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Intellectual property and taxation of digital platforms

Juan Manuel Sánchez-Cartas[1]

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Abstract
I study the impact of ad-valorem and unit taxes on the intellectual property policies of two-sided digital platforms. First, I address the monopoly case, in which I show that the effects of taxes depend on which side they are levied on. If developers are taxed, I find that ad-valorem taxes reduce the platform openness and the exclusivity period granted to developers to exploit their innovations. The opposite is true when taxes are levied on users. On the other hand, the effect of unit taxes is ambiguous in general. Then, I extend the model to address the duopoly case, and I find that competition may increase welfare, but it is not guaranteed. The effects of taxes on welfare are similar in both regimes. In general, they are ambiguous, but I characterize those cases which are welfare-enhancing unambiguously. I conclude highlighting the potential impact of the Digital Service Tax (DST) proposed by the European Commission on platform openness and digital innovation in Europe.

Keywords Two-sided markets · Digital platforms · Taxation · Intellectual property · Openness

JEL Classification H22 · L13 · L51 · L86 · O34

1 Introduction

Digital platforms like Android or iOS depend on third-party developers to foster their ecosystems. To attract those developers, platforms have to offer them enough tools to innovate, and let them exploit their innovations profitably. For example, Android and iOS provide system development toolkits (SDKs) and application programming interfaces (APIs) that allow third-party developers to build new applications, such as Whatsapp, Uber, or Airbnb. Thus, via SDKs or APIs, platforms

✉ Juan Manuel Sánchez-Cartas
juanmanuel.sanchez@upm.es

[1] Universidad Politecnica de Madrid, Madrid, Spain

disclose part of their core to foster innovation (they "open" themselves), and grant developers control rights over their innovations to exploit them.

Some of those platforms have been quite successful and have created multimillionaire businesses, such as Google or Amazon, which have also attracted the attention of public authorities, who under the idea that there is a "mismatch" between where value is created and where taxes are paid, have proposed reforms of corporate tax rules. Nonetheless, given the difficulty to tax the corporate income of global digital platforms, several countries have implemented other tax instruments, such as the "YouTube Tax" in France, which taxes advertising revenues.[1] In contrast with corporate taxes, these new taxes directly influence the competition among platforms. However, could those taxes influence how control rights are allocated? In other words, could those taxes influence the intellectual property (IP) policies of platforms? Could those taxes be used to promote platform openness? How?

These questions belong to a strand of literature that has been scarcely addressed in the last decade, the competition in non-price features. As Jullien and Sand-Zantman (2019) or Foros et al. (2015) point out, the gratuity of digital platforms shifts the locus of competition from prices to the non-price features, such as privacy or intellectual property rights. In this sense, to the best of my knowledge, only Parker and Van Alstyne (2018) address the role of intellectual property rights in two-sided platforms.

Therefore, to answer those questions, I extend the Parker and Van Alstyne (2018) model, in which a monopoly chooses the openness degree and the length of the exclusivity period awarded to developers to exploit their innovations. Following this framework, I address the impact of taxation on the original model and the duopoly extension. In the monopoly case, ad-valorem taxes have clear effects on openness and the exclusivity period, but unit taxes have ambiguous effects in general. Ad-valorem taxes levied on developers reduce openness and the exclusivity period. Intuitively, the attractiveness of future profits derived from cumulative innovations is less appealing, which reduces the incentive to support third-party developers' activities. However, the impact on welfare is generally ambiguous. Only when the optimal exclusivity period is perpetual, the effect is unambiguously negative. In other words, an ad-valorem tax on developers' revenues may reduce welfare if the platform never incorporates developers' innovations to its core. This is, for example, the case of video game platforms, where developers keep the control rights over their games indefinitely. In this case, such a tax reduces the available tools for developers, their innovations, and welfare. The opposite would be true if taxes would be levied on users. In the duopoly extension, I find that, in general, competition decreases the length of the exclusivity period, but it may reduce openness, which has ambiguous effects on welfare. Nonetheless, taxes have a similar effect as in the monopoly case. The effect depends on which side taxes are levied on, and in general, when developers' revenues are taxed, the openness degree is smaller. Thus, platforms are not so prone to share their technology with

[1] https://marketinglaw.osborneclarke.com/advertising-regulation/called-youtube-tax-now-effective-france/.

developers because part of the profits of such interaction is taxed. Therefore, openness is reduced, which reduces innovation on platforms. In terms of welfare, the effects are intuitively similar to the monopoly case. When it is optimal to set a perpetual exclusivity period, taxes on developers' revenues have an unambiguously negative effect on welfare. In the rest of the cases, such effects are ambiguous. Lastly, when developers can be on both platforms at the same time (multihoming), the exclusivity period increases because multihoming mitigates competition on that side. There are no gains in competing for developers. Therefore, platforms behave as monopolies on that side, as the multi-sided theory predicts, and the intuitions about taxation are unchanged.

I conclude by highlighting how the taxation of digital platforms modifies the optimal IP policies of platforms. It matters who pays. If we tax developers or the side that creates value (apart from a pure network effect), platforms will be less open. Therefore, if the Digital Service Tax (DST) proposed by the European Commission comes into force in its current form, it may lead to a lower level of openness and innovation in the European Union.

2 Taxation of multi-sided platforms

A decade after the seminal contribution of Kind et al. (2008), there is a renewed attention to taxation of digital platforms as a consequence of their growing capacity to influence the economy.[2] At this moment, the literature agrees that tax authorities should reform and adapt their instruments to take into account the new conditions created by the emergence of the digital economy, see Bacache et al. (2015).

Up to now, the focus of the literature has been on pricing, where the effects of taxation have been well studied. For example, Kind et al. (2008) and Kind et al. (2010) find that a higher value-added tax on one side may make profitable for the platform to shift revenue from that side to the other one (from the heavily taxed to the untaxed side). These authors also find that the dominance of ad-valorem taxes that is common in one-sided markets does not hold in two-sided markets. In fact, unit taxes may yield higher welfare than ad-valorem taxes, see Kind et al. (2009).[3] Recently, Belleflamme and Toulemonde (2018) have found that transaction taxes hurt agents on both sides but benefit platforms. On the other hand, they also confirm the result found by Kind et al. (2008), that ad valorem taxes may benefit the agents that are taxed, but it may hurt agents on the other side of the market.[4]

Additionally, in a recent literature review, Bacache et al. (2015) point out that taxation distorts the investment decisions of platforms. Hence, it may hamper innovation. In that sense, it is imperative to keep a careful watch on the evolution of internet platforms.

[2] See Belleflamme and Toulemonde (2018) for a short review on this topic.

[3] In recent work, they also find that taxes may affect the political views of newspapers, see Kind et al. (2013).

[4] Other interesting works in this area are Bourreau et al. (2018), Kind et al. (2010), Kind and Koethenbuerger (2018) and Tremblay (2018).

Despite considerable research on the taxation of digital platforms, the evidence in non-price variables is scarce. For example, to the best of my knowledge, no formal analysis investigates how taxes may affect the intellectual property (IP) rights of platforms and third-party developers. It is well known that taxation distorts the investment incentives, and therefore that may hamper the innovations carried out by platforms. However, up to the date, we do not know if taxation is hampering the innovations generated by third-party developers, or if it is modifying the openness level of digital platforms. My contribution is precisely to spark the discussion about the effects of taxation on openness and IP policies of two-sided digital platforms.

3 The fundamentals of Parker and Van Alstyne model

This model encompasses a developer and a consumer that get in touch on a digital platform during three stages. The developer produces apps using the platform resources, such as APIs or SDKs. The consumer uses both, the platform and the developer's apps.[5]

The intuition of the model is the following. By giving away some IP rights, the platform offers some technologies that the developer can use to innovate upon. In return, the developer shares with the platform part of its revenues by paying royalties. After a certain amount of time, the platform absorbs the developer's IP rights and the pool of technologies available to innovate grows (cumulative innovation).

The model encompasses three stages. In the first stage, the platform sets the proportion of the platform that is open to the developer (σ),[6] and the time awarded to the developer to exploit its innovations (t). The developer sells its apps to the consumer, and it pays royalties to the platform. At the same time, the consumer pays a fee for using the app, and she pays for the non-open part of the platform. At the end of this stage, the platform absorbs the innovations that are incorporated into the pool of technologies that will be awarded to the developer in the next stage to innovate upon. The period that the developer has exclusive rights over its innovations defines the length of this stage. If $t = 0$, innovations are immediately absorbed, if $t = \infty$ innovations are never absorbed. In the second stage, the developer innovates on top of the pool of technologies that the platform has, sells apps to the consumer and, pays royalties to the platform. In the third stage, the model ends (Fig. 1).

The consumer has a uniform value v for developers' apps and a uniform value V for the platform. Nonetheless, the consumer can wait until the second stage, when the apps will be free. Therefore, the consumer is not willing to pay more than the difference between the value today (v), and the discount value of waiting for the

[5] This framework is intuitively similar to Chowdhury and Martin (2017), in which an upstream monopolist provides platforms (newspapers) with a complementary good (comics) that only some users (readers) value. In contrast, in this model, the platform itself provides the complementary good (the APIs or SDKs) and sets how long it could be enjoyed.

[6] The openness could be higher than 1, which implies that the platform is subsidizing the developer.

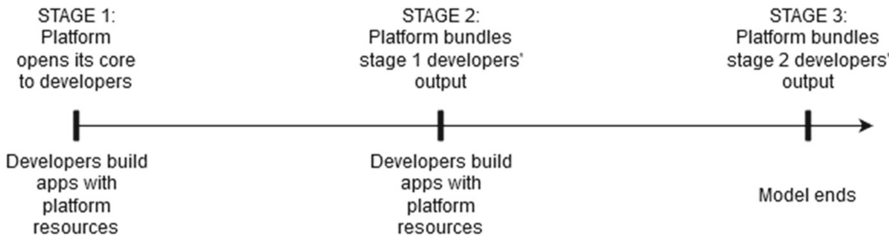

Fig. 1 Model timing

next stage (δv).[7] The maximum price she is willing to pay is $p = (1 - \delta)v$. On the other hand, the platform can sell its technology to the consumer (V), but if it sets a positive σ, its sales fall to $(1 - \sigma)V$ because part of the technology is given for free to the developer.

The developer generates innovations (apps) following a Cobb–Douglas production function, $y = k(\sigma V)^{\alpha}$. Where σV represents the open resources of the platform, k is the re-usability parameter, and α represents the diminishing returns of the technology. The output of the first stage is $y_1 = k(\sigma V)^{\alpha}$, and the output of the second stage is $y_2 = k(y_1)^{\alpha}$. Note that innovations are recursive, they are generated on top of previous innovations.

Lastly, the platform imposes a royalty on the developer's revenues. For simplicity's sake, Parker and Van Alstyne assume the Nash bargaining solution, giving each party 50%.[8] Therefore, the profits of the platform (Π) and the developer (π) are respectively

$$\Pi = V - \sigma V + \frac{1}{2}(py_1 + \delta p y_2) \tag{3.1}$$

$$\pi = \frac{1}{2}(py_1 + \delta p y_2). \tag{3.2}$$

The platform faces two trade-offs. One the one hand, it should decide how much intellectual property it gives away. By giving away intellectual property (higher σ), it increases the pool of technologies upon which the developer can innovate, and therefore, the more valuable the innovations at the second stage, and the larger the royalties. However, not giving away intellectual property allows the platform to monetize its technologies.

On the other hand, it must set the length of the period to exploit developers' innovations before they are integrated into the pool of the platform technologies (higher t, lower δ). The longer the developer keeps its rights, the higher the revenues that the platform and the developer earn in the first stage. In contrast, the sooner the technologies are absorbed, the sooner the developer can innovate upon the new set of technologies, and the larger the added-value generated in the second stage.

[7] Note that $\delta = e^{-rt}$.

[8] I keep the same assumption.

This behavior is common in digital markets. Examples of this trade-off can be found on many digital platforms, such as Facebook, Google, Apple, or eBay.[9] All of them offer APIs to developers that can use to innovate, and from time to time, they acquire some technologies by merger or acquisition. See, for example, the acquisition of Whatsapp by Facebook, or the acquisition of Paypal by eBay.

Therefore, the platform has to choose a pair $\langle \sigma^*, \delta^* \rangle$ that maximizes Eq. 3.1. In Parker and Van Alstyne's model, the optimal length of the exclusivity period has an interior and a corner solution

$$\delta^* = \begin{cases} \frac{1}{2}\left(1 - \frac{\pi_1}{\pi_2}\right) & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise.} \end{cases} \tag{3.3}$$

On the other hand, the optimal solution of σ can be implicitly found when δ^* has an interior solution. Nonetheless, σ^* has a closed-form solution when $\delta^* = 0$

$$\sigma^* = \begin{cases} \frac{\alpha(\pi_1 + \delta\alpha\pi_2)}{V} & \text{if } \delta^* > 0 \\ \frac{(v\alpha k/2)^{1/(1-\alpha)}}{V} & \text{if } \delta^* = 0. \end{cases} \tag{3.4}$$

On the one hand, when the platform chooses the length of the exclusivity period (δ), it grants to developers a short-term monopoly on their innovations in exchange for access to the platform and royalties on sales. The length of this period depends on what is more relevant to the platform; first-stage, or second-stage outputs. If stage 1 profits matter more, the platform will grant a perpetual monopoly. An example of this behavior is Valve's Steam, a digital video game platform in which developers can publish their video games. The platform only takes a percentage of the sales, but let developers keep their IP over their games indefinitely. If stage 2 profits matter more, the platform will absorb those innovations into the corpus of open innovation resources at some point in time. For example, Microsoft has absorbed innovations such as disk defragmentation, encryption, streaming media, and web browsing, then opened APIs to allow access to these new layers. Normally, first-stage profits would matter more in those cases in which there are no big cumulative innovation effects. That is the case, for example, in industries where there are niche innovations that cannot be easily exploited by other developers in other areas, such as the design of a videogame.

On the other hand, when setting how open the platform should be, two effects are at play. The platform balances the revenues from sharing in developer profits and the sales of the platform. The larger the gain from sharing in developer profits, the more open the platform is. The higher the stand-alone value (V), the larger the platform sales, the less open the platform is. Therefore, the optimal openness degree depends on a proper balance between the prospects of revenues from these two

[9] Nowadays, Google or Apple themselves generate fewer innovations than Android or iOS ecosystems. It has become more important the investment carried out by independent developers on the platform than the investment carried out by the owner of the platform. See, for example, Uber, Tinder, Airbnb, or Whatsapp.

sources. These results provide an alternative explanation to the coexistence of different platforms with different openness degrees, such as Matlab, TensorFlow, or Wolfram Mathematica.

3.1 Taxation: ad-valorem and unit taxes in Parker and Van Alstyne's model

The inclusion of taxes in the original model is quite natural, and it only requires a slight modification of Eq. 3.1. Let's denote by τ^{vat} the ad-valorem tax, and by τ^{sp} the unit tax, and let's assume that the tax affects the revenues coming from royalties only,

$$\begin{cases} \Pi = V - \sigma V + \frac{1}{2}\left(\frac{py_1 + \delta py_2}{1 + \tau^{vat}}\right) & \text{if Ad-valorem} \\ \Pi = V - \sigma V + \frac{(p - \tau^{sp})}{2}(y_1 + \delta y_2) & \text{if Unit tax.} \end{cases} \tag{3.5}$$

Likewise the original model, platforms profits are well behaved, and it exists a unique pair $\langle \sigma^*, \delta^* \rangle$ that maximizes Π. There are two solutions too, an interior and a corner solution. Following Parker and Van Alstyne's expressions, the optimal lengths of the exclusivity period and the openness degree with ad-valorem taxes are respectively,

$$\delta^* = \begin{cases} \frac{1}{2}\left(1 - \frac{\pi_1}{\pi_2}\right) & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise} \end{cases} \tag{3.6}$$

$$\sigma^* = \begin{cases} \frac{\alpha(\pi_1 + \delta\alpha\pi_2)}{V(1 + \tau^{vat})} & \text{if } \delta^* > 0 \\ \frac{(v\alpha k/2(1 + \tau^{vat}))^{1/(1-\alpha)}}{V} & \text{if } \delta^* = 0. \end{cases} \tag{3.7}$$

Apparently, ad-valorem taxes only influence the openness decision. However, a reduction in the openness leads to a reduction of the exclusivity period, $\frac{\partial\delta}{\partial\sigma} < 0$, and by the implicit function theorem, $\frac{\partial\sigma}{\partial\delta} < 0$. Therefore, in a monopoly framework, an increase in ad-valorem taxes levied on developers unambiguously reduces openness and the exclusivity period. Intuitively, in a similar way as Kind et al. (2008), the tax creates an incentive to profit from selling proprietary software, $(1 - \sigma)V$. The tax reduces openness, which reduces the potential cumulative innovation. Therefore, the royalties extracted from developers become less attractive from the platform's point of view.

On the other hand, if we consider the unit taxes, the optimal δ and σ are,

$$\delta^* = \begin{cases} \frac{1}{2}\left(1 - \frac{\pi_1}{\pi_2} - \frac{\tau^{sp}}{v}\right) & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise} \end{cases} \tag{3.8}$$

$$\sigma^* = \begin{cases} \dfrac{\alpha(v(1-\delta)-\tau^{sp})(y_1+\delta\alpha y_2)}{2V} & \text{if } \delta^*>0 \\ \dfrac{((v-\tau^{sp})\alpha k/2)^{1/(1-\alpha)}}{V} & \text{if } \delta^*=0. \end{cases} \tag{3.9}$$

Contrary to the previous case, unit taxes have a direct positive effect on the period of exclusivity, and a direct negative effect on the openness. Following the previous reasoning, the unit tax has ambiguous effects. The tax directly increases the exclusivity period and reduces the openness degree, but it also leads to an indirect reduction of the exclusivity period when ($\delta^* > 0$). However, when it is optimal to set a perpetual exclusivity ($\delta^* = 0$), the tax unambiguously leads to lower platform openness. The intuition is similar to the previous case, the platform tries to compensate the tax by profiting from the other side. Therefore, taxes levied on developers may lead to a reduction of openness. In the case of digital platforms, such as Valve's Steam, it would imply that fewer resources would be available to developers to innovate, and the platform would be more focused on selling its proprietary software.

On the other hand, instead of levying the taxes on developers, let's tax the proprietary software sales. In this case, Eq. 3.1 becomes

$$\begin{cases} \Pi = \dfrac{V-\sigma V}{1+\tau^{vat}} + \dfrac{1}{2}(py_1+\delta py_2) & \text{if Ad-valorem} \\ \Pi = (V-\tau^{sp})(1-\sigma) + \dfrac{p}{2}(y_1+\delta y_2) & \text{if Unit tax} \end{cases} \tag{3.10}$$

Maximizing those profits with respect to δ and σ shows that the expression of the optimal length of the exclusivity period does not change when taxes are levied on users' sales.

$$\delta^* = \begin{cases} \dfrac{1}{2}\left(1-\dfrac{\pi_1}{\pi_2}\right) & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise} \end{cases} \tag{3.11}$$

Taxes have no direct impact on the exclusivity period, but it is influenced by how taxes affect the openness.

$$\sigma^*_{vat} = \begin{cases} \dfrac{\alpha(1+\tau^{vat})(\pi_1+\delta\alpha\pi_2)}{V} & \text{if } \delta^*>0 \\ \dfrac{(v\alpha k(1+\tau^{vat})/2)^{1/(1-\alpha)}}{V} & \text{if } \delta^*=0 \end{cases} \tag{3.12}$$

$$\sigma^*_{sp} = \begin{cases} \dfrac{\alpha(\pi_1+\delta\alpha\pi_2)}{V-\tau^{sp}} & \text{if } \delta^*>0 \\ \dfrac{(v\alpha Vk/2(V-\tau^{sp}))^{1/(1-\alpha)}}{V} & \text{if } \delta^*=0 \end{cases} \tag{3.13}$$

In both cases, taxes increase the openness, which indirectly leads to an increase of the exclusivity period (a reduction in δ). Intuitively, when a tax is levied on users, the platform tries to profit from the other side by increasing its openness and attractiveness to developers. Therefore, it has the opposite effects as a tax levied on developers. Such a tax may promote openness.

As a summary, when a monopoly finds optimal to set a perpetual exclusivity period (for example, Steam or other video-game platforms that allow developers to keep exploiting their innovations indefinitely), taxes on revenues coming from developers decrease platform openness, which may hamper the innovation. On the other hand, the same taxes on users may promote openness, which may foster innovation. However, when platforms grant developers a finite exclusivity period, taxes may have ambiguous results.

Proposition 1 *Taxes reduce the platform openness when levied on developers. The effects on the exclusivity period depend on the type of tax chosen. If taxes are levied on users, taxes are more likely to promote openness.*

3.2 Welfare impact of taxes

Intuitively, taxes can be used to correct market imperfections by incentivizing a different allocation of resources. To address the impact of taxes on welfare, let's identify the social optimum. Following Parker and Van Alstyne's model, the equation that determines the social planner's optimization is

$$\arg\max_{\delta,\sigma} = V + \pi_1 + \delta\pi_2.$$

But subject to a developer participation constraint, $\pi_1 + \delta\pi_2 \geq 0$. Given that the price paid by the user and the extent of platform openness are wealth transfers, both are irrelevant from a social planner point of view, see Parker and Van Alstyne (2018). In this situation, a social planner allocates all resources for innovation without delay. In other words, it sets $\langle \sigma^*, \delta^* \rangle = \langle 1, 1 \rangle$. As Parker and Van Alstyne (2018) point out, a social planner prefers an open platform that immediately discloses all the technologies, which contrasts with the private platform that never finds optimal full disclosure at $t = 0$.

Although taxes may help in closing the gap between the private platform's and the social planner's decisions, such an effect is not so clear in this model. It depends on which side the tax is levied on, and what kind of tax is adopted. For example, an ad-valorem tax on the developer's royalties reduces platform openness, which reduces welfare, but it also implies shorter exclusivity periods, which increases welfare. In the case of unit taxes, the net effect is more difficult to address because they have ambiguous effects on the exclusivity period. Only when it is optimal to set a perpetual exclusivity period ($\delta = 0$), taxes levied on users (developers) increase (reduce) welfare unambiguously.

4 The role of competition and strategic interactions: the duopoly

In this section, I extend Parker and Van Alstyne's model to consider the duopoly case. I consider there are two platforms ($j = 1, 2$), a set of homogeneous users,[10] and a set of heterogeneous developers à la Hotelling.[11] To avoid the possibility of developers changing from one platform to another at the second stage, I assume that switching costs are extremely high.[12] In comparison with the original model, this framework modifies the production function in the second stage,

$$y_{2,j} = k\left(\sum y_{1,j}\right)^{\alpha} = k^{1+\alpha} m_{e,j}^{\alpha} (\sigma_j V_j)^{\alpha^2}$$

where $m_{e,j}$ is the expected number of developers that contributed to the j-platform in the first stage. Developers' utilities are also modified in our framework. Developers are heterogeneous à la Hotelling, so they face transportation costs, $\lambda|x_i - l_j|$, where $(l_j, x_i) \in [0, 1]$, λ is the transportation cost, x_i represents the developers' position at the Hotelling segment, and l_j represents the platforms' position at the same segment. I assume platforms are at the extremes of that segment.

The intuition is the following. Developers, as well as users, have different tastes about how a platform should look like. Some developers may prefer to code on platforms based on Python, although there may be others who prefer to code on Java-based platforms. There may be those who prefer to code on a cloud-based platform, others may prefer to code on in-house platforms. This subjective part of the decision is what the Hotelling model addresses. The transportation costs represent the opportunity costs of consuming a platform that does not fit perfectly developers' tastes.[13] Therefore, when a developer evaluates the possibility of joining one of the platforms, they address the profits they would earn in the two periods, and the opportunity costs of choosing one of the platforms, $(\lambda|x_i - l_j|)$. Therefore, the developers' profit function is

$$\pi_{i,j}^{d} = \frac{p_j^e k\left(\sigma_j V_j\right)^{\alpha} + \delta_j p_j^e m_{e,1}^{\alpha} k^{\alpha+1}\left(\sigma_j V_j\right)^{\alpha^2}}{2} - \lambda|x_i - l_j|. \tag{4.1}$$

For simplicity's sake, I denote $\pi_{1,j} = p_j^e k(\sigma_j V_j)^{\alpha}$ and $\pi_{2,j} = p_j^e m_{e,j}^{\alpha} k^{\alpha+1} (\sigma_j V_j)^{\alpha^2}$ the developers' profits at the first and second stages respectively. Normally, developers cannot directly infer how many users are on a platform. Nonetheless, indirectly, by using the data, APIs, and so on, they can infer that size. That is the idea in this formulation. The utility function does not explicitly state the number of users on the

[10] The presence of heterogeneous users does not change our conclusions because developers are the ones who set the prices for their apps, not the platforms. This is a realistic approach because Google Play and the App store do not set the price for third-party apps.

[11] In the annex, I prove that this assumption does not modify the previous conclusions, but it makes the model analytically more tractable. This approach is also adopted in other works, such as Belleflamme and Peitz (2019).

[12] I assume the market is complete, and all developers want to stay in the market.

[13] Similar frameworks can be found in the multi-sided literature when addressing monopoly and duopoly models, such as Armstrong (2006), or Chowdhury and Martin (2017).

platforms, but it indirectly considers them via the resources available to developers ($\sigma_j V_j$). Additionally, I assume the developers have some expectations about the price of their production (apps) on the platforms (p_j^e).[14] Solving $\pi_{i,j}^d \geq \pi_{i,-j}^d$, I obtain the demand expressions for both platforms.[15]

$$M_j^d = \frac{1}{2} + \frac{\pi_{1,j} - \pi_{1,-j} + \delta_j \pi_{2,j} - \delta_{-j}\pi_{2,-j}}{4\lambda}. \tag{4.2}$$

Note that implicitly it is assumed that the market is covered, which is equivalent to assume that both platforms provide developers with a stand-alone value enough to compensate for any joining costs. This assumption also implies that both platforms compete for all developers. Intuitively, this stand-alone value may represent a stand-alone programming environment that developers value.[16] When developers make their decisions, they are not certain about how platforms will behave. Therefore, they have expectations about the number of other developers on the platform, and the prices they will set. In the same way, platforms are not certain about how many developers will join, but they know how their policies will influence developers pricing decisions. Platforms anticipate that developers will set $p_j = v(1 - \delta_j)$. The intuition is the following. The people behind platforms are also developers. Therefore, it makes sense to think that the developers working in the platform know how other developers will behave under specific market policies. What they cannot anticipate is the adoption of the platform.[17] In this scenario, platforms choose the openness degree and the duration of the exclusivity contract simultaneously, formally

$$\max_{\sigma_j, \delta_j} \mathit{\Pi}_j = V_j(1 - \sigma_j)n_j(\sigma_j) + \frac{1}{2}M_j^d p_j \tag{4.3}$$

where n_j represents the users that consume proprietary part of the platform. The higher the openness, the large the number of functionalities, and the higher the demand, $\frac{\partial n_j}{\partial \sigma_j} > 0$.[18] Intuitively, when platforms set their openness (σ_j), they are choosing how much technology will be available to developers, but there is another part that will remain proprietary. For example, in the case of iOS, Apple offers developers APIs and SDKs to create apps, but there is a great part of iOS that is proprietary. When users consume the iOS platform, they may not pay for some apps, but they pay for the proprietary part of the platform. Those revenues are the first term in Eq. 4.3. Therefore, Eq. 4.3 represents the optimization problem of a multi-

[14] Note that σ cannot be lower than 0, which implies the platform subsidizes the proprietary side. In this framework, a negative σ would imply that developers produce negative quantities, which is not possible. On the other hand, I assume developers always set a non-negative price for their apps.

[15] Symmetrically, M_{-j}^d.

[16] This same assumption is also made on Armstrong (2006).

[17] I solve the model without assuming any specific expectation formation process to allow clear comparisons with the Parker and Van Alstyne's framework.

[18] Current evidence highlights that digital products within a given category are highly differentiated in the eyes of the consumer; therefore, the demand for any product is hardly affected by other products, see Belleflamme and Peitz (2015), p. 557.

product firm. Note that platforms put in touch users who want to consume apps and developers that need users for their apps. Therefore, the platforms are two-sided.

Platforms profits are well behaved, and it exists a unique pair $\langle \sigma^*, \delta^* \rangle$ that maximizes Π_j. Nonetheless, I find two solutions, an interior and a corner solution ($\delta_j = 0$)

$$\delta_j^* = \begin{cases} \frac{1}{2}\left[1 - \frac{\pi_{1,j}^d - \pi_{1,-j}^d + 2\lambda - \delta_{-j}\pi_{2,-j}^d}{\pi_{2,j}^d}\right] & \text{if } 2\pi_{2,j}^d + \pi_{2,-j}^d > \Delta_1 + 6\lambda \\ 0 & \text{otherwise} \end{cases} \tag{4.4}$$

where Δ_1 represents $(\pi_{1,j}^d - \pi_{1,-j}^d)$. It is interesting to point out that Eq. 4.4 shows a clear link with Parker and Van Alstyne's model that can be observed in the interior solution

$$\frac{1}{2}\left[\underbrace{1 - \frac{\pi_{1,j}^d}{\pi_{2,j}^d}}_{\text{PV(2018)}} - \underbrace{\frac{-\pi_{1,-j}^d + 2\lambda - \delta_{-j}\pi_{2,-j}^d}{\pi_{2,j}^d}}_{\text{Duopolyeffects}}\right].$$

This expression points out that, when choosing how long should be the period of exclusivity awarded to developers, platforms take into account what other platforms do. In this case, they influence each other, and that influence is positive. They are strategic complementaries. Competition in δ leads to shorter periods of exclusivity (bigger δ). Solving the system of equations $\delta_j(\delta_{-j}), \delta_{-j}(\delta_j)$,

$$\delta_j^* = \begin{cases} \frac{1}{3}\left[\frac{2\pi_{2,j}^d + \pi_{2,-j}^d - \Delta_1 - 6\lambda}{\pi_{2,j}^d}\right] & \text{if } 2\pi_{2,j}^d + \pi_{2,-j}^d > \Delta_1 + 6\lambda \\ 0 & \text{otherwise.} \end{cases} \tag{4.5}$$

On the other hand, the optimal solution of σ depends on the equilibrium solution of δ. Therefore, two cases are possible.

$$\sigma_j^* = \begin{cases} \frac{\alpha\left(\pi_{1,j}^d + \delta_j\alpha\pi_{2,j}^d\right)}{4\lambda}\frac{v\left(1 - \delta_j^*\right)}{2V_j n_j\left(1 + \epsilon^n\right)} + \frac{\epsilon^n}{1 + \epsilon^n} & \text{if } \delta_j^* > 0 \\ \frac{\left(v\alpha p_j^e k/8\lambda\left[n_j\left(1 + \epsilon^n - \frac{\partial n}{\partial \sigma}\right)\right]\right)^{1/(1-\alpha)}}{V_j} & \text{if } \delta_j^* = 0 \end{cases} \tag{4.6}$$

where ϵ^n is the elasticity of users' demand with respect to openness. In this case, it is interesting to point out that platforms do not take into account what their competitors do in terms of openness. Nonetheless, this is a consequence of one implicit assumption, $\frac{\partial \sigma_j}{\partial \sigma_{-j}} = 0$. It is unknown to what extent this is a realistic depiction of the market. Intuitively, I have reasons to think that openness decisions are independent of each other, and they depend more on the culture of the company that supports the platforms than on the market itself. If we pay attention to Android or iOS, their IP policies differ significantly. For example, iOS has kept the same integrated structure regarding their openness since the launch of the first iPhone, despite numerous changes in the competition in the market. Although their policies have changed during this period, it seems that such changes were a consequence of other market features.[19] On the other hand, it is also interesting the role of ϵ^n. Platforms may not take into account how the other platforms set their openness, but they acknowledge that openness influences users' demand. More open platforms imply more "free" functionalities that attract users. At the same price level, platforms that offer more functionalities are more attractive. As before, the optimal σ also shows a clear link with Parker and Van Alstyne's model.

$$\begin{cases} \overbrace{\frac{\alpha\left(\pi^d_{1,j} + \delta_j \alpha \pi^d_{2,j}\right)}{V_j}}^{\text{PV(2018)}} \overbrace{\frac{\nu(1-\delta^*_j)}{8\lambda n_j(1+\epsilon^n)} + \frac{\epsilon^n}{1+\epsilon^n}}^{\text{Differentiation and Users' side effect}} & \text{if } \delta^*_j > 0 \\ \underbrace{\frac{(\nu\alpha k/2)^{1/(1-\alpha)}}{V_j}}_{\text{PV(2018)}} \underbrace{\left(p^e_j/4\lambda\left(n_j(1+\epsilon^n) - \frac{\partial n_j}{\partial \sigma_j}\right)\right)^{1/(1-\alpha)}}_{\text{Differentiation and Users' side effect}} & \text{if } \delta^*_j = 0 \end{cases} \tag{4.7}$$

The comparison between Eqs. 4.5 and 4.6, and those of the Parker and Van Alstyne's model highlights that the competition between platforms may shorten the optimal period of exclusivity and, by the implicit function theorem, it may decrease the degree of openness when $\delta^* > 0$. Nonetheless, there are other effects at stake, such as the elasticity of users' demand that promotes more open platforms. When users' demand is elastic and $\delta^*_j > 0$, platforms tend to be more open. Note that Eq. 4.6 has two terms. The first term represents the relevance of the developers' side on the openness decision, and the second one, the relevance of the users' side. When the elasticity on the users' side is large, it can counterbalance the influence of the developers' side. In the extreme case in which the users' demand is perfectly elastic, δ does not influence σ, and welfare improves unambiguously. Therefore, the impact of competition on openness depends on which term is larger. This result would explain why platforms react differently to an increase in competition. For example, in the e-Reader market, there has been a constant increase in competition in the last decade. However, Amazon Kindle has reacted to these new increases differently. In 2010, it published its first Kindle Development Kit (KDK), and later in October 2014, it was announced that future versions would not support the content created with the KDK, despite the increasing competition of Huawei and other companies.

Nonetheless, as in Parker and Van Alstyne's model, two equilibria are possible, but they depend on which region we pay attention to. An optimal positive δ is only possible if the total production at the second stage is larger than the difference in the outputs of developers on both platforms at the first stage plus the transportation costs, see Eq. 4.5. This condition points out three key results. First, similarly to

[19] See https://www.theregister.co.uk/2018/08/31/apple_privacy_policy/.

Parker and Van Alstyne (2018), to set the period of exclusivity, platforms must pay attention to how much output developers may obtain on their platforms with respect to other platforms. If the output in the first period is large, platforms set larger periods of time. In this case, platforms prefer to benefit from the royalties in this stage. On the other hand, if the output in the first period is small in comparison with the other platform, platforms prefer to reach sooner the second stage to profit from the royalties of that stage.

Second, the higher the transportation costs, the smaller the δ, and the larger the period of exclusivity. However, higher transportation costs imply less openness, which triggers a reduction in the exclusivity period. Therefore, differentiation has ambiguous effects on openness and exclusivity. Third, the higher the production of the competitor, the shorter the period of exclusivity, and the smaller the openness. Competition dissipates profits on the developers' side, and platforms prefer shifting revenues to proprietary software. Nonetheless, this result depends on the assumption that platforms are monopolies on the user side. It is interesting that, under any circumstance, it is never optimal to force immediate openness of developers' rights. The same result was found by Parker and Van Alstyne (2018), and it seems to be robust in duopolistic frameworks.

Proposition 2 *Competition leads to shorter periods of exclusivity, which calls for a lower openness. However, the net effect on openness also depends on how users' openness elasticity reacts. Therefore, the effect on openness is ambiguous a priori.*

Proof See the "Appendix". □

Interestingly, competition may not increase welfare. This result resembles the optimal monopoly platform of the multi-sided literature when network effects are strong. In this case, it is not a consequence of network effects, but a consequence of the IP policies. On the other hand, public authorities should be careful with the policies they promote. A digitalization policy that forces the use of some digital services may make users inelastic to openness, which may reduce openness and welfare.

4.1 The role of taxes: ad-valorem and unit taxes

As a robustness check, let's introduce taxes in the duopoly model. When introducing an ad-valorem tax on the developers' side, Eq. 4.3 becomes

$$\max_{\sigma_j,\delta_j} \Pi_j = V_j(1-\sigma_j)n_j(\sigma_j) + \frac{1}{2}\frac{M_j^d p_j}{1+\tau^{vat}}. \tag{4.8}$$

Respectively, when I introduce the unit tax, Eq. 4.3 becomes

$$\max_{\sigma_j,\delta_j} \Pi_j = V_j(1-\sigma_j)n_j(\sigma_j) + \frac{1}{2}M_j^d\left(p_j - \tau^{sp}\right). \tag{4.9}$$

There is a tuple $\langle\sigma^*,\delta^*\rangle$ that solves the maximization problem. In the ad-valorem tax case, Eqs. 4.5 and 4.6 become

$$\delta_j^* = \begin{cases} \dfrac{1}{3}\left[\dfrac{2\pi_{2,j}^d + \pi_{2,-j}^d - \Delta_1 - 6\lambda}{\pi_{2,j}^d}\right] & \text{if } 2\pi_{2,j}^d + \pi_{2,-j}^d > \Delta_1 + 6\lambda \\ 0 & \text{otherwise} \end{cases} \tag{4.10}$$

$$\sigma_j^* = \begin{cases} \dfrac{\alpha(\pi_{1,j}^d + \delta_j \alpha \pi_{2,j}^d)}{4\lambda(1+\tau^{vat})(1+\epsilon^n)} \dfrac{v(1-\delta_j^*)}{2V_j n_j} + \dfrac{\epsilon^n}{1+\epsilon^n} & \text{if } \delta_j^* > 0 \\ \dfrac{\left(\dfrac{v\alpha p_j^e k}{8\lambda\left(1+\tau^{vat}\right)\left(n_j\left(1+\epsilon^n\right) - \dfrac{\partial n}{\partial \sigma}\right)}\right)^{1/(1-\alpha)}}{V_j} & \text{if } \delta_j^* = 0 \end{cases} \tag{4.11}$$

Ad-valorem taxes have no direct effect on the length of the exclusivity period (Eq. 4.10), but they affect the openness decision (Eq. 4.11), which indirectly influences the length of the exclusivity period. This effect was also found in the monopoly case, and by the implicit function theorem, $\frac{\partial \sigma}{\partial \delta} < 0$ also holds. Therefore, the higher the ad-valorem taxes, the smaller the openness, and the smaller the length of exclusivity period indirectly, which triggers another reduction in the openness. In other words, the effect of ad-valorem taxes is unambiguously negative on openness. Platforms prefer to profit more by selling proprietary software ($n_j(1-\sigma_j)V_j$) like in the monopoly case. Intuitively, a tax on the advertising revenues or developers' royalties will reduce the openness degree of platforms, which may hamper innovation on those platforms. This result is especially relevant in the European context, in which several countries have either announced, proposed, or implemented a digital services tax (DST) on selected gross revenue streams of large digital companies. Although the DSTs differ significantly in their structures, all of them are levied on revenues that do not come from users directly, such as advertising or selling of data. The expected effect of those taxes is that it will be more difficult to innovate on digital platforms in Europe because platforms will reduce the available tools for developers and advertisers. Nonetheless, such a tax also reduces the exclusivity period, which increases welfare. The net effect on welfare is ambiguous, except in those cases in which the exclusivity period is perpetual. In those cases, such a tax unambiguously reduces welfare, such as video game platforms. Instead of levying the tax on developers, let's levy it on users. In such a case, Eq. 4.10 is unchanged, but Eq. 4.11 becomes

$$\sigma_j^* = \begin{cases} \dfrac{\alpha(\pi_{1,j}^d + \delta_j \alpha \pi_{2,j}^d)}{4\lambda} \dfrac{v(1-\delta_j^*)(1+\tau^{vat})}{2V_j n_j(1+\epsilon^n)} + \dfrac{\epsilon^n}{1+\epsilon^n} & \text{if } \delta_j^* > 0 \\ \dfrac{(v\alpha p_j^e k(1+\tau^{vat})/8\lambda(n_j + \epsilon^n - \dfrac{\partial n}{\partial \sigma}))^{1/(1-\alpha)}}{V_j} & \text{if } \delta_j^* = 0. \end{cases} \tag{4.12}$$

Platforms become more open. The intuition is similar to the previous case. Platforms prefer to be more open and provide larger exclusivity periods because, in that way, they can profit from developers' innovations. This result highlights that levying ad-valorem taxes on users may incentive more open platforms. Therefore, if instead of levying an ad-valorem tax on developers, it is levied on users, the proposed European DSTs may promote more open platforms and, as a consequence, more innovations. Nonetheless, a key limitation to implement those DSTs on users is that many platforms are free on the users' side, such as Facebook or Google. In those cases, there is not a clear answer, and probably, more innovative tax instruments are needed. For example, a tax based on users' data consumption.

On the other hand, in the case of unit taxes (Eq. 4.9), there is also a tuple $\langle \sigma^*, \delta^* \rangle$ that solves the maximization problem too. In this case, the Eqs. 4.5 and 4.6 become

$$\delta_j^* = \begin{cases} \frac{1}{3}\left[\frac{(v-\tau^{sp})(2\pi_{2,j}^d + \pi_{2,-j}^d) - \Delta_1 - 6\lambda v}{v\pi_{2,j}^d}\right] & \text{if } (v-\tau^{sp})2\pi_{2,j}^d + \pi_{2,-j}^d > \Delta_1 + 6\lambda v \\ 0 & \text{otherwise} \end{cases} \tag{4.13}$$

$$\sigma_j^* = \begin{cases} \frac{\alpha(\pi_{1,j}^d + \delta_j \alpha \pi_{2,j}^d)}{4\lambda(1+\epsilon^n)} \frac{v(1-\delta_j^*) - \tau^{sp}}{2V_j n_j} + \frac{\epsilon^n}{1+\epsilon^n} & \text{if } \delta_j^* > 0 \\ \frac{\left(\frac{(v-\tau^{sp})\alpha p_j^e k}{8\lambda(n_j(1+\epsilon) - \frac{\partial n}{\partial \sigma})}\right)^{1/(1-\alpha)}}{V_j} & \text{if } \delta_j^* = 0 \end{cases} \tag{4.14}$$

The direct effect of unit taxes is to increase the exclusivity period and reduce openness. Nonetheless, it also changes the threshold at which platform set $\delta_j = 0$, which implies that platforms are more willing to let developers keep their rights. However, there are indirect effects at play. An increase in the exclusivity period increases openness, which is also directly reduced by the tax. Depending on which of these two effects are larger, the exclusivity period would increase/decrease, which at the same time is affected by the change in the threshold of δ^*. Therefore, in this case, the effect of the tax is ambiguous when $\delta^* > 0$. On the other hand, if $\delta^* = 0$, there is an unambiguously negative effect on openness. In other words, putting aside the difficulties in implementing such a tax, it seems that a unit tax levied on developers' revenues is more complicated to evaluate from a social planner's point of view.

Instead of levying the unit tax on the developer's side, let's levy it on the other side. In this case, Eq. 4.5 is unchanged, but Eq. 4.6 becomes

$$\sigma_j^* = \begin{cases} \dfrac{\alpha(\pi_{1,j}^d + \delta_j \alpha \pi_{2,j}^d)}{4\lambda} \dfrac{v(1-\delta_j^*)}{2(V_j - \tau^{sp}) n_j (1+\epsilon^n)} + \dfrac{\epsilon^n}{1+\epsilon^n} & \text{if } \delta_j^* > 0 \\ \dfrac{\left(\dfrac{v V_j \alpha p_j^e k n_{1,j}}{8\lambda (V_j - \tau^{sp})(n_j + \epsilon^n - \dfrac{\partial n_{1,j}}{\partial \sigma_j})} \right)^{1/(1-\alpha)}}{V_j} & \text{if } \delta_j^* = 0 \end{cases} \tag{4.15}$$

In this case, the previous results are reversed, and the unit tax increases openness and the exclusivity period. As before, this increase is more important when platforms set $\delta = 0$.

These results point out that taxation modifies how platforms make profits, as predicted by Kind et al. (2008). However, this time is not the mechanism of prices, but the IP policies. Therefore, the consequences of a digital tax could be larger than initially thought because its impact is not limited to prices, which makes even more difficult to evaluate its consequences in terms of welfare.

Proposition 3 *If taxes are levied on developers, platforms become less open, and the set of tools available to innovate is smaller. If taxes are levied on users, platforms tend to set more open IP policies, which may promote innovation. However, the effects on welfare are ambiguous.*

Proof See the "Appendix". □

The taxation of digital platforms modifies the optimal intellectual property policies of platforms. It is reasonable to think that the DST proposed by the European Commission would reduce platform openness in Europe. Nonetheless, this result depends on the openness elasticity of users' demand. In the end, the tax incidence depends on the elasticity, as classical theory predicts, but in this case, it is not the price elasticity, but the openness elasticity. This result has relevant implications because it highlights that the assessment of the real tax incidence of such a tax is more complicated. Price and openness elasticities must be taken into account jointly.

Nevertheless, these results depend on the assumption of singlehoming developers, which may not be realistic in some settings. In the following section, I relax this assumption.

5 Use of both platforms at the same time: multihoming developers

Many apps are available on several platforms. For example, Facebook, Airbnb, Tinder, or Uber are available on Google Play and the App Store. This is an essential characteristic of digital markets. Users normally have one kind of device only (an Android smartphone or an iPhone), and developers normally make their apps available on both platforms. In other words, developers multihome.

In this section, I relax the singlehoming assumption, and I consider that developers can multihome. Therefore, the profit of a developer who multihomes is

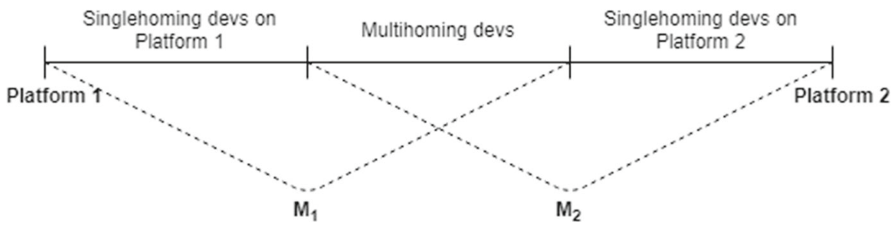

Fig. 2 Market structure with multihoming developers

$$\pi_{mh}^{d} = \frac{\pi_{1,j} + \pi_{1,-j} + \delta_j(\pi_{2,j} + \pi_{2,-j})}{2} - \lambda. \tag{5.1}$$

Platforms address two different kinds of developers. Those who multihome, and those who singlehome. That implies two immediate consequences. First, total demand will be higher than one, because there are developers on both platforms. Second, demands are formed by two different populations of developers (Fig. 2).[20]

To characterize the demands addressed to each platform, I identify the marginal developers between singlehoming and multihoming on both platforms. Formally, $\pi_{mh}^{d} \leq \pi_j^d$ and $\pi_{mh}^{d} \leq \pi_{-j}^{d}$. Solving these two expression,

$$x_1 \leq 1 - \frac{\pi_{1,-j} + \delta_{-j}\pi_{2,-j}}{2\lambda}$$
$$x_2 \geq \frac{\pi_{1,j} + \delta_j\pi_{2,j}}{2\lambda}$$

Using these expressions, I can directly derive the demands

$$M_j^d = m_{sh}^d + m_{mh}^d = \frac{\pi_{1,j} + \delta_j\pi_{2,j}}{2\lambda} \tag{5.2}$$

Note that $M_1 + M_2 > 1$ if $m_{mh}^d > 0$, which I assume. Then, I solve Eq. 4.3 using this new demand function, and I find that the expression of the interior solution of σ does not change too much. In fact, the only change is the constant in the denominator, which is smaller in this case.

On the other hand, in the case of δ, I find that the interior solution is the same as in Parker and Van Alstyne (2018). The presence of multihoming developers mitigates the competition between platforms. They behave like monopolies with respect to developers when setting the exclusivity period.[21] When developers multihome, their decision of joining an extra platform only depends on whether or not joining it provides a non-negative utility. Therefore, its demand is independent of the other platform. It is more inelastic. Because it only matters whether or not each platform provides non-negative utility, platforms do not compete for them, and

[20] A similar approach can be found in Choi et al. (2010).

[21] However, because of a larger σ and $\frac{\partial \delta}{\partial \sigma} < 0$, the δ^* would be lower than in the monopoly.

the monopoly equilibrium arises. Thus, it seems that competitive bottlenecks extend to non-price competition naturally, see Armstrong (2006).

In this situation, it is also interesting to address the impact of taxes. Solving Eq. 4.8 with the demand derived in this section, I find that there are no changes in the effect of ad-valorem taxes. On the other hand, when unit taxes are levied on developers, I find that Eq. 4.13 becomes

$$\delta_j^* = \begin{cases} \frac{1}{2}\left[1 - \frac{\pi_1}{\pi_2} - \frac{\tau^{sp}}{v}\right] & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise} \end{cases} \tag{5.3}$$

which is equal to Eq. 3.8. Lastly, there are no big changes in σ as a consequence of multihoming, and therefore, the effect of taxation will be the same as in the monopoly model.

Proposition 4 *When there are multihoming developers, platforms set their monopolistic exclusivity period. The effects of taxation are not qualitatively different from those in the singlehoming case.*

Therefore, promoting multihoming may counterbalance the welfare effects of competition. For example, when competition increases welfare, multihoming reduces it. In those cases, switching costs that hinder multihoming may be pro-competitive, as Lam (2017) found.

6 Conclusions

Under the idea that there is a disconnect- or 'mismatch'-between where value is created and where taxes are paid, the European Commission has proposed a reform of corporate tax rules that will come into force in 2020.[22] As KPMG (2018) points out, the Digital Service Tax (DST) should be seen in the context of fighting against base erosion and profit shifting (BEPS) but also, it has a clear objective of collecting revenues from the digital markets, which are becoming more and more relevant each day. Different works have highlighted possible consequences of such tax in platforms markets, such as Kind et al. (2008) and Kind and Koethenbuerger (2018), but they have focused on the price structure.

In this work, I address the impact of taxation on the intellectual property policies of two-sided digital platforms by extending the monopolistic framework of Parker and Van Alstyne (2018). First, I find that ad-valorem taxes reduce openness and the exclusivity period when levied on developers. On the other hand, unit taxes have ambiguous effects in general, but they reduce openness when the exclusivity is perpetual. From the social planner's point of view, such taxes have opposite effects depending on which side they are levied on. When extending the model to the duopoly, I find that competition shortens the length of the exclusivity period, but it may reduce openness, which has ambiguous effects on welfare. Interestingly, competition may not increase welfare. In fact, it depends on whether users'

[22] https://ec.europa.eu/taxation_customs/business/company-tax/fair-taxation-digital-economy_en.

openness elasticity dominates the effects of the developers' side. Additionally, I confirm a previous result highlighted by Parker and Van Alstyne (2018); it is never optimal to force immediate disclosure of developers' rights from the platforms' point of view, although it is optimal from the social planner's.

When I introduce taxes in the duopoly, I find the same results as in the monopoly case. The taxation of digital platforms modifies the optimal intellectual property policies of platforms. If we tax developers' activities, platforms become less open, and the set of tools available to developers is smaller. This conclusion also applies to advertisers. Taxing revenues obtained from advertisers would reduce platform openness, and innovation would be lower in that sector. Therefore, a tax levied on developers may likely harm innovation. This is especially relevant in the European context, in which the DSTs are designed in this way. If instead of levying those taxes on developers or advertisers, they would be levied on users, it would be more likely to promote more open platforms and innovation. Therefore, taxes could be used as an instrument to incentive platform openness.

Nonetheless, from a social planner's point of view, it is also important to pay attention to the exclusivity period granted to developers. Normally, a tax that increases openness tends to call for a reduction of the exclusivity period, and the opposite is also true. Therefore, taxes have ambiguous effects on welfare a priori, except in those cases in which platforms set perpetual exclusivity periods. In those cases, taxes on users unambiguously improve welfare by increasing openness. That is the case of video game platforms, where developers tend to have perpetual exclusivity periods over their games. In those cases, the current DST unambiguously reduces welfare.

However, there are two other ways to increase welfare. If competition reduces it, promoting multihoming may increase welfare. On the other hand, an increase in users' elasticities leads to a larger openness degree, which may increase welfare too. The current evidence highlights that taxes have effects beyond prices, and a proper assessment of the tax incidence should consider the IP policies too. An open question that remains unanswered is how price and openness elasticities interact in terms of the tax incidence. Another question that remains open for future research is whether or not these results hold under more general production functions.

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Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

Appendices

A: Parker and Van Alstyne model with horizontally differentiated developers

In the duopoly setting, developers are horizontally differentiated. To prove that this change does not qualitatively change the conclusions, let's extend Parker and Van Alstyne's model to accommodate such an assumption. Eq. 3.1 becomes,

$$\max_{\sigma,\delta} \Pi = V(1-\sigma) + \frac{1}{2}M^d p$$

where $M^d = \frac{p^e k(\sigma V)^{\alpha} + \delta p^e M_e^{\alpha} k^{\alpha+1}(\sigma V)^{\alpha^2}}{2\lambda}$, the monopoly demand that the platform faces on the developer's side. Likewise the original model, platforms profits are well behaved, and there exists a tuple $\langle \sigma^*, \delta^* \rangle$ that maximizes Π_j. Therefore, the optimal lengths of the exclusivity period and the degree of openness are respectively,

$$\delta^* = \begin{cases} \frac{1}{2}\left(1 - \frac{\pi_1}{\pi_2}\right) & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise} \end{cases}$$

$$\sigma^* = \begin{cases} \frac{\alpha v(1-\delta)(\pi_1 + \delta\alpha\pi_2)}{4V\lambda} & \text{if } \delta^* > 0 \\ \frac{(vp^e\alpha k/4\lambda)^{1/(1-\alpha)}}{V} & \text{if } \delta^* = 0. \end{cases}$$

Note that the optimal δ does not change, but the optimal σ is expressed differently. The transportation cost (λ) appears in the denominator, reducing the optimal σ. On the other hand, in the numerator, $v(1-\delta)$ is increasing the optimal σ. This value was included in π in the original model because it considers that the platform and developers can perfectly predict the price. In this extended version, I distinguish between the expected price that developers take into account to form their profit expectations (p^e) and the price ($v(1-\delta)$) that platforms know that developers will set under their intellectual property policies. Lastly, by the implicit function theorem, it is possible to prove that $\frac{\partial\sigma}{\partial\delta} < 0$ like in Parker and Van Alstyne's model,

$$\frac{\partial\sigma}{\partial\delta} = \frac{v\alpha[\pi_1 - \pi_2\alpha(1-2\delta)]}{-\sigma 4\lambda V + v(1-\delta)\alpha^2[\pi_1 + \alpha^3\delta\pi_2]} < 0$$

With respect to taxes, the optimal δ and σ become,

$$\delta^*_{vat} = \begin{cases} \frac{1}{2}\left(1 - \frac{\pi_1}{\pi_2}\right) & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise} \end{cases}$$

$$\delta^*_{sp} = \begin{cases} \frac{1}{2}\left(1 - \frac{\pi_1}{\pi_2} - \frac{\tau^{sp}}{v}\right) & \text{if } \pi_2 > \pi_1 \\ 0 & \text{otherwise} \end{cases}$$

$$\sigma^*_{vat} = \begin{cases} \frac{\alpha v(1-\delta)(\pi_1 + \delta\alpha\pi_2)}{V4\lambda(1+\tau^{vat})} & \text{if } \delta^* > 0 \\ \frac{(v\alpha k p^e/4\lambda(1+\tau^{vat}))^{1/(1-\alpha)}}{V} & \text{if } \delta^* = 0 \end{cases}$$

$$\sigma^*_{sp} = \begin{cases} \frac{\alpha(v(1-\delta) - \tau^{sp})(\pi_1 + \delta\alpha\pi_2)}{V4\lambda} & \text{if } \delta^* > 0 \\ \frac{(\alpha(v-\tau^{sp})kp^e/4\lambda)^{1/(1-\alpha)}}{V} & \text{if } \delta^* = 0 \end{cases}$$

In this general model, the conclusions remain the same as in Sect. 3.1.

B: Optimal solutions for δ and σ: Proof Proposition 2

Taking Eq. 4.3, the first-order conditions on platform profits with respect to δ_j are

$$\frac{\partial \Pi_j}{\partial \delta_j} = \frac{[1-\delta_j]v\pi^d_{2,j}}{8\lambda} - v\left(1/4 + \frac{\pi^d_{1,j} + \delta_j\pi^d_{2,j} - \pi^d_{1,-j} - \delta_{-j}\pi^d_{2,-j}}{8\lambda}\right) = 0 \tag{B.1}$$

If I rearrange terms in Eq. B.1, I arrive at the first case of Eq. 4.5. Note that the second-order conditions are

$$\frac{\partial^2 \Pi_j}{\partial \delta_j^2} = \frac{-k^{1+\alpha} v m^{\alpha}_{e,j} p^e_j (\sigma_j V_j)^{\alpha^2}}{4\lambda} < 0$$

which implies that Π_j is concave in δ_j, and by solving the first-order conditions, I obtain the maximum. Also, note that this interior solution only exists if $2\pi^d_{j,2} + \pi^d_{-j,2} > \Delta_1 + 6\lambda$. This expression can be easily derived from Eq. 4.5. Otherwise, $\delta_j = 0$, the corner solution. Taking Eq. 4.3, the first-order conditions on platform profits with respect to σ_j are

$$\begin{aligned} \frac{\partial \Pi_j}{\partial \sigma_j} &= -V_j n_{1,j} + V_j(1-\sigma_j)\frac{\partial n_{1,j}}{\partial \sigma_j} \\ &\quad + \frac{(1-\delta)v\left(\alpha\sigma_j^{\alpha-1}V_j^{\alpha}p^e_j k + p^e_j m^{\alpha}_{e,j}\alpha^2\delta_j k^{1+\alpha}\sigma_j^{\alpha^2-1}V_j^{\alpha^2}\right)}{8\lambda} = 0 \end{aligned} \tag{B.2}$$

Again, if I rearrange terms in Eq. B.2, I arrive at the first case of Eq. 4.6. In this case, the second-order conditions are

$$\frac{\partial^2 \Pi_j}{\partial \sigma_j^2} = -\,2V_j \frac{\partial n_{1,j}}{\partial \sigma_j} + V_j(1-\sigma_j)\frac{\partial^2 n_{1,j}}{\partial \sigma_j^2}$$
$$\frac{(1-\delta_j)v\Big((\alpha-1)\alpha k p_j^e \sigma_j^{\alpha-2} V_j^{\alpha} + \alpha^2(\alpha^2-1)\delta_j k^{1+\alpha} m_{e,j}^{\alpha} p_j^e \sigma_j^{\alpha^2-2} V_j^{\alpha^2}\Big)}{8\lambda} < 0 \tag{B.3}$$

it implies that Π_j is concave in σ_j, and by solving the first-order conditions, I obtain the maximum. Also, note that this interior solution only exists if $\delta_j > 0$. Otherwise, I only have to substitute $\delta_j = 0$ in Eq. B.2, and σ would be equal to the second case of Eq. 4.6, the corner solution.

Eq. 4.6 shows that σ depends on $\pi_{i,j}$, $i = 1, 2$ that also depends on σ. This situation may raise concerns about the uniqueness of the solution, but the proof is similar to the one in Parker and Van Alstyne (2018). Nonetheless, it is a little bit more tedious. For simplicity's sake, I omit it here, but it is available upon request. Lastly, Eq. 4.5 depends on σ that depends on δ, by the implicit function theorem, $\frac{\partial \sigma}{\partial \delta} < 0$. Note that σ^* is similar in both the duopoly and the monopoly frameworks.

C: Optimal solutions for δ and σ: Proof Proposition 3

Taking Eq. 4.8, the first-order conditions on platform profits with respect to δ_j are the same as before. Therefore, the previous proof applies here. On the other hand, the first-order conditions on platform profits with respect to σ_j are

$$\frac{\partial \Pi_j}{\partial \sigma_j} = -\,V_j n_{1,j} + V_j(1-\sigma_j)\frac{\partial n_{1,j}}{\partial \sigma_j} + \frac{(1-\delta)v\Big(\alpha \sigma_j^{\alpha-1} V_j^{\alpha} p_j^e k + p_j^e m_{e,j}^{\alpha} \alpha^2 \delta_j k^{1+\alpha} \sigma_j^{\alpha^2-1} V_j^{\alpha^2}\Big)}{8\lambda(1+\tau^{vat})} = 0 \tag{C.1}$$

If I rearrange terms, I arrive at the first expression of Eq. 4.11. In this case, the second-order conditions also verify that the interior equilibrium is the maximum. Nonetheless, it also exists a corner solution that is reached when $\delta_j = 0$, as in the previous case. To prove whether or not σ_j is decreasing with respect to τ^{vat}, I proceed in two parts. First, there is a direct and negative effect of τ^{vat} on σ_j, but a change in σ_j triggers a change in δ_j that influence σ_j again and so on. By the implicit function theorem, $\frac{\partial \sigma}{\partial \delta} < 0$, and by differentiating Eq. 4.5, $\frac{\partial \delta}{\partial \sigma} < 0$. Therefore, the impact of ad-valorem taxes on σ_j is negative when $\delta^* > 0$. If $\delta^* = 0$, there an unambiguously negative effect of τ^{vat} on σ_j.

Lastly, if I take Eq. 4.9, the first-order conditions on platform profits with respect to δ_j are

$$\frac{\partial \Pi_j}{\partial \delta_j} = \frac{([1-\delta_j]v - \tau^{sp})\pi_{2,j}^d}{8\lambda} - v\left(1/4 + \frac{\pi_{1,j}^d + \delta_j \pi_{2,j}^d - \pi_{1,-j}^d - \delta_{-j}\pi_{2,-j}^d}{8\lambda}\right) = 0 \tag{C.2}$$

In this case, the second-order conditions also verify that the interior equilibrium is a maximum. Nonetheless, it also exists a corner solution that is reached when $(v-\tau^{sp})2\pi_{j,2}^d + \pi_{-j,2}^d > \Delta_1 + 6\lambda v$. Lastly, if I take Eq. 4.9, the first-order conditions on platform profits with respect to σ_j are

$$\begin{aligned} \frac{\partial \Pi_j}{\partial \sigma_j} = & -V_j n_{1,j} + V_j(1-\sigma_j)\frac{\partial n_{1,j}}{\partial \sigma_j} \\ & + \frac{((1-\delta)v - \tau^{sp})\left(\alpha\sigma_j^{\alpha-1}V_j^{\alpha}p_j^e k + p_j^e m_{e,j}^{\alpha}\alpha^2\delta_j k^{1+\alpha}\sigma_j^{\alpha^2-1}V_j^{\alpha^2}\right)}{8\lambda} = 0 \end{aligned} \tag{C.3}$$

If I rearrange terms, I arrive at the first expression of Eq. 4.14. The second-order conditions also verify that the interior equilibrium is a maximum, and it also exists the corner solution that is reached when $\delta_j = 0$, like in the previous cases. To prove whether or not σ_j is decreasing with respect to τ^{sp}, the procedure is the same as before. The effect is ambiguous when $\delta^* > 0$ and negative if $\delta^* = 0$.

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