative statics and present our results in the following corollary.

Corollary 2 (**Profit of device sellers on platform** B). *The equilibrium profit of device sellers on platform B rises with consumer value for developers θ and developer value for the presence of developers ϕ.*

An increase in θ or ϕ increases margins of each seller on platform B as well as the output of the two sellers. A direct consequence of this is that profits of device sellers rise with an increase in θ or ϕ.

5 Competitive and welfare implications of compatibility

We are now in the position to assess the competitive and welfare effects of a policy that mandates compatibility on the developer side. A useful first step is to compare equilibrium fees and then

we compare platform profits and then total consumer and developer surplus.
Comparing the participation fees and advertising intensity in the compatibility case with the incompatibility case yields the following results.

Proposition 1 (**Developer participation fees and advertising intensity**). *Under compatibility, the equilibrium developer participation fees chosen by each platform is higher than the fees set by each platform under incompatibility — $l_i^I < l_i^C$. The advertising intensity on consumers is higher than under incompatibility — $\alpha^I < \alpha^C$.*

The intuition for this result is straightforward and arises from the fact that under compatibility firms do not compete by attracting developers as developers always multi-home. This can be observed by noticing that developer participation fees under compatibility are strategic substitutes and not strategic complements. Specifically, it is less profitable for a platform to lower its developer participation fee when the rival platform does so. Thus, developer participation fees and the advertising intensity are higher post mandated compatibility.
Comparing platform profits in the two regimes, we present our results below.

Proposition 2 (**Platform profits**). *Under compatibility, the profit of (the device-funded) platform A and (the ad-funded) platform B are higher than under incompatiblity — $\tilde{\Pi}_A(l_A^C, l_B^C, \alpha^C) > \Pi_A^\star(l_A^I, l_B^I, \alpha^I)$ and $\tilde{\Pi}_B(l_B^C, l_A^C, \alpha^C) > \Pi_B^\star(l_B^I, l_A^I, \alpha^I)$.*

The result on platform profits is straightforward as well and again arises directly from reduced competition to attract developers under compatibility than under incompatibility. Compatibility makes it less likely for platforms to lower prices to attract developers as this lowering of prices also benefits their rivals. This implies that both platforms set higher developer participation fee under compatibility (see Proposition (1)). Interestingly, even the advertising intensity on platform B is higher as lowering the advertising intensity implies higher demand of platform B which increases the mass of developers on both platforms and benefits platform A.

Consumer surplus: Towards computing the consumer surplus in the market, we first define the equilibrium indifferent consumers in the incompatibility case and compatibility case respective as follows.

$$r^I \triangleq P_A(\Delta_A^\star(l_A^I, l_B^I, \alpha^I), X^I) - \Delta_A^\star(l_A^I, l_B^I, \alpha^I)$$

and

$$r^C \triangleq P_A(\tilde{\Delta}_C(l_A^C, l_B^C, \alpha^C), X^I) - \tilde{\Delta}_C(l_A^C, l_B^C, \alpha^C).$$

Thus, consumer surplus under incompatibility is given as

$$CS^I \quad \triangleq \quad \int_{r^I}^1 (r + \theta\Delta_A^\star(l_A^I, l_B^I, \alpha^I) - P_A(\Delta_A^\star(l_A^I, l_B^I, \alpha^I), X^I)dr = \frac{(X^I)^2}{2}.$$

Similarly, the consumer surplus compatibility is given as

$$CS^C \quad \triangleq \quad \int_{r^C}^1 (r + \theta\tilde{\Delta}_C(l_A^C, l_B^C, \alpha^C) - P_A(\tilde{\Delta}_C(l_A^C, l_B^C, \alpha^C), X^C)dr = \frac{(X^C)^2}{2}.$$

It is straightforward to observe that a sufficient and necessary statistic for comparing consumer surplus in the two compatibility regimes is just the total market output under the two regimes.

Developer surplus: Under incompatibility, the developer surplus on each market i is given by

$$DS_i^I \triangleq \int_0^{\Delta_i^\star} (\phi x_i^I - l_i^I - k)dk \text{ for } i = A, B.$$

Total developer surplus is given as

$$\begin{aligned} DS^{Tot} &\triangleq DS_A^I + DS_B^I \\ &= \frac{\begin{pmatrix} (\theta+\phi)^2(2-\theta\phi)^2(8-15\theta\phi+4\theta^3\phi-6\theta^2(1-\phi^2))^2 \\ +4(6+\theta^3\phi-2\phi^2-\theta\phi(8-\phi^2)-2\theta^2(1-\phi^2))^2(2\phi+\theta(3-2\phi(\theta+\phi)))^2 \end{pmatrix}}{2\mathcal{X}^2} \end{aligned} \tag{43}$$

Under compatibility, the developer surplus is given by

$$DS^C \triangleq \int_0^{\tilde{\Delta}^C(\cdot)} (\phi X^C - l_A^C - l_B^C - k)dk = \frac{25(\theta+2\phi)^2}{2\left(48-5\theta^2-31\theta\phi-2\phi^2\right)^2}.$$

Comparing the consumer surplus and developer surplus under incompatibility with compatibility, we present our results in the following proposition.

Proposition 3 (**Consumer surplus and developer surplus**). *Total consumer surplus in the platform market is higher under incompatibility than under compatibility. Total developer surplus is unambiguously higher under incompatibility than under compatibility.*

Comparing the total market output under compatibility with the total market output under incompatibility, we find that the total market output is higher under incompatibility. A direct consequence of this is that the total consumer surplus is higher under incompatibility than under compatibility. Under compatibility, platforms compete less fiercely on the developer side as developers always multi-home. A consequence of this is that platform's do not have incentive to expand output as it indirectly also benefits their rivals. This inter-platform demand spillover through compatibility lowers consumer surplus. A similar argument applies to the developer side of the market. Compatibility increases the developer participation fee while avoiding duplication of development costs associated with each. We find that the developer benefit from efficiencies afforded by compatibility are outweighed by the negative impact arising from a a lack of competition on developer side. As a result, surprisingly, developer surplus also falls under compatibility in comparison to the incompatibility case.

Total Welfare: We compute total welfare in the economy as the sum of surpluses of all the market participants. Specifically, total welfare under incompatibility and under compatibility is given as

$$TW^I \triangleq CS^I + DS_A^I + DS_B^I + \Pi_A^\star + \Pi_B^\star + 2\pi^I,$$

and

$$TW^C \triangleq CS^C + DS^C + \tilde{\Pi}_A + \tilde{\Pi}_B + 2\pi^C.$$

Comparing consumer surplus in the two regimes, we discuss the results in the following Proposition.

Proposition 4 (**Total Welfare**). *Total welfare is higher under incompatibility than under compatibility.*

The above result suggests that policy makers should be careful when designing compatibility regimes as it may be detrimental to their objective. Specifically, if the objective of policy makers is to increase consumers' and developers' surplus, compatibility on the developers' side may not be ideal as it actually lowers the surplus of these participants. Instead such a compatibility regime strengthens the profitability of platforms as it lowers the incentive of platforms to set lower developer fees thus hurting both consumer and developer developer participation on the platform. Ignoring the above two goals, suppose policy makers choose to implement compatibility to enhance total welfare, we find that mandated compatibility lowers the total surplus implying that platform profit increase (under compatibility) is not enough to compensate for the losses experienced by other market participants. Thus, suggesting that this form of compatibility may be grossly misaligned with the objectives of policy makers.

6 Mandated Compatibility on Consumer side

Another approach to model compatibility is to allow consumers to multi-home and access apps from competing stores. This, in fact, has recently become a EU legislation through the Digital Markets Act (Article 6 (c)) which includes the obligation for gatekeepers like Apple and Google to "allow the installation and effective use of third party software applications or software application stores using, or interoperating with, operating systems of that gatekeeper and allow these software applications or software application stores to be accessed by means other than the core platform services of that gatekeeper".[10]

In our model, this form of compatibility implies that consumers in an ecosystem have access to and derive value from developers on both the ecosystems. Specifically, by virtue of buying one device, consumers can access applications present on both the ecosystems and thus form expectations accordingly. This implies (multi-homing) developers do not have to multihome in order to interact with consumers of different app stores as consumers have access to more than one app store in their mobile device. As a consequence of this, developers enjoy the benefits of multi-homing (expanded consumer demand) without the need to incur additional development costs. This implies that developers do not have incentives to multihome between ecosystems. In equilibrium, by affiliating with one app store, developer can interact again with all consumers joining platforms A and B, receiving network benefit $\phi(x_A^e + x_B^e)$ (See the expressions presented in equations (2) and (3)).

[10]See link for further details on European policy making discussions.

We solve the model backwards. The outcome of the output setting stage ($t = 3$) and expectations formation stage ($t = 2$) are identical with minimal changes.[11] The main difference to the previously studied compatibility regime arises in stage $t = 1$.

Advertising intensity and developer fee setting stage. In stage 1, while platform A sets participation fee l_A to developers to maximize profits, platform B sets participation fee l_B and advertising intensity α to maximize profit. Thus, their maximization problem is given as in equations (36) and (37).

Before we proceed further, recall that consumers on a platform can access developers affiliated with both the platforms. Therefore, developers do not have to multi-home and just choose to affiliate with one of the platform ecosystems. From the perspective of developers the two platforms are identical as they offer access to identical masses of consumers and therefore participation fee charged by a platform is the only differentiating factor. As a result, developers choose the platform that sets the lowest participation fee and thus, platforms are engaged in a Bertrand competition over developersâ participation fees. There exists no equilibrium in which the two platforms charge a positive participation fee to developers. This is because given any positive fee charged by a platform, the rival platform always has incentives to undercut the price of it's rival in order to attract the single-homing developers and benefit from the developer revenue. Similarly, platforms will not set negative fees. This is because setting negative fees and attracting developers will directly benefit the rival platform. From a candidate negative participation fee, each platform has incentive to free-ride on the rival setting a negative fee. Therefore, the only candidate equilibrium is participation fees being set at zero. In equilibrium:

$$l_A^{CC} = 0 \text{ and } l_B^{CC} = 0.$$

Given these equilibrium participation fees, platform B sets advertising levels α to maximize its profit. Differentiating the expression for platform B's profit with respect to α and solving yields the equilibrium advertising intensity. We perform some comparative statics and discuss the equilibrium fees in the following Lemma..

Lemma 5 (**Developer fees and advertising intensity**). *The equilibrium developer participation fee set by either platform is given by $l_A^{CC} = 0$ and $l_B^{CC} = 0$. The equilibrium advertising intensity set by platform B is $\alpha^{CC} \triangleq \frac{1}{4-2\theta\phi}$. This advertising intensity is always rising in θ and ϕ.*

An increase in θ or ϕ implies that the value generated from network interactions increases, this makes it profitable for platform B to set higher advertising intensity and extract some of the surplus generated on the consumer side. This is because on the developers' side there is no possibility of profitably changing developer participation fees. Before we proceed further, it is important to note that the advertising intensity under compatibility is higher than the advertising intensity under incompatibility — i.e., $\alpha^{CC} > \alpha^I$. From equation (21), one can observe that

[11] For more details on this, see the output and developer demand expression as presented in equations (28) - (31).

setting $l_B = 0$ eliminates the developer effect which negatively impacts the incentive to increase α. Therefore, it is not surprising that the advertising intensity is higher under compatibility.

Substituting these equilibrium outcomes into platform outputs and profits yields the equilibrium output at platform A and B and the total market output which are given as

$$\begin{aligned} x_A^{CC} &\triangleq \tilde{x}_A(0,0,\alpha^{CC}) = \frac{3-2\theta\phi}{8-1\theta\phi 0+3\theta^2\phi^2},\ x^{CC} \triangleq \tilde{x}_i(0,0,\alpha^{CC}) = \frac{1}{8-6\theta\phi}, \\ x_B^{CC} &\triangleq \tilde{x}_B(0,0,\alpha^{CC}) = \frac{2}{8-6\theta\phi},\ X^{CC} \triangleq x_A^{CC} + 2x_B^{CC} = \frac{5-3\theta\phi}{8-10\theta\phi+3\theta^2\phi^2}. \end{aligned}$$

The total mass of developers active in the platform ecosystem is

$$\Delta^{CC} \triangleq \phi X^{CC}.$$

Substituting these equilibrium outputs into platform profits yields equilibrium profits as

$$\Pi_A^{CC} \triangleq \tilde{\Pi}_A(0,0,\alpha^{CC}) = \frac{(3-2\theta\phi)^2}{(4-3\theta\phi)^2(2-\theta\phi)^2} \tag{44}$$

$$\Pi_B^{CC} \triangleq \tilde{\Pi}_B(0,0,\alpha^{CC}) = \frac{1}{16-20\theta\phi+6\theta^2\phi^2} \tag{45}$$

We perform some comparative statics and present our results in the following proposition.

Lemma 6 (**Platform outputs and profits.**). *Under compatibility on the consumer side, the individual output of each device seller on platform B, the output of platform A, the total market output and the profits of platforms A and B increase as value of network interactions (θ or ϕ) increases.*

Since, participation fees do not depend anymore on network effects and are zero, any increase in network interaction parameters θ and ϕ only adds value to the ecosystems and has a positive impact on outputs and profits. The profit of decice sellers on platform B is given as

$$\pi^{CC} \triangleq (x^{CC})^2.$$

Collorary 2 on profits of the device sellers on platform B still applies in this extension.

6.1 Competitive and welfare implications of mandated compatibility on the consumer side

In the following, we discuss how platform profits, consumersâ surplus and developersâ are impacted by mandated compatibility.

Proposition 5 (**Platform profit comparison.**). *Under compatibility on the consumer side, profit of of the (the device-funded) platform A is higher than under incompatibility if and only* *if $\theta > \max\{\theta_A^{CC}, 0\}$. Profit of the (the ad-funded) platform B is higher under compatibility than under incompatibility if and only if $\theta > \theta_B > \theta_A^{CC}$.*

The result on platform profits is more nuanced in comparison to the benchmark model. We find that both the platform profits are higher under compatibility than under incompatibility when the value of network interactions is sufficiently high. Although, mandated compatibility shuts down a revenue source from developers, it also lowers competition between the two platform ecosystems and that is why platform profits rise in the value of network interactions. So, when the value of network interactions are sufficiently high, the gains from reduced inter-ecosystem competition dominate any loss due to loss in revenue streams from developers.

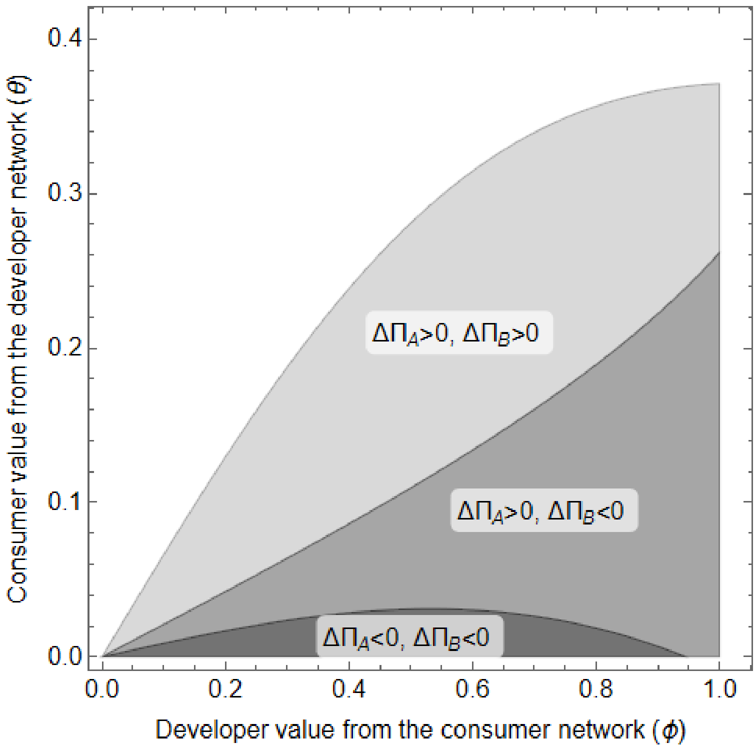

Figure 1: Platform profit comparison under compatibility vis-á-vis incompatibility — i.e., $\Delta\Pi_i = \Pi_i^{CC} - \Pi_i^I$ for $i \in \{A, B\}$.

Consumers' and Developers' Surplus. The expression for consumers' surplus is as in the benchmark model and after making the appropriate changes, it is given as

$$CS^{CC} \triangleq \int_{r^{CC}}^{1} (r + \theta\Delta^{CC} - P_A(\Delta^{CC}, X^{CC}))dr = \frac{(X^{CC})^2}{2}.$$

It is straightforward to observe that a sufficient and necessary statistic for comparing consumer surplus in the two compatibility regimes is just the total market output under the two regimes.

The expression for developers' surplus is derived as follows:

$$DS^{CC} \triangleq \int_0^{\Delta^{CC}} (\phi X^{CC} - k)dk = \frac{\phi^2(5-3\theta\phi)^2}{2(4-3\theta\phi)^2(2-\theta\phi)^2} = \frac{(\phi X^{CC})^2}{2}.$$

The total welfare is given as

$$TW^{CC} \triangleq CS^{CC} + DS^{CC} + \Pi_A^{CC} + \Pi_B^{CC} + 2\pi^{CC}.$$

In the following, we discuss the impact of mandated compatibility on consumers' and developers' surplus.

Proposition 6 (**Consumer surplus and developer surplus comparison.**). *Total consumer surplus in the platform market is higher under incompatibility than under compatibility on the consumer side if and only if* $\theta > \theta_{CS}^{CC}$. *Total developer surplus is unambiguously higher under compatibility than under incompatibility on the developer side.*

The results on consumer surplus are nuanced and intuitive. Comparing the total market output under compatibility on the developer side with the total market output under incompatibility, we find that the total market output is higher under compatibility only if network effects are sufficiently large. A direct consequence of this is that in this case also the total consumer surplus is higher under incompatibility than under compatibility. The following figure plots the regions where consumer surplus is higher or lower under compatibility vis á vis incompatibility.

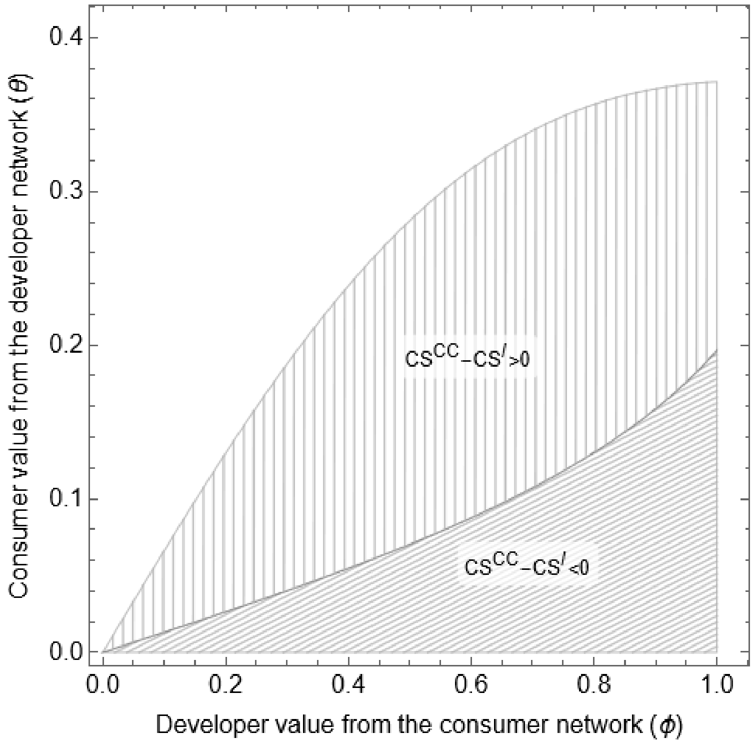

Figure 2: The area shaded with vertical lines depicts the region where consumer surplus is higher under compatibility vis á vis incompatibility — i.e., $\Delta CS \triangleq CS^{CC} - CS^{I} > 0$. The gray shaded region depicts the region where where consumer surplus is lower under compatibility vis á vis incompatibility.

Compatibility presents the following trade-off. On the one hand, it lowers competition between the platforms and on the other hand it expands the mass of active developers on the market as participation fees are zero. As a can be observed in Figure (3), when the value of network interactions is large, consumer value gain arising from increased interaction volume with developers dominates any losses arising from lowered inter-platform competition. In contrast to the benchmark case, developers' surplus is always higher under compatibility than under incompatibility. This is a direct consequence of participation fees set at zero.

Combining the above results, we discuss the impact of mandated compatibility on the total welfare.

Proposition 7 (**Total Welfare**)**.** *Mandated compatibility on the consumer side always leads to higher welfare than the incompatibility regime.*

From the previous Proposition (6), we know that consumers' surplus and developers' surplus is always higher under compatibility than under incompatibility. Interestingly, we find that even if platform profits fall under compatibility, total welfare in the economy is higher. This suggests that the increase in consumers' and developers' surplus outweighs despite a fall in platform profits. This result comes directly from the fact that such a regulation enhances competition for developers and drives down developer participation fees. In addition to lowered developer fees, developers' participation is further enhanced as they need to participate only on one platform and can interact with consumers on both platforms thus, saving them additional development costs. These two reinforcing and positive effects enhance developers' participation such that even consumers are better off due to increased interactions with developers despite higher advertising intensity on consumers on platform B.

Interestingly, we find that compatibility can result in Pareto improvement where all market participants can benefit from the fruits of the mandated compatibility regime.

Proposition 8 (**Pareto improvement due to mandated compatibility.**). *Mandated compatibility on the consumer side can be a win-win outcome which enhances the value of all market participants when* $\theta > \{\theta_B, \theta_{CS}^{CC}\}$.

This result is a direct consequence of the results presented in the previous Propositions. For large enough value of network interactions, platform profits and consumer surplus are higher under compatibility. Additionally, we know that developers are always better off under compatibility. All these results together imply that there can be a Pareto improvement due to mandated compatibility. This is an important result which states that the regulation being discussed in the Digital Markets Act (DMA) which can be viewed as consumer side compatibility can make all market participants better off and lead to a win-win outcome, at least, in network markets with strong network effects.

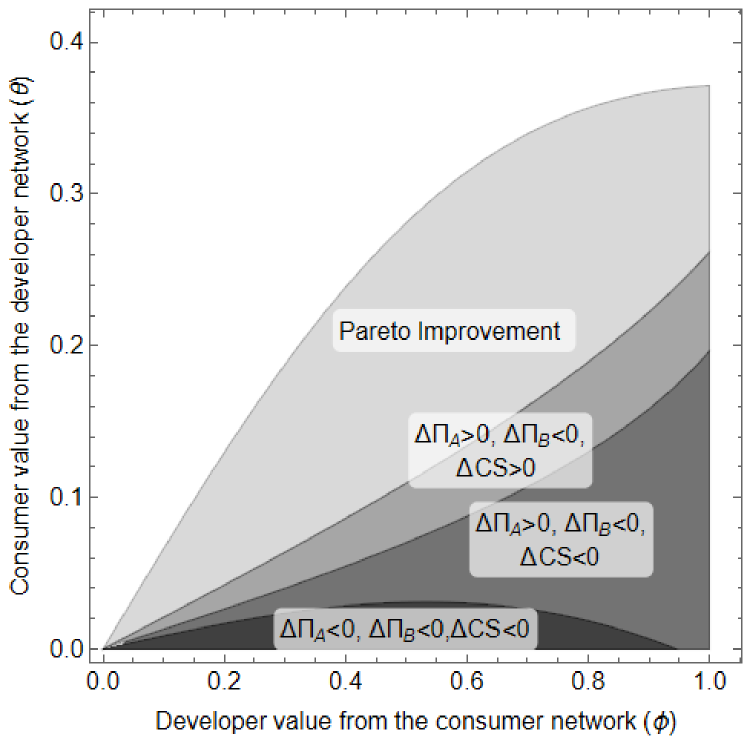

Figure 3: Combining the profit results in Figure (1) and the Consumer Surplus results in Figure (2), this figure plots the region where we obtain Pareto Improvement under mandated (consumer) compatibility.

7 Conclusions and Extensions

In this paper, we build a stylized model that reflects the competitive dynamics of the current mobile ecosystems market where both platforms earn revenues from developers and one platform is device funded and the other platform is ad-funded while relegating the device market to competitive device manufacturers.

We study the welfare implications of two modes of mandated compatibility. The first mode refers to compatibility on the app developer side, by reducing the developers' technical cost of multihoming between two different platform ecosystems. The second mode refers to compatibility on the consumer side, by allowing consumers to multihome between two platforms at much lower cost. This second mode is in line with the EU's Digital Market Act and the U.S. Open App Markets Act, which allow consumers of one device to be able to interact with apps from both the app stores of Apple and Google.

We show that compatibility on the developer side may make consumers and developers worse off. This result is a direct consequence of the fact that compatibility makes the platforms complementary to each other on the developer side and competition between them is reduced. This leads to higher developer fees under compatibility and lower consumer surplus. This consumer harm arises from a reduction in total output in the market and thus also higher quality adjusted price along with consumers facing higher advertising intensity on the ad-funded platform under compatibility.

Platforms are the only ones that benefit from this type of compatibility. We show that mandated compatibility may solve a prisoners' dilemma type situations between platforms. This can make platforms more dominant in the expense of consumers and developers. This expected outcome of mandated compatibility may be in stark contrast with the objective of policymakers trying to curb the market power of these giant platforms.

In contrast, compatibility on the consumer side can lead in equilibrium to a Pareto improvement and it can be a win win situation for all market participants under the presence of strong network effects. We find that platform do not make revenues on the developer side under compatibility. Notwithstanding this loss in revenue stream, we find that platform profits and consumer surplus are higher under compatibility when the value of network interactions is sufficiently high. Developers are always better off as participation fees are set to zero.

There is a lot of potential for future work. Future works can endogenize compatibility as a choice variable. Moreover, it is of significant importance to understand how mandated compatibility between platforms impacts platforms long run incentives such as specific innovation vis-á-vis the status quo incompatibility regime. Due to the lack of empirical evidence on this topic, a particular effort must be made to collect, combine and analyze such evidence in order to verify modelling options and approach.

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