Explaining Platform Value: Membership, Usage and Competition Effects

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\textbf{Abstract.} The value of a two-sided platform to users depends critically on the variety of complementary products available for it, and on their quality. The platform owner chooses the royalties (usage) and the access (membership) fees for the developers of complementary products, and the price of the hardware for the users. Yet the quality and price of complementary products are controlled strategically by the third-party developers. The platform’s and the developers’ choices reflect the relative strength of the membership effects (how the users are attracted by the number of developers and complements) and usage effects (how the users are attracted by the quality of the available complements). We model the strategic interaction between the platform owner and its developers, and among developers that compete for the users, deriving endogenously the platform’s pricing strategy and the price and quality of complementary products. Although the price of complementary products decreases with the number of developers, the quality can increase or decrease depending on the relative strength of membership and usage effects. The combination of these two effects also affects the platform’s choice to subsidize only one side (the users) or both sides of the market. These results hinge on the developers’ competition for users within the platform, but they resonate with previous findings that pertain to competition across platforms.

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INTRODUCTION

In industries characterized by network externalities the value of a technology largely depends on the size of its user base, to the extent that a single technology standard often rises to dominance (Arthur, 1989; Schilling, 2002; Suarez, 2004). Adding to the so called direct network effects in communication markets (e.g., Katz and Shapiro 1986; Economides 1996), two-sided platform markets like videogame systems, smartphones, and tablets are also influenced by the indirect network effects (Armstrong 2003; Evans 2003; Rochet and Tirole 2003, 2006) that arise between the users of applications and the developers that affiliate with a platform to transact. It is now well understood that the indirect network effects are a crucial driver of a platform strategy in platform competition (Cennamo and Santaló 2013; Corts and Lederman 2009; Evans 2003; Shankar and Bayus 2003; Clements and Ohashi 2005). The platforms facilitate the interaction between developers and users and must aim to attract two (multiple) sides on board (Evans 2003; Rochet and Tirole 2006). The prospect of winner-take-all outcome pushes firms to use aggressive strategies to quickly grow their network, like “freemium” strategies that subsidize one side in order to attract the other side (Parker and Van Alstyne 2005; Rochet and Tirole 2003, 2006). For example, platform owners can subsidize users by selling the hardware at a price close or below the marginal cost to increase the installed base, and then charge access fees and royalties to the members on the other side (complementors) that are interested in transacting with the subsidized users. Or else, platform owners can also subsidize in part complementors for the development and marketing activities, as it happens in some cases in the videogame console industry. The firm that wins the platform competition then will manage the platform as to get the network effects going.

In more details, the indirect effects that arise between users and developers come from two sources: a membership effect, according to which members on one side enjoy greater benefits from having more members on the other side to potentially transact with, independent by the nature of the product; and a usage effect, according to which users have greater benefits from using better complementary products (Rochet and Tirole 2003). Most of the theoretical and empirical work on two-sided markets has focused on the first source of platform value (membership effect), but less is understood about the usage effect, let alone about how it interacts with the membership effect. Yet, the relevance of the usage effect, as theorized by Rochet and Tirole (2003), has been recently highlighted by few empirical studies.

In particular, a technological platform is more valuable, and thus
attractive to users when there are better and cheaper compatible applications (e.g., Binken and Stremersch 2009); a platform with smaller user base can eventually outcompete the incumbent leading platform when it offers superior quality or better consumption experience (Shankar and Bayus 2003; Zhu and Iansiti 2012). Also, platforms wherein complementors face intense levels of (within platform) competition experience a decrease in the quality and rate of innovation of their complements (Boudreau 2012). Similarly, Cennamo and Santaló (2013) provide evidence that multiple aggressive strategies used to quickly grow the size of the network can in fact undermine the quality of the compatible complementary products, and ultimately lower platform performance.

These findings point to a few important aspects that have been overlooked by previous research. First, and foremost, the price, the quality, or more generally the innovativeness of compatible applications are controlled by third-party developers who ultimately aim to sell their complementary products to the users. In other words, beyond the decision to affiliate or not with the platform, complementors make other choices that affect the value of the platform, and that depend upon the pricing strategies (membership and usage charges) chosen by the platform, which are seldom accounted for in current models. Second, it is assumed that users’ preferences for applications’ variety, i.e., membership effect, is what mainly drives their decision to join the platform; yet, the role of the price and quality of complementary products, i.e., usage effect, is not directly addressed (but see the papers cited above for empirical analyses of related issues).

These are important omissions that obscure the role of platform strategies. On the one hand, the price and quality of complementary products are influenced by the membership and usage fees set by the platform, but also, and importantly, by competition among developers for attracting platform’s users. On the other hand, besides affecting the users’ decision about which product to buy, the overall prices and quality of complementary products generate a system effect (product value system) that influences the users’ choice to buy and/or use the platform in the first place. Addressing these important gaps, and moving beyond the standard set up with competition among technological platforms and postulated network effects, we develop a theoretical model with the aim of gaining a better understanding of the links between the platform’s and the developers’ strategies, and the effect of within platform competition among developers for users. In this respect, the existing distinction between membership and usage effects provides a good starting point, yet extant formal literature does not account for the aspects illustrated above. The relationship between the platform owner and the two sides
of the market is modelled essentially as a seller-buyer relationship: The platform decides the pricing strategy, while users and developers are treated as consumers who basically make adoption decisions. Moreover, the network effects are taken as exogenous and assumed to be unchanging with respect to developers’ choices (Gawer 2014).

Our main scope in this paper is to investigate formally important and unexplored aspects of the functioning of technological platforms. Maintaining the distinction between membership effects and usage effects, we build a solvable model of within platform competition that captures the strategic interaction between a platform owner and its own developers. Our set up has the following features. First, we consider a monopoly platform that chooses the price of the hardware charged to the users, and the royalties and access fees for the developers, thus designing the price structure. The platform owner anticipates the developers’ reaction to a given price structure, and the resulting demand of the hardware and of the applications. The focus on the monopoly platform allows us to study the effects of the developers’ competition for users within the platform in isolation from the competition for developers and users across platforms. Second, we consider third-party developers that, given the platform’s pricing strategy, choose autonomously the price and quality of complementary products when competing for platform users. We model the demand of the individual products using a share-attraction framework familiar to strategy and marketing scholars (i.e., Karnani 1985), also allowing for a system effect of the complementary products on the demand for the hardware. The relative strength of membership and usage effects is the crucial aspect driving the developers’ and the platform’s strategy.

The principal insight of our analysis is that the quality of a platform’s complements can increase or decrease with higher levels of within platform competition (larger number of developers) depending on the combination of the relative strength of membership and usage effects, and of the users’ sensitivity to the price of complements. We identify two scenarios: one in which there is a negative correlation between price and quality (with strong usage effects), and one in which price and quality covary (with strong membership effects). Second, our analysis reveals how the relative strength of membership and usage effects affect the platform’s pricing strategy. Even absent competition among platforms, the optimal pricing strategy is to subsidize the users by selling the hardware at a price below the marginal cost. And the price of the hardware decreases when there are stronger usage effects. The intuition behind these results hinges on how the (negative) competition effect for the developers when they are in a greater number compares with the
(positive) indirect network effects.

Although our results about the pricing strategy of the platform on the user side mirror those in other analyses of two-sided platforms (e.g., Parker and Van Alstyne 2005), the rationale and mechanism in our model is different. As for the developers, they are always asked to pay per-unit royalties. Yet the platform could theoretically ask for a membership fee such to extract all the developers’ surplus when they obtain positive profits in equilibrium, or else subsidize them when they are too many and obtain negative profits in equilibrium. The analysis also reveals the extent to which the platform’s optimal pricing strategy and the equilibrium profits depend on the number of developers.

LITERATURE REVIEW

Our focus is on two-sided platform markets that have been defined as "businesses in which pricing and other strategies are strongly affected by the indirect network effects between the two sides of the platform" (Evans and Schmalensee 2008). Our key contribution is to disentangle the two sources of indirect network effects, namely membership and usage effects, considering their effects on the platform strategy and on the decisions about the pricing and quality of the complements provided by third-party complementors. Accordingly, our work adds to the strategy and economics studies on two-sided markets (Armstrong 2006; Boudreau 2010; Caillaud and Jullien 2003; Cennamo and Santaló 2013; Clements and Ohashi 2005; Eisenmann et al. 2006; Hagiu 2005, 2009; Rochet and Tirole 2003, 2006; Zhu and Iansiti 2012). Many of the formal models on two-sided markets analyze the optimal pricing by a platform when the end-users on the two sides of the market enjoy direct and/or indirect network effects. The typical approach is to start from a utility function with network externalities for the users, derive the number of users on the two-sides as a function of the membership fee and the usage fee charged by the platform, and then compute the optimal price scheme set by the platform. For example, Caillaud and Jullien (2003) study the equilibrium pricing when service providers compete for users whose utility is greater the greater the number of users on the other side of the market; Rochet and Tirole (2003) study platforms with usage externalities, Armstrong (2006) studies monopolist and competing platforms with membership externalities, and both models lead to a Lerner pricing formula (Rochet and Tirole 2006).

These approaches offer deep insights and provide a reasonable description of two-sided markets, but they also miss important pieces. Like

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This explains for instance the pricing strategy of platforms like Google’s search engine or Facebook’s social network, who do not charge users.
the impact that complement quality, not just variety, has on platform value via the usage effects of the indirect network externalities; or how third-party complement quality (and price) is influenced by platform pricing decisions that affect complementors’ incentives directly (via access fees and royalties) and indirectly (via the degree of within platform competition ensuing from those pricing decisions.

Our work is related to recent efforts to expand the analysis of two-sided platforms beyond the “network size” hypothesis (Boudreau 2012; Binken and Stremersch 2009; Cennamo and Santaló 2013; Gawer and Henderson 2007; Zhu and Iansiti 2012). Recent empirical analyses show that membership, or complement variety, is not the only component of a platform’s value, as the technological quality or functionality of the platform (Schilling 2002; Zhu and Iansiti 2012) and the quality of platform’s complements (Binken and Stremersch 2009) may have even more impact than complements variety on users’ adoption decision of the platform. In other words, the findings of these studies suggest that there are different components of platform value; one being related to variety of platform complements (that fuel indirect network externalities via the membership effect), one being related to quality of platform complements (that fuels indirect network externalities via the usage effect), and a last one being related to technological attributes of the platform itself (Gawer and Cusumano 2002; Baldwin and Woodard 2009). Another set of empirical studies has focused on the strategic interaction between the platform and its complementors, documenting potential conflicts that may arise and that undermines complementors’ incentives to contribute content to the platform. In this regard, it has been shown that intense within platform competition among complementors reduce the amount of complements provided to the platform (Boudreau 2012); direct competition by the platform with first-party content may have negative effects on the amount and quality of third-party content provided to the platform unless the platform put in place appropriate organizational mechanisms to reduce the threat of rent extraction (Gawer and Henderson 2007; Huang et al. 2013); and aggressive strategies by the platform to grow the user base and lock-in complementors (via exclusivity contracts) may create a ‘market for lemons’ of platform third-party content, negatively affecting platform performance (Cennamo and Santaló 2013).

Our theoretical analysis provides a rationale for many of these effects, helping to disentangle when, for instance, within platform competition has negative or positive effects on third-party content quality, the extent to which content variety and quality, captured in our model via the membership and usage effect respectively, contribute to platform value and ultimately to performance. We do not, however, allow for first-party
content strategic decision in our model; such issue is treated elsewhere (see Hagiu and Spulber 2013). Instead, we are primarily interested in how platform pricing decisions influence the strategic decisions of complementors about complement quality and price, and how these vary depending on the relative strength of membership and usage sources of indirect network effects. Also, as a first step to gain a deeper understanding of the effects of within platform competition on strategic choices of complementors, we consider the case of monopoly platform.

MODEL SET UP

We develop a parsimonious and solvable model that captures the economic forces behind two-sided platform markets like videogame systems, smartphone or tablet platforms, etc. Our analysis emphasizes the strategic interaction between a platform owner and third-party application developers. Specifically, we examine how the platform’s pricing strategy affects the price and quality of products such as applications, that are under the control of developers that compete for the users. The platform’s and the developers’ decisions ultimately determine the demand for the hardware and for the compatible applications. We relate the demand of each application to its attractiveness, which is higher when an application has a greater quality and is sold at a lower price. We then employ a share-attraction framework (see Karnani 1985 for a discussion), accounting for a system effect whereby the greater attractiveness of all the applications translates into a greater demand for the hardware.

Main variables. The platform owner produces the hardware at a constant marginal cost $C > 0$ and it controls three variables: i) the price (membership charge) $P$ that the users pay to purchase the hardware; ii) the fee (membership charge) $F$ that the developers pay (receive) to access the platform, and iii) the per-unit royalty (usage charge) $R$ that the developers pay when selling their compatible applications through the platform. We refer to the triplet $(P, F, R)$ as the platform’s price structure.

We assume that there are $m \geq 2$ developers, with $m \geq (1 - \theta)^{2\theta}$, each offering one compatible application and all competing for the users that choose the application after having bought the hardware. Developer $i = 1, \ldots, m$ supplies an application of quality $q_i \geq 0$ and sells it at a price $p_i \geq 0$, incurring a cost of development that is assumed to be quadratic and equal to $c(q_i) = \frac{1}{2}(q_i)^2$. Let $p = (p_1, \ldots, p_m)$ and $q = (q_1, \ldots, q_m)$ be the vector of prices and qualities of the applications available on the

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This condition guarantees that the developers’ maximization problem is well-defined.
platform. The developers’ choice of the price and quality of applications is endogenously determined and result from the within-platform competition for the users.

**Demands and profits.** On the users’ side, we distinguish between the demand for the hardware and the demand for the compatible applications. The demand for the hardware, i.e., the installed base of users, is determined by the function $D(P, p, q, m)$. $D$ is decreasing with the price of the hardware $P$; $D$ is also lower if the developers charge higher prices and offer lower quality applications, such that $D$ decreases with $p_i$ and increases with $q_i$, $i = 1, ..., m$; finally, we also account for the standard indirect network effect due to the fact that, ceteris paribus, more users purchase the hardware if there are more developers, such that $D$ increases with $m$. As for the demand of a given application, we assume that, given the installed base of users, developer $i$’s market share corresponds to a share $s^i(p, q)$ of $D$, where $s^i$ is increasing (decreasing) with $q_i$ ($p_i$), and increasing (decreasing) in the price (quality) of the other applications.

The platform’s profits $\Pi$ correspond to the sum of the revenues from selling the hardware to the users and of the royalties and fees collected by (paid to) the developers, less the cost of production, and write as

$$\Pi = (P - C)D(P, p, q, m) + \sum_{i=1}^{m} R s^i(p, q)D(P, p, q, m) + mF$$

(1)

$$= [P - C + R] D(P, p, q, m) + mF.$$  

Developer $i$’s profits $\pi^i$ are instead given by the revenues from selling its application, net of the royalties and fees paid (received) and of the cost of development, and write as

$$\pi^i = (p_i - R)s^i(p, q)D(P, p, q, m) - \frac{1}{2}(q_i)^2 - F.$$  

(2)

In order to better reveal the intuitions behind the formal results of the analysis, we aim to provide closed-form solutions working with specified functional forms. First, to capture the developers’ competition for users, we model the users’ attraction for an application $i$ as a function that decreases with the price and increases with the quality of the application, imposing the following three properties. First, no user purchases an application $i$ that is not attractive at all, such that the developer $i$ has a zero market share if its attraction is zero. The second and the third properties instead allow to maintain symmetry in the model. On the one hand, we want to make sure that developers $i$ and $j$ that sell equally attractive applications end up having the same market share.
On the other hand, we impose that the equally attractive applications $i$ and $j$ are affected in the same way by changes in the attraction of a third application $k$. As proved by Bell, Keeney, and Little (1975), these three properties imply that the market share of each developer is a linear normalization of attraction. Following a standard approach in the strategy and marketing literature on share-attraction framework, we assume that the attraction of developer $i$’s application is equal to $q_i p_i^{-\delta}$, where $\delta > 1$ is the price elasticity, and that developer $i$’s market share is

$$s^i(p,q) = \frac{q_i p_i^{-\delta}}{\sum_{j=1}^{m} q_j p_j^{-\delta}}. \quad (3)$$

Having specified the market shares of each developer, the second step is to account for the demand for the hardware, i.e., the determinants of the installed base of users. We use a specification that allows us to express two common approaches used in the literature as particular cases of our setting. To start with, suppose that if the hardware is a standard product, the demand is $D = P^{-\sigma}$, where $\sigma > 1$ is the price elasticity. In a two-sided market the demand could be augmented to account for the indirect network effects. Building on Armstrong (2006) and Rochet and Tirole (2003), the users’ demand of the hardware could depend on the membership effect and thus be increasing in the number of developers, with $D = P^{-\sigma} m$. Note that this specification does not account for the users’ actual benefits from using the compatible applications. The other case is when the demand for the hardware depends only on the usage effect, i.e., the fact that users are more willing to join the platform if the developers offer better price/quality combinations. We use the same reasonable assumption used in other contexts of interests to strategy and marketing scholars, assuming that the demand $D$ increases with the total attraction of the applications, such that $D = P^{-\sigma} \left( \sum_{i=1}^{m} q_i p_i^{-\delta} \right)$. In our analysis, we use a Cobb-Douglas specification that captures the relative importance of membership and usage effects, assuming that

$$D(P, p, q; m) = P^{-\sigma} m^{1-\theta} \left( \sum_{i=1}^{m} q_i p_i^{-\delta} \right)^{\theta}, \quad \theta \in (0,1). \quad (4)$$

With this specification, the usage effect becomes increasingly more important than the membership effect as $\theta$ increases. Intuitively, when both effects are more prominent there is a larger installed base of users (and the developers face a lower competitive pressure). But here we are concerned with the relative importance of these two effects as captured by $\theta$, studying how it affects the developers’ equilibrium choices.

With the specification in (3) and (4), the demand for application $i$
becomes
\[ s^i(p, q)D(P, p, q, m) = P^{-\sigma}m^{1-\theta} \left( \frac{q_i P_i^{-\delta}}{\sum_{i=1}^{m} q_i P_i^{-\delta}} \right) \left( \sum_{j=1}^{m} q_j P_j^{-\delta} \right)^{\theta}. \quad (5) \]

We note that this specification is consistent with the standard specification used in share-attraction frameworks, with the last term in the equation expressing the so-called system effect. Our setting augments the standard formula with the term \( m^{1-\theta} \) to account for the membership effect in a platform market. Finally, the platform’s and developer \( i \)'s profits in (1) and (2) rewrite as
\[ \Pi = (P - C + R) \left[ P^{-\sigma}m^{1-\theta} \left( \sum_{i=1}^{m} q_i P_i^{-\delta} \right)^{\theta} \right] + mF \]
and
\[ \pi^i = (p_i - R) P^{-\sigma}m^{1-\theta} \left( \frac{q_i P_i^{-\delta}}{\left( \sum_{j=1}^{m} q_j P_j^{-\delta} \right)^{1-\theta}} \right) - \frac{1}{2} (q_i)^2 - F. \quad (7) \]

Equations (6) and (7) reveal the strategic interaction between the platform owner and the developers on the one hand, and among the developers on the other hand, showing how the profits of each party depend on its choices as well as on the choices of the others.

**Timing and equilibrium concept.** The sequence of events in our model is as follows. The platform first designs the pricing structure \((P, R, F)\). The developers then decide the price and quality of their applications, and the vectors \( p \) and \( q \) are determined. Finally, the users make their purchasing decisions, deciding whether to buy the hardware or not (membership) and then which application to use (usage), thus determining the demands \( D \) and \( d^i \).

We proceed as follows. First, we consider as given the platform’s price structure \((P, R, F)\) and determine the developers’ equilibrium choice of the price and quality of applications. Because we have maintained symmetry in the model, we can focus on the symmetric Nash equilibrium, that yields equilibrium values \( p^* \) and \( q^* \). Second, we compute the platform’s profits corresponding to the symmetric Nash equilibrium and then solve for the model by using backward reasoning, solving for the optimal price structure \((P^*, R^*, F^*)\). As we proceed with the analysis we also illustrate the comparative statics and the different scenarios that can emerge.
ANALYZING COMPETITION AMONG DEVELOPERS

We start analyzing the equilibrium price and quality of applications that correspond to a given price structure. \((P, R, F)\). The developers act as rational players that participate to the competition game for attracting the users, and we can prove the following result:

**Proposition 1** The equilibrium price of applications on a monopoly platform increases with the royalties \(R\), decreases with the number of developers \(m\), and is greater when membership effects are relatively stronger than usage effects, with \(p^*(R) = \delta R \frac{m - (1 - \theta)}{\delta (m - (1 - \theta)) - m} \).

To explain the intuition behind Proposition 1 it is useful to derive the Lerner pricing formula for the equilibrium price \(p^*(R)\),

\[
L(p^*(R)) = \frac{p^*(R) - R}{p^*(R)} = \frac{1}{\delta} \frac{m}{m - (1 - \theta)}. \tag{8}
\]

Equation (8) reveals first the intuitive fact that there is a greater competitive pressure when there are more developers competing for users within the platform, such that the equilibrium price decreases with \(m\). But note that as \(m\) increases the equilibrium price does not converge to the perfectly competitive benchmark, with price equal to the marginal cost \(R\), as it happens in the standard oligopolist model. This is because the greater competition effect when \(m\) increases is compensated by the indirect network effect that guarantees a greater demand for the hardware. Thus, although declining, the equilibrium price remains above the "marginal cost" \(R\), and the Lerner index converges to the condition for the single product monopolist, with \(L(p^*) = \frac{1}{\delta}\). Also note that (8) coincides with this standard pricing formula when \(\theta = 1\), i.e., when the indirect network effects are purely driven by usage effects. This is because when \(\theta = 1\) the greater competition for a given users installed base is exactly compensated by an increase in the users installed base, and therefore each developer acts de facto as a monopolist on the platform.

Our second result pertains to the developers’ equilibrium choice of the quality of applications. We can prove the following:

**Proposition 2** The equilibrium quality of applications on a monopoly platform increases with \(R\) and \(m\) if \(\delta \theta > 1\), and decreases otherwise, with \(q^*(P, R) = \delta^2 \frac{\delta \theta}{2} P^{-\alpha} \left( \frac{m - (1 - \theta)}{\delta (m - (1 - \theta)) - m} \right)^{\frac{1 - \delta \theta}{2 - \theta}}\).

Differently from the equilibrium price, the impact of the royalty \(R\) and the number of developers \(m\) on the quality of applications is not
straightforward. This ambiguity is not specific to our model. For example, the standard analysis of the monopolist’s behavior reveals that it can sell a product of lower or greater quality relatively to the perfectly competitive benchmark. Our analysis reveals the main drivers of developers’ choice of quality. Similarly to what happens with the prices, when the number of developers increases there is greater competition for users but also greater indirect network effects. Interestingly though, the competition effect does not always dominate, and so the comparative statics on the equilibrium level of quality reveals different scenarios.

**Negative correlation between price and quality.** The first scenario corresponds to the case when the users are highly sensitive to the prices of applications and/or usage effects are relatively more important than membership effects, such that $\delta \theta > 1$. This is the case when the competition effect dominates the indirect network effects. As prescribed by Proposition 1, the developers charge lower prices as $m$ increases, and the greater competitive pressure is such that they also increase the quality of their applications to make them more attractive for users. On the other hand, we can note that the equilibrium quality decreases with the royalty $R$, whereas the equilibrium price increases. Ultimately, there is a negative correlation between prices and quality both when $m$ and $R$ increase. We shall focus on this scenario when analyzing the platform’s optimal pricing strategy.

**Positive correlation between price and quality.** The second scenario corresponds to the case when the membership effect is relatively more important and/or users are not too sensitive to the price of applications, such that $\delta \theta < 1$. In this case the competition effect is dominated by the indirect network effects, and because the users are mainly attracted by the number of developers, there are lower incentives to invest in quality. Therefore, in this second scenario a larger installed base is associated with lower quality of applications. On the other hand, the equilibrium quality increases when the platform increases the royalty $R$, and now price and quality covary as $m$ and $R$ increase.

We can also note that the equilibrium quality is inverted-U shaped with respect to $\theta$. Intuitively, the developers’ incentives to invest in quality are lower at the extremes, when either users are mainly attracted by the number of developers or when the system effect minimizes the competitive pressure. This pattern also explains the pattern of the developers’ equilibrium profits, $\pi^*(P, R)$, that are obtained by substituting the equilibrium values $p^*(R)$ and $q^*(P, R)$ into (7), revealing that $\pi^*(P, R)$ decreases with $m$. Developing and selling applications over the platform becomes less and less profitable when there are more developers. More interestingly though, the equilibrium profits are U-shaped with respect
to \( \theta \), meaning that a greater profitability corresponds to the extremes when the users are more interested either in membership or in usage effects. As explained above, the intuition is that when \( \theta \approx 1 \) the profits are high because the developers act like monopolists, and when \( \theta \approx 0 \) profits are high because competition is not fierce since users are mainly attracted by the number of developers, not by the price/quality characteristics. Thus, for intermediate values of \( \theta \), in between \( \underline{\theta} \) and \( \bar{\theta} \), there is a combination of strong competition and low system effects that can also results in negative profits. We shall see that in these cases the platform must subsidize the developers to induce them to produce compatible applications.

Next we conclude our analysis studying the platform’s optimal pricing decision.

**ANALYZING THE PLATFORM’S CHOICE OF THE PRICE STRUCTURE**

Having determined the developers’ equilibrium choice of the price and quality of applications that correspond to a given price structure, the next step is to close the model and consider the optimal choice of the price structure. This last step allows us to provide different insights into the platform’s pricing strategy in the absence of across platform competition. The analysis refers to the case \( \delta \theta > 1 \), when the platform’s profits are well defined and the first order conditions characterize the optimal strategy.

It is well understood that in a two-sided market the platform owner can affect the volume of hardware and applications sales by charging more one side and reducing the burden of the price for the other side (Rochet and Tirole 2006). By endogenizing the membership fees \( P \) and \( F \) and the usage fee \( R \) we reveal the drivers of the platform’s pricing strategy. We can prove the following:

**Proposition 3** The monopoly platform subsidizes the users by charging a price of the hardware \( P^* = \frac{\sigma}{\sigma - 1 + \delta \theta} C < C \).

Thus, users are subsidized even in the absence of competition among platforms. By selling the hardware at a price below the marginal cost, a monopoly platform can enlarge the installed base of users, create a greater demand for applications, and then transfer the charge of the price to the developers, as discussed below. We can also note that the price of the hardware decreases when the usage effect is relatively more important than the membership effect, as well as when the users are more sensitive to the price of applications. To fully understand the intuition about the platform’s pricing strategy, we must consider also how the platform charges the developers. We can prove our last result.
Proposition 4 The monopoly platform charges the developers with a royalty $R^* = \frac{2\theta - 1}{\sigma - 1 + \theta} C > 0$. The platform also charges the developers with a membership fee $F > 0$ if $\theta \in (\bar{\theta}, \hat{\theta}) \subset (0, 1)$, and subsidizes them with a fee $F < 0$ otherwise.

Although the number of developers influences the equilibrium choice of the price and quality of compatible applications, we note that the platform’s price structure largely does not depend on $m$, as we can see by looking at $P^*$ and $R^*$. The access fee $F^*$ can be positive, allowing to extract all the developers’ surplus when they obtain positive equilibrium profits, or negative, as to subsidize the developers when they obtain negative equilibrium profits. The latter case can be observed when $\theta$ is intermediate. The platform also subsidizes the users selling the hardware at a loss, i.e., at a price which is below the marginal cost of production, but then it makes money by charging the developers a positive royalty $R^* > 0$. Thus, even absent cross-platform competition, the platform decreases the price of the hardware below its marginal cost to create a larger users installed base. We can also note that the relative burden of price for users and developers, as expressed by the ratio $\frac{P^*}{R^*} = \frac{2\sigma}{\theta(2\theta - 1)}$, decreases when usage effects become more important and when users are more sensitive to the price of applications. On the other hand, when $\sigma$ increases the platform reacts decreasing the royalties as to induce the developers to reduce the price of applications and increase their quality, but then it charges a higher price for the hardware.

DISCUSSION

We have modeled the strategic interaction between a monopoly platform and third-party developers who control the quality and price of compatible products. As the value of a two-sided platform to users depend critically on the variety of complementary products available for it (as affected by the number of developers affiliating with the platform), and on their quality, our model captures the distinction between the two via membership and usage effects. Our analysis reveals the mechanics of platform markets and the role of indirect network effects, thus contributing to the strategy and economics literature on two-sided markets.

We show how the pricing decisions of the platform not only affect directly the decision of developers (and users) to affiliate with the platform (i.e., membership), but also, and importantly, how they indirectly influence the price and quality of the complementary products supplied by these developers. This, in turn, determines the benefits from transacting on the platform (i.e., usage effects). Thus, platform-pricing strategy
(on the users and complementors side) affects the value of the platform directly via the membership effect and indirectly via the usage effect.

The idea that users enjoy greater benefits from a platform not only from having more members on the other side to potentially transact with (membership effect) but also from greater volume of transactions (usage effect) has been highlighted elsewhere (Rochet and Tirole 2003). Usage effect has been mainly conceived as ensuing from economizing on transaction costs. Nonetheless, in many platform markets including video games, smartphone and other mobile systems, newspapers or shopping malls, usage effect is linked to doing transactions of higher value; that is, using better products. Since quality of such products is supplied by third-party complementors, the platform cannot directly control it; the level of usage effects could be only induced indirectly. Yet, how does the platform influence the usage effect is not fully understood, also because of the scant theoretical analysis on this yet relevant component of platform value. In particular, extant models have focused on quantity, considering mainly how pricing affect the number of users accessing the platform (membership) and the volume of transactions (usage) occurring therein (affected by the royalties levied on complementors). Instead we consider the quality level of the products exchanged on the platform as important component of platform value, which can be only induced indirectly by the platform, and depends critically on the extent of within-platform competition (among complementors) and the relative importance of usage and membership effects. This makes the management of the platform system particularly complex, beside the well-explored coordination problem of matching users and developers.

According to our results, quality of a platform’s complementary products can increase or decrease with higher levels of within-platform competition ensuing from a greater number of developers. On one side, increases in the number of developers lead to a market expansion since more users will join the platform (due to indirect network effects). However, there is also greater (within-platform) competition among developers: although the user market expands offering more opportunities for value transactions, the portion of such value that each developer can capture shrinks. Ultimately, developers’ decision to supply higher or lower quality depends on the relative strength of membership and usage effects.

In contexts where the usage effect is relatively more important than the membership effect, developers respond to enhanced competitive pressure by increasing the quality and lowering the price of the goods supplied to the platform, thus attracting a larger share of users. Nonetheless, the equilibrium quality decreases with the royalty R set by the platform.
This is the scenario that we consider when we investigate the optimal price structure. We show that an optimal strategy for the platform is to subsidize users by charging a platform access price below the marginal cost such to enlarge the installed base of users and create greater demand for complementary products. Profits would then be generated on the developers’ side by charging royalty $R^*$. This explains for instance the pricing strategy in the video game industry, whereby console manufacturers sell the console at a price below or close to the marginal cost and charge the developers per-unit royalties for the video games sold through the platform. We also find that the developers’ equilibrium profits decrease with their number, up to the point when they become negative for intermediate values of theta. Thus, at some point the platform can decide to subsidize developers (in our model this corresponds to $F^* < 0$) to reduce their costs and induce them to provide compatible products of greater quality. This finding offers important implications.

From a theoretical point of view, a key learning point of our model is that the relative strength of usage and membership effects critically determines the extent to which the quality vis-à-vis variety of complementary products affect the value of a given platform. This is not a trivial point since existing theory tends to treat all platform markets as similar in terms of determinants of platform value to users. In other words, most studies start form the assumption that users derive utility from greater number of members on the other side of the platform, and thus focus the analysis on the strategies to attract users on both sides or coordinate the matching between the different groups of platform users. This is indeed the case where membership effects are the dominant component of platform value. Yet, we show how inducing higher quality of complementary products is equally important for platform value, and particularly so in contexts where usage is more relevant.

One straight theoretical implication is that what platforms do to influence the interaction between users and developers, that is, managing the platform to induce higher usage, is equally, if not more important than just solving the chicken-and-egg problem (inducing the membership of users and developers). One prediction that could derive from our model is that in contexts where usage effects are relatively stronger than membership effects, platform value is mainly affected by the quality of the complementary products the platform obtains, and less so by the user installed base. This is consistent with some of the recent findings in the empirical literature on platform markets (e.g., Binken and Stremersch, 2009; Cennamo and Santaló, 2013; Zhu and Iansiti, 2012) and factual evidence from a number of platform markets. Think for instance of Apple’s mobile iOS platform. It only has about twenty per
cent share of the mobile market, whereas Android system holds almost 80% of it; yet, despite this asymmetry in terms of user base (i.e., membership), different sources indicate that most of the web traffic and apps sales (usage) happen on Apple’s devices, making Apple iOS platform the most valuable and profitable.\footnote{Digits from the Wall Street Journal reported that, as for Q2 of 2013, while Android platform had a reach of almost 80% of the smartphone market, and Apple’s iOS of only 12%, when it comes to profits, it is Apple harvesting the most, with a 33% profit margin as compared to the best of the followers, Samsung running Android platform (with an estimated 19% profit margin). For more details see \url{http://blogs.wsj.com/digits/2013/08/07/android-continues-to-obliterate-smartphone-market-blackberry-hits-new-lows/}. This is also the case in the newspaper industry, where specialist platforms like financial newspapers generally have a smaller number of readers compared to generalist newspapers; yet, because these readers value much more the quality of the content of the newspapers, advertising in such newspapers is more expensive than on generalist.

Also, in contexts where usage is relatively more important, our model predicts that developers would obtain higher margins in equilibrium as shown by our Learner index result. This might offer an explanation of why, for instance, developers may decide to keep supply high quality products to platforms that are particularly crowded (i.e., with high levels of within-platform competition). To the extent that users value quality more than ‘quantity’, developers would attract users mainly on the basis of the quality of their products, and act, de facto, as local monopolists. On the other hand, although not captured in our model, this finding might also offer an intriguing explanation of why some platforms coexist in the market despite a smaller user base compared to dominant platforms. It might well be that these platforms may target a different audience of users (e.g., Cennamo and Santaló 2013) who value more usage relatively to membership, and accordingly be able to attract developers of high quality products.

These are all testable propositions. One could empirically explore for instance when quality of complementary products is higher in platforms with high levels of within-platform competition (e.g., Cennamo and Santaló 2012) by identifying contexts where usage is relatively more important than membership (e.g., videogames, smartphones, newspapers, shopping malls) compared to the opposite case (e.g., dating services, payment systems, auctions). In these contexts, developers should choose higher margins according to our model. Yet, our model does not account for the causality between the two. Future studies might empirically assess whether developers make higher quality products in such contexts in order to improve their profit margins (i.e., ex-post incentives
for investment in higher quality are higher) or because they can leverage on the positive margins to make extra investments in quality (i.e., ex-ante incentives for investment in higher quality are higher).

Another aspect not explored in our analysis is the dynamics of platform evolution. Membership may be more important at certain stages of platform evolution while usage may be more important at other stages. For instance, gaining a sizeable user base (and complementors) might be more important in early stages to show the value of the platform; but at later stages, once the platform has a well established installed base of users and complementors, what they do on the platform (usage) would likely become more important and contribute more to platform value than the effect of adding new members. Pricing and other strategies vis-à-vis developers may need to be adjusted accordingly over time (Cennamo 2013). Note that most of the extant theorizing has focused on the users side when examining how to solve the ‘membership problem’ at early stages of platform evolution. Instead, an implication of our model is that the platform might need to subsidize also (or refrain from extracting full rent from) developers to create value. This would be an interesting extension of our theoretical model, and an important aspect that warrant empirical examination.

Managerial implications
From a practical, managerial point of view, although the strategy of subsidizing complementors to generate more value via greater usage effect might be theoretically effective, it could also require heavy cash allowance for the platform that would need to subsidize both users and developers. This might be not feasible in practice or simply not sustainable. The platform might eventually do it selectively for a number of developers or a number of projects that have the highest potential of capturing the attention of users as in the case of Sony with Rockstar’s Gran Theft Auto game. Alternatively, a case that we do not consider here but that could be introduced in the analysis, the platform could decide to invest in technological infrastructures or development kits that may lower development costs and facilitate production of higher quality complementary goods. This is for instance what Microsoft has done when it entered the video game industry. It produced a development kit, which was given for free to developers willing to make commitment to Microsoft’s Xbox console. Similarly, in the smart phone industry, Apple provides a development kit to producers of apps, which allow them to build apps that can perfectly integrate within the iPhone operating system and run smoothly. Interestingly, in this case, producers shall pay an annual fee, though relatively small, for using such kit (which corresponds to \( F^* > 0 \) in our case).
Compared to the direct monetary subsidy strategy, this approach might be more beneficial to the platform for mainly two reasons. First, these technological infrastructures or development kits can be made available potentially to all developers with just a minimal variable cost (close to zero). Whatever the amount of the up-front investment, it would be spread out on a large number of developers, such that the total average cost will be small as well. Second, by reducing the technical hurdles and development costs for developers, it lowers entry barriers for a large set of producers, and thus enables the platform to attract more developers. As a consequence, this form of subsidy would not only affect platform value via the usage effect, but also via the membership effect. The case of Apple’s App Store again here is emblematic, having spurred an entire new market through such a strategy.

EXTENSIONS AND CONCLUSIONS
An important aspect that we could introduce in our framework relates to the fact that the platforms could eventually produce in-house the needed high-quality complements, as indeed happens for many platforms. This vertical integration strategy has been proposed as a solution to the classical ‘chicken-and-egg’ problem of two-sided markets (Hagiu & Spulber 2009; Hill 1997). However, authors have also discussed the set of problems such strategy entails; most notably the conflicting incentives this could create for complementors (Gawer and Henderson, 2007; Yoffie and Kwak 2006). The vertically integrated platform would basically enter direct competition on the complement level with its set of third-party developers, whose decisions would be influenced by the platform’s choice of the price and quality of its own applications. In our model this would show as enhanced within-platform competition. Developers could for instance perceive an increased threat of rent expropriation, and accordingly limit their investment effort or decide not to support the platform at all. Although this is out of the scope of our analysis, it would be interesting to understand how provision of in-house complements would change results.

Our analysis refers to the case of monopoly platforms that deal with third-party developers, but our formal model could be extended to account for other interesting aspects. For example, allowing for a duopolistic platform market, whereby two identical platforms compete to attract the developers and the users. We expect that the main qualitative results of the model remain unchanged. In the case where usage is relatively more important than membership, standing competition among the platforms for developers of high quality products, we speculate a potential shift of the bargaining power from the platform to developers. Platforms would have to leave money on the table to attract those developers rel-
atively to the competing platform such that they cannot fix the access fee $F$ to extract the developers’ surplus (in case of positive profits) as in our model. Eventually, platforms may waive completely the fee ($F = 0$). Also, platforms may compete for developers by conceding lower royalties in exchange of particular licensing agreements such as exclusivity. Indeed, Sony and Microsoft have used both mechanisms to attract (and steal from each other) developers of high quality complements. However, low $F$ and low $R$ is not necessarily a natural result in the case of competing platforms; in the smartphone industry, despite strong competition faced from Google’s Android platforms, Apple still charges a positive $F$ to developers and $R$ (around 30% of per-unit sales). This is in line with our model predictions, whereby the optimal level of $R$ and $F$ is determined by the level of within-platform competition. These are just speculations though. A number of models have explored the case of platform competition. However, to the best of our knowledge, none have considered how platform competition affects the quality of complementary products provided to competing platforms, and thus the platform capacity to create value via usage effects. This case is technically more demanding; yet, highly interesting. We leave these extensions to further research.

Finally, we only considered quality of complementary goods as main element contributing to usage effects. However, other dimensions of quality in platform contexts may be equally important. Zhu and Ian-siti (2012) consider for instance the technical quality of the platform and show how it might be a critical determinant of platform value and performance. Other dimensions of quality may be related to the governance of relationships with complementors (Cennamo and Santaló 2013) or more generally to the governance of all transactions within the platform (Wareham et al., in press). In some contexts, one dimension might be more important than others for usage effects; or in other contexts, all might add to the overall quality of the platform system in ways yet to be understood. Exploring the different sources of quality and their relative impact on platform value in terms of usage effects compared to membership effects would highly enrich our knowledge of platform value creation dynamics and extend the range of strategies available for platforms to create value beyond the current pricing prescriptions aimed at maximizing network size.
References

Appendix

Proof of Proposition 1

**Proof.** By deriving (7) with respect to $p_i$, neglecting the constant term $P^{-\delta}(m^{1-\theta})$, the first order condition writes as

$$
\frac{q_i p_i^{-\delta}}{\left(\sum_{j=1}^{m} q_j p_j^{-\delta}\right)^{1-\theta}} + (p_i - R) \frac{(-\delta)q_i p_i^{-\delta-1}\left(\sum_{j=1}^{m} q_j p_j^{-\delta}\right)^{1-\theta}}{\left(\sum_{j=1}^{m} q_j p_j^{-\delta}\right)^{2-2\theta}}
$$

$$
= \frac{q_i p_i^{-\delta}}{\left(\sum_{j=1}^{m} q_j p_j^{-\delta}\right)^{1-\theta}} - \delta(p_i - R)q_i p_i^{-\delta-1}\left(\sum_{j=1}^{m} q_j p_j^{-\delta}\right)^{1-\theta} = 0.
$$

(A1)

Imposing the symmetry condition $q_i = q, p_i = p, i = 1, \ldots, m$, (A1) rewrites as

$$
\frac{qp^{-\delta}}{(mqp^{-\delta})^{1-\theta}} - \delta(p - R)qp^{-\delta-1}\left(mqp^{-\delta}\right)^{1-\theta} = 0
$$

(A2)

After simplifying, the equilibrium price is

$$
p^*(R) = \delta R \frac{m - (1 - \theta)}{\delta(m - (1 - \theta)) - m}.
$$

(A3)
For the second order condition, deriving A1 we obtain

\[-\delta q_i p_i^{-\delta -1} \left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{1-\theta} - (1 - \theta) q_i p_i^{-\delta} \left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{-\theta} \]

\[-\delta q_i p_i^{-\delta -1} \sum_{j=1}^{m} q_j p_j^{-\delta} - q_i p_i^{-\delta} (1 - \theta) \]

\[-\delta (p_i - R) (-\delta - 1) q_i p_i^{-\delta -2} \sum_{j=1}^{m} q_j p_j^{-\delta} - q_i p_i^{-\delta} (1 - \theta) \]

that at the symmetric equilibrium reduces to

\[-2 m - (1 - \theta) + (p - R) (\delta + 1) p^{-1} m - (1 - \theta) \]

\[-\delta \left( \frac{p - R}{p} (1 - \theta) [2m - (2 - \theta)] \right) \]

which is satisfied provided that \( m \geq (1 - \theta) \frac{2 \delta}{\delta - 1} \).

Proof of Proposition 2

Proof. By deriving (7) with respect to \( q_i \), the first order condition writes
as

\[(p_i - R)P^{-\sigma}m^{1-\theta}p_i^{-\delta} \left( \frac{\sum_{j=1}^{m} q_j p_j^{-\delta}}{\left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{2-2\theta}} \right)^{1-\theta} (A5) \]

\[-(p_i - R)P^{-\sigma}m^{1-\theta}p_i^{-\delta} \frac{q_i (1 - \theta)p_i^{-\delta} \left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{-\theta}}{\left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{2-2\theta}} - q_i = 1 \]

\[= (p_i - R)P^{-\sigma}m^{1-\theta}p_i^{-\delta} \sum_{j=1}^{m} q_j p_j^{-\delta} - q_i (1 - \theta)p_i^{-\delta} \left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{-\theta} \]

Imposing the symmetry condition \( q_i = q, p_i = p, i = 1, \ldots, m, \) A5 rewrites as

\[ (p - R)P^{-\sigma}m^{1-\theta}p^{-\delta} (mqp^{-\delta})^{1-\theta} - q(1 - \theta)p^{-\delta} (mqp^{-\delta})^{-\theta} \]

\[= (p - R)P^{-\sigma}p^{-\delta} \frac{m - (1 - \theta)}{m^{1-\theta}} = q \]

(A6)

Substituting A4 into A6 and solving for \( q, \) the equilibrium level of quality is and substituting for \( p, \) we obtain

\[ q = \delta^{-\frac{\delta}{2-\theta}} \cdot p^{-\frac{\sigma}{2-\theta}} \cdot \left( \frac{m - (1 - \theta)}{\delta (m - (1 - \theta)) - m} \right)^{\frac{1-\delta}{2-\theta}}. \]

For the second order condition, deriving A5

\[ (p_i - R)P^{-\sigma}m^{1-\theta}p_i^{-\delta} \left[ \frac{[p_j^{-\delta} - (1 - \theta)p_i^{-\delta}] \left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{2-\theta}}{\left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{4-2\theta}} - \frac{\left[ \sum_{j=1}^{m} q_j p_j^{-\delta} - q_i (1 - \theta)p_i^{-\delta} \right] (2 - \theta)p_i^{-\delta} \left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{1-\theta}}{\left( \sum_{j=1}^{m} q_j p_j^{-\delta} \right)^{4-2\theta}} \right] - 1 < 0. \]
At the symmetric equilibrium,

\[
(p - R)P^{-\sigma}m^{1-\theta}p^{-\delta}[p^{-\delta} - (1 - \theta)p^{-\delta}] (mqp^{-\delta})^{2-\theta} \frac{(mqp^{-\delta})^{4-2\theta}}{(mqp^{-\delta})^{4-2\theta}} = (p - R)P^{-\sigma}m^{1-\theta}p^{-\delta}[mqp^{-\delta} - (1 - \theta)mqp^{-\delta}] (2 - \theta)p^{-\delta} (mqp^{-\delta})^{1-\theta} \frac{(mqp^{-\delta})^{4-2\theta}}{(mqp^{-\delta})^{4-2\theta}} - 1
\]

\[
= (p - R)P^{-\sigma}m^{1-\theta}p^{-\delta}[1 - (1 - \theta)]m - [m - (1 - \theta)](2 - \theta) \frac{(mqp^{-\delta})^{4-2\theta}}{(mqp^{-\delta})^{4-2\theta}} - 1
\]

which is always satisfied.

**Proof of Proposition 3**

**Proof.** Substituting the equilibrium value of the price and quality, the platform’s profits reduce to

\[
\Pi = [P - C + R] P^{-\sigma}m \left( \delta^{\frac{2\sigma}{2-\theta}} P^{-\frac{\sigma}{2-\theta}} \left( R^\theta \frac{m - (1 - \theta)}{\delta (m - (1 - \theta)) - m} \right)^{\frac{1-2\theta}{2-\theta}} \right)
\]

\[
= [P - C + R] P^{\frac{2\sigma}{2-\theta}} R^{-\frac{2\theta-1}{2-\theta}} m^{\delta-\theta} \frac{2\delta}{2-\theta} \frac{2\delta}{2-\theta} \left( \frac{m - (1 - \theta)}{\delta (m - (1 - \theta)) - m} \right)^{-\theta \frac{2\delta-1}{2-\theta}},
\]

which is well defined because \(-\frac{2\sigma}{2-\theta} < -1\) and \(\delta \theta > 1\). The first order condition for \(P\) writes as

\[
P \frac{2\sigma}{2-\theta} - \frac{2\sigma}{2-\theta} P^{-\frac{2\sigma}{2-\theta}} \left[ P - C + R \right] = 0 \rightarrow P(R) = \frac{2\sigma}{2\sigma - (2 - \theta)(C - R)}.
\]

The first order condition for \(R\) writes as

\[
R^{\frac{\theta - 2\delta}{\theta - \delta}} + \frac{\theta - 2\delta \theta}{2 - \theta} R^{-\frac{2\delta}{\theta - \delta}} \left[ P - C + R \right] = 0 \rightarrow R(P) = (P - C)^{\frac{\theta(2\delta - 1)}{2(1 - \delta \theta)}}.
\]

Solving for \(P\) and \(R\), we obtain

\[
R^* = \frac{1}{2} C \frac{\theta(2\delta - 1)}{\sigma - 1 + \delta \theta};
\]

\[
P^* = C \frac{\sigma}{\sigma - 1 + \delta \theta}.
\]