The Role of Coordination Bias in Platform Competition*

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Abstract

This paper considers platform competition in a two-sided market that includes buyers and sellers. One of the platforms benefits from a favorable *coordination bias* in the market, in that for this platform it is less costly than for the other platform to convince customers that the two sides will coordinate on joining it. We find that the degree of the coordination bias affects the platform's decision regarding the business model (i.e., whether to subsidize buyers or sellers), the access fees and the size of the platform. A slight increase in the coordination bias may induce the advantaged platform to switch from subsidizing sellers to subsidizing buyers, or induce the disadvantaged platform to switch from subsidizing buyers to subsidizing sellers. Moreover, in such a case the advantaged platform switches from oversupplying to undersupplying sellers, and the disadvantaged platform switches from undersupplying to oversupplying sellers.

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1 Introduction

When platforms compete in a two-sided market, each platform's attractiveness to customers depends on intrinsic quality and its ability to convince customers that it can attract the other side as well. The market may have a "coordination bias in favor or one, "advantaged, platform when customers expect that the other side joins it rather than the other, disadvantaged, platform. In this paper, we analyze how the degree of coordination bias affects platforms strategies and equilibrium outcome.

In many markets we observe that platforms face varying degrees of coordination bias. For example, at the time Apple launched the iPhone 5, most application developers have not yet developed new applications that can support the new features of the device (such as the wider screen, for example). Nevertheless, the iPhone 5 pre-orders topped 2 millions, only one day after its launch, and analysts predicted that 50 millions users would buy the new smartphone within 3 months of its launch. [1] This suggests that at the time, the market expected that the iPhone 5 will attract users and developers. In other words, Apple benefited from a strong coordination bias. New operating systems for tablets and smartphones, such as Microsoft's Windows Phone and RIM's Blackberry 10, may not benefit from such favorable coordination bias. Analysts report that some application developers doubt Microsoft can catch up to Google and Apple.[2] Consequently, developers prefer to focus their energies on developing new applications for Apple and Android. Obviously, such disadvantaged position makes it difficult for Microsoft to attract users as well, as users may expect that developers are more likely to continue focusing on Apple and Android. RIM is facing a similar problem: When launching its new operating system, the Blackberry 10, some

[1] Faughnder and Satariano (2012)

[2] Ovide and Sherr (2012)

application developers where skeptical concerning its ability to attract users, making it unattractive to developers as well.[3] As one developer remarked, "*If this is a horse race, RIM is two laps behind and has a lame leg.*" This is again a problem for RIM, when competing to attract users. As RIM's vice president remarked: "*If we launch without applications, well, it will be slow.*" Similarly, in the battle between HD DVD and BluRay, it mattered not only which format provides better experience of high-definition movies (one of the sides of the market), but also how many movies would be released by the movie studios in a given format (the other side of the market).

We can think of coordination bias advantage as a more recognizable brand name or better track record in the past. While these may come from higher quality offered in the past, they do not need to be related to the quality offered currently. In some cases, a platform can be disadvantaged in market coordination bias even though it offers a product of equal, or even superior, quality than that of an advantaged platform. For example, the hardware of Blackberry's new smartphones, running on Blackberry 10 operating system, received very good reviews from market analysts.[4] However, the lack of applications, current and expected, is crucial. A reviewer commented that: "4 months after launching, BB10 [Blackberry 10] is still struggling to attract developers of quality apps."[5] This evidence suggests that the main competitive disadvantage of Blackberry is coordination bias, and not the quality of its hardware.

In their competition to attract the two sides of the market, platforms should take into account the degree of their coordination bias, as it may affect a platform's strategic decisions. In particular, a platform that enjoys favorable coordination bias, needs to identify how to translate it into competitive advantage over its rival. Likewise, a platform that suffers from unfavorable coordination bias needs to identify how to choose its prices in order to overcome its competitive disadvantage

[3] Austen (2012). It is also the source of all quotes in this paragraph.

[4] PC Magazine compared between the technical specifications of the Blackberry Z10 smartphone and the iPhone 5 and found that "...it's a pretty close match" (Colon 2013). In another review, the Z10 is said to have a faster processor, higher screen resolution and longer battery life than the iPhone 5 (Holly 2013). In a review of another Blackberry's smartphone, the Q10, it is said that the Q10 has a comfortable keyboard and design, with a superior battery and signal strength than the iPhone (Bunton 2013).

[5] Bunton (2013)

and win the market, and under which conditions winning the market is profitable.

The main research question of this paper is: How the coordination bias affects the platform's pricing strategies? Platforms usually compete by setting different prices to the two sides of the market. In particular, a platform may offer a low, perhaps negative price to one of the sides, and then charge a high price to the other side. For example, videogame consoles like Xbox or PlayStation, often sell at a loss in retail, but they make profits by charging the game developers who sell games to be played on the consoles. In contrast, Samsung offered prizes to support application developers in developing applications to Samsung's new tablets.[6] Likewise, Microsoft hosted more than 850 sessions world-wide to coach application developers on Windows Phone, as well as other means for helping developers to profit from developing applications for its new operating system. While other firms were also known to offer some support to developers, the scale of Microsoft's efforts is unprecedented.[7] We therefore specifically ask how the coordination bias affects the platforms' pricing strategies in terms of (i) the side to attract and (ii) the number of sellers to attract. Notice that we raise this question for both the platform with favorable coordination bias and the platform with unfavorable bias. This is because, as we show, a platform with unfavorable coordination bias can still win the market if it has sufficiently high quality, and if the platform correctly chose its pricing strategies in accordance with the coordination bias against it.

To answer this question, we consider a model with the following features. There are two sides of a market, buyers and sellers, which cannot interact without a platform. Once they join a platform, sellers compete among themselves for buyers. This means that sellers can make positive profit from joining a platform only if buyers indeed joined the same platform and only if not too many other sellers joined the platform.[8]

There are two platforms that compete by setting access fees to sellers and buyers. The platforms

[6] See: http://www.smartappchallenge.com/eng/challenge/awardsJudging.do

[7] Ovide and Sherr (2012)

[8] Our results depend on such an asymmetry of the two sides. This asymmetry is common in many real-life two-sided markets. However, there are also two-sided markets to which our model does not apply, e.g., on-line dating.

differ in two respects. First, they may differ in the quality. We allow for cases where either platform is of higher or lower quality than the other. Second, one platform benefits from a favorable coordination bias of the market, in that it is less costly for it to convince the two sides that all agents will coordinate on joining it. The degree of coordination bias in our analysis varies along a continuous spectrum, such that it can be weak or strong. As the degree of coordination bias increases, it becomes cheaper for the advantaged platform to convince the customers that both sides would join it. We analyze how the firms' strategies and the market outcome is affected by the degree of coordination bias.

We find that the platforms' pricing strategies can be characterized by two distinct business models. When neither of the platforms enjoys a favorable coordination bias and the sellers' fixed costs are very low, then both platforms will choose a business model that relies on the revenue from the buyers while fully subsidizing the sellers' fixed costs. We refer to it as a *buyers-pay* business model. When, however, the sellers' fixed costs are very high, both platforms adopt a business model that relies mainly on the revenues from sellers, while competing to attract buyers—a *sellers-pay* business model. For the case where sellers have intermediate values of the fixed costs, and the degree of coordination bias is high enough, the advantaged platform adopts a *sellers-pay* business model, while the disadvantaged platform adopts a *buyers-pay* business model. Therefore, an increase in the degree of coordination bias can have two effects on the platforms' business models. First, it may motivate the advantaged platform to switch from a *buyers-pay* to a *sellers-pay* business model. Second, it may motivate the disadvantaged platform to switch from a *sellers-pay* to *a buyers-pay* business model. This is because the profitability of a *sellers-pay* business model relies on the platforms' ability to attract buyers, which in turn relies on the degree of coordination bias towards the advantaged platform. We also find that a platform's business model affects not only prices but also the size of the platform, in terms of the number of sellers it will attract. Whenever a platform attracts buyers (*sellers-pay*), it will attract fewer sellers than the trade-maximizing level.

And when a platform subsidizes sellers (*buyers-pay*), it will attract more sellers than the trade-maximizing level. In the context of our model, the business models are characterized only by access fees. In reality, the choice of a business model is related to important decisions on the structure of firm, architecture of supply chain, or investment in marketing (see e.g., Casadesus-Masanell and Zhu, 2010 and Hagiu and Halaburda, 2009).

We then extend the base model to the case of heterogeneous buyers. We assume that due to horizontal differentiation, some buyers are loyal to a specific platform. The model reveals that an increase in the degree of horizontal differentiation, measured by the proportion of loyal buyers, gives both platforms a stronger incentive to subsidize the sellers. If the advantaged platform has more loyal buyers than the disadvantaged platform, then the advantaged platform may subsidize sellers even when the disadvantaged platform competes by attracting buyers.

In another extension to our base model, we consider a multi-period game, in which platforms and agents repeat playing the static game analyzed in our base model, but the coordination bias adjusts along time. In each period, the bias slightly increases in favor of the platform that won the previous period. We find that staring from no coordination bias, beliefs converge faster, on average, to full coordination bias when platforms use the sellers as the main source of revenues, than when platforms subsidize sellers.

Related Literature

The economic literature on competing platforms extends in various directions the work of Katz and Shapiro (1985) on competition with network effects. Spiegler (2000) analyzes an "extractor," such as a platform who can extract positive externalities from two agents. In Spulber (1996, 1999) intermediary firms establish a market between buyers and sellers. Caillaud and Jullien (2001, 2003) consider competition between undifferentiated platforms, where one of them benefits from favorable beliefs. In Hagiu (2006) undifferentiated platforms compete in a setting where sellers join the platform first, and only then buyers. Lopez and Rey (2009) analyze competition between two telecommunication networks when one of them benefits from "customers' inertia," such that in the case of multiple responses to the networks' prices, consumers choose a response which favors one of the networks. Jullien (2011) investigates undifferentiated platform competition in a multi-sided market. In Hagiu and Spulber (2012) a platform that connects between buyers and sellers can also offer first-party content. They show that the expectations of the two sides concerning market participation in the platform affects the strategic use of first-party content. Halaburda and Yehezkel (2013) consider undifferentiated competition where the two sides of the market are ex-ante uninformed about their utilities, and are ex-post privately informed. A common feature in the above literature is the assumption that one platform fully benefits from a belief advantage. This is equivalent to assuming full coordination bias in our model. We make two contributions to this literature. First, we consider the case where the advantaged platform benefits from only a partial coordination bias. As we explained above, this distinction turned out to be important because a platform may choose a different business model depending on whether it faces full or partial coordination bias. The second contribution of our paper is considering endogenous coordination bias, based on the platforms' track record of past successes in the marketplace.

Zhu and Iansiti (2012) consider dynamic price competition between an entrant platform with a quality advantage, and an incumbent platform with an installed base advantage. If indirect network effects are sufficiently strong, the incumbent can use its superior installed base to overcome its quality disadvantage and win the market. Our paper contributes to this idea by considering how platforms can use coordination bias to overcome the quality disadvantage. Moreover, our paper identifies how the platforms' business models affect their abilities to exploit agents' coordination bias.

Hossain and Morgan (2013) also investigate the issue of multiplicity of equilibria in platform competition. They show that a unique equilibrium arises when even a small number of agents are boundedly rational and naively choose one of the platforms disregarding strategic behavior of other agents. In a related experimental study Hossain, Minor and Morgan (2011) consider a two sided market when platforms are not strategic players and cannot manipulate prices for attracting agents. They find that even though a static theoretical model allows for multiple equilibria in the agents' choices, in a dynamic game, agents converge to the Pareto-dominant equilibrium. Jullien and Pavan (2013) also deal with the issue of multiple equilibria in platform competition. In their model agents receive noisy private signals to the platforms' qualities. They apply the framework of global games and find that the dispersion of information among agents solves the agent's coordination problem. Moreover, they identify how the dispersion of information affects the platforms' prices.

Alexandrov, Deltas and Spulber (2011) consider competition between dealers and a market maker, acting as intermediaries between buyers and sellers. They assume that one of the two sides of the market (sellers in their case), is a bottleneck, such that competition is stronger on this side. In our model, it is possible to interpret the buyers as the bottleneck side, because all buyers make the same decision while some sellers join a platform while others do not. Our paper contributes to Alexandrov, Deltas and Spulber (2011) by considering a coordination bias. We find that a platform's profit is more sensitive to its coordination bias if it attracts the bottleneck side (buyers in our model) than the other side. This is because the platform needs to compensate buyers for their alternative payoff from joining the competing platform, which rely on the degree of the coordination bias. To attract sellers, a platform only needs to compensate them for their reservation utility from not trading, which is independent on the coordination bias.

Our paper also contributes to the literature on business models. Ghemawat (1991) and Casadesus-Masanell and Ricart (2010) refer to firms strategy as its choice of a business model: the business model is a set of committed choices that lays the groundwork for the competitive interactions between the firms. The choice of the business model enables or limits particular tactical choices (e.g., prices). Specifically, our paper analyzes the choice of the business model in the context of two-sided platforms. As pointed by Rochet and Tirole (2003) and by Casadesus-Masanell and Zhu (2010), in the context of two-sided markets, one of the most important aspects of the business model is which side of the market is the primary source of the revenue. Casadesus-Masanell and Zhu (2013) consider an incumbent and entrant that can choose between a traditional business model in which they charge a price to consumers, or sponsor-based business model in which they earn revenues from sponsors that negatively affect consumers' utility. The incumbent is aware of the latter option only if the entrant chooses it first. The first (second) business model is somewhat similar to our buyers (sellers)-pay business model, in which a platform main source of revenues is buyers (sellers). As in our paper, Casadesus-Masanell and Zhu identify market conditions under which the two firms choose each combination of business models. Our paper contributes to their analysis by identifying how coordination bias affects the platforms' business models and the number of sellers that platforms attract.

2 Characteristics of the Market

We consider an environment with two competing platforms. Each platform needs to serve two sides of the market, buyers and sellers.

Buyers. There are N_B identical buyers.[9] Buyers may be smartphone users, who have a demand for smartphone applications. Likewise, buyers may be gamers, who have a demand for videogames. The consumption utility of each buyer from buying n products is $u_B(n)$. The number n may represent the number of applications, videogames, etc. This consumption utility is positive for any $n > 0$ and increasing with n, but it reaches a saturation point at $\hat{n}$, i.e., $u'_B(n) > 0$ for $n < \hat{n}$ and $u'_B(n) < 0$ for $n > \hat{n}$. Moreover, $u''_B(n) < 0$.[10] To make sure that the second order conditions

[9] In Section **??** we extend the model to include heterogeneous buyers.

[10] We consider the apps within the same category (e.g. mobile games), so that each additional app yields lower marginal benefit. Moreover, the marginal benefit eventually declines below the marginal cost of providing an application. This is captured by negative $u'(n)$ for sufficiently large n, because we normalize the marginal cost of producing an app to zero (as described later in this section). This effect may also come from congestion, e.g., having too many

are satisfied, we assume that the third derivative is either negative, or positive but not too large. Specifically, $u_B''' < -\frac{u_B''}{n}$. The total buyer's utility also incorporates the cost of purchasing the products. If the price of every product is p, then the total buyer's utility is

$$U_B(n) = u_B(n) - p\,n\,.$$

Sellers. There is a large number, N_S, of identical sellers ready to enter the market, where $N_S > 2\hat{n}$. Sellers may be developers of smartphone applications, developers of videogames, etc. Each seller offers one product (a smartphone app, a videogame for a console, a movie in a given format), but he can sell multiple copies of it to multiple buyers. A seller receives p for every copy of the product he sells. Sellers have a fixed cost of developing the product, $K > 0$, which is the same for all sellers. We normalize marginal production costs to 0.

Buyers and sellers trading on a platform. If n sellers join a platform, they provide n products and they behave competitively. Hence, products are sold at the price equal to the marginal consumption utility of the n-th product, $u_B'(n)$. If $n > \hat{n}$ such that $u_B'(n) < 0$, buyers will not pay a positive price. As sellers would not sell at a loss, we assume that if $n > \hat{n}$, then only $\hat{n}$ are sold at $p(\hat{n}) = u_B'(\hat{n}) = 0$. Therefore, the equilibrium price is $p(n) = \max\{u_B'(n), 0\}$, and it is the same for all products.

After incorporating the development costs, a seller's payoff when he sells to all buyers is $N_B\,p(n) - K$. Let $k = \frac{K}{N_B}$. Then this payoff can be represented by $N_B\big(p(n) - k\big)$. As $p(n)$ is decreasing with n, we assume that $p(0) > k$, such that k is low enough so that sellers' total payoff is positive for some $n > 0$.

Network effects and the asymmetry between the sides. This model has two main features that will play an important role in the analysis. First, there are positive network effects between

applications in a smartphone that may affect its performance.

the two sides of the market: buyers (sellers) gain higher utility from joining a platform the more sellers (buyers) join the same platform.

The second main feature of our model is asymmetry between the two sides of the market. Buyers' participation is non-rivalous. The number of other buyers on the same platform does not affect each buyer's utility. This is not true for the sellers. Larger number of sellers on the same platform increases competition and decreases each seller's payoff. We believe that this asymmetry in rivalry reflects many (but not all) two-sided markets: Consumption of smartphone apps is non-rivalous, even if the developers compete for the users. Similar statement is true about video games released for consoles, or movies released for a given format.

Trade-maximizing outcome (first-best). To solve for the first-best outcome, notice first that it is cost-reducing for all buyers to join the same platform. This is because the sellers' fixed costs, K, are spread among a larger number of buyers. Given that all buyers join the same platform, the number of sellers that maximizes total gains from trade between sellers and buyers, n^*, is the solution to

$$n^* = \arg\max_n \left\{ N_B(U_B(n) + n\big(p(n) - k\big)\big) \right\} . \tag{1}$$

Given our assumptions, n^* is unique, with $\hat{n} > n^* > 0$ for any $k > 0$ and $n^* = \hat{n}$ for $k = 0$. Moreover, n^* is decreasing with k.

Platforms. There are two competing platforms, which we call platform A and platform D. They differ in two aspects: in terms of the coordination bias they face in the market, and in that they are vertically differentiated.[11] We discuss the issue of coordination bias in Section **??**. We measure the vertical differentiation with Q—additional utility that a buyer gains by joining platform A. Variable Q captures, for example, difference in the quality of service between the platforms; or an additional stand-alone value that one platform offers but the other one does not. We allow for both

[11] In Section **??**, we extend our analysis to an environment where each platform has its loyal following.

positive and negative Q, i.e., platform A may be perceived as better or worse than platform D. We assume that platforms do not incur costs.[12]

Platforms compete by setting access fees to buyers and sellers, which can be positive or negative: (F_B^A, F_S^A), (F_B^D, F_S^D). As platforms aim at attracting two groups of "customers," the buyers and the sellers, they may find it optimal to offer lower access fee to one side than the other. The business model identifies the side which is the primary source of revenue.

Timing. In our initial analysis, we consider the case where the winning platform sets its access fees and business model slightly before the competing platform.[13] The buyers and sellers observe the fees, and then based on the fees make their (simultaneous) decision which platform to join. As they join the platform, the trade takes place according to the competitive environment described earlier.[14]

Dominant firm equilibria. We focus on equilibria in which one platform "wins" the market and the competing platform earns zero profit. We ignore equilibria with two active platforms because such equilibria are unstable. This result follows from our assumption that all buyers are identical.

In real-life situations, however, most markets involve more than one active platform. This is because buyers may differ in their preferences for platforms. Consequently, a platform can always focus on attracting buyers that have strong preferences for this specific platform. In order to keep our model tractable, we focus in our base model on the case of homogeneous buyers. We extend our analysis to heterogeneous buyers in Section **??**, where we consider equilibria with two active platforms.

A related assumption is that platforms in our model do not have an initial installed base of

[12]The analysis is very similar (but mathematically significantly more complicated) with positive fixed and marginal costs.

[13]Later (at the end of Section **??**) we comment on the robustness of our results to the case of a simultaneous move game.

[14]Since we focus on the platforms strategies for attracting buyers and sellers, we do not treat trade as a separate stage of the game.

existing buyers and sellers that have already joined a platform. We make this assumption because we are interested in examining the net effect of beliefs concerning future participation of agents on the platforms' competitive advantage and choice of a business model. Obviously, if platforms have an initial installed base, the platform with the largest installed base will have a competitive advantage, that may outweigh (or supplement) the advantage coming from beliefs. While we make this assumption for the sake of simplifying our model and focusing on beliefs, this assumption may still qualitatively hold in several of our examples above. This assumption may hold whenever platforms introduce a completely new product.

3 The Concept of Coordination Bias

In the last stage of the game the two platforms charge access fees (F_B^A, F_S^A), (F_B^D, F_S^D), and buyers and sellers simultaneously decide which platform to join. Since each side gains by joining the same platform, there might be multiple equilibria, resulting from the coordination problem between the sides. We therefore turn to offer a principle that generates a unique equilibrium for any (F_B^A, F_S^A), (F_B^D, F_S^D).

Suppose that there are two potential subgame equilibria in the last stage:

dominant-A, where all buyers and some sellers join A, and there is no trade on platform D; and

dominant-D, where all buyers and some sellers join D, and there is no trade on platform A.

For some access fees (F_B^A, F_S^A), (F_B^D, F_S^D), there exists only one of the equilibria, and for others both. Intuitively, if the difference in the buyers' access fees, $F_B^A - F_B^D$, is sufficiently high, then only dominant-D is possible. In such case, we assume that agents play dominant-D. Likewise, if the difference $F_B^A - F_B^D$, is sufficiently small, then only dominant-A is possible, in which case we assume that this is what agents play. For the intermediate values of the difference $F_B^A - F_B^D$ both equilibria are possible. This raises the question of which equilibrium agents will play.

To answer this question, Caillaud and Jullien (2001) introduce the concept of favorable beliefs. Accordingly, for any access fees that sustain both dominant-A and dominant-D, agents always play dominant-A, expecting that all other agents play dominant-A as well. Therefore, the favorite beliefs principle selects a unique equilibrium, with rational expectations in that agents correctly believe that other agents play the same equilibrium. In the context of our model, this implies that agents play dominant-A whenever the difference, $F_B^A - F_B^D$, is small enough that dominant-A exists, and play dominant-D when the difference is so large that only dominant-D exists.

Such a principle provides a strong advantage to platform A. A natural way to relax it is to assume that there is a cutoff—somewhere in the intermediate range of the difference between access fees, where both equilibria exist—such that agents play dominant-A if the difference is below the cutoff, and dominant-D for the gap above the cutoff. Since the cutoff is common knowledge, this relaxed version of the Caillaud and Jullien (2001) favorable beliefs concept also selects a unique equilibrium with rational expectations in that agents correctly believe that other agents play the same equilibrium.

The cutoff is characterized using parameter α, measuring coordination bias of the market in favor of platform A. That is, the cutoff is constructed as if the sellers played dominant-A with probability α, and dominant-D with probability $1 - \alpha$. If given this rule a buyer prefers to join platform A, he rationally expects that other buyers, and consequently sellers, play dominant-A. The coordination bias parameter, α, indicates how much one platform needs to compensate the agent in fees to convince the market to coordinate on that platform. The larger is the coordination bias in favor of platform A (α closer to 1), the larger discount platform D needs to offer to convince both sides to coordinate on platform D.

Definition 1 *Suppose that both dominant-A and dominant-D are possible and the market has α-coordination bias in favor of platform A. Then, agents play—and expect that others play—dominant-A (dominant-D) if the difference between F_B^A and F_B^D is below (above) a cutoff value.*

The cutoff value is defined as the difference between buyers' expected utility from joining platform A and joining platform D if sellers were to play dominant-A with an exogenous probability $\alpha \in \left[\frac{1}{2}, 1\right]$*, and dominant-D with probability* $1-\alpha$*.*

We need to keep in mind that it does not mean that we assume that sellers play one equilibrium or the other with positive probabilities. The parameter α is therefore not the beliefs concerning the equilibrium outcome. The sellers play either dominant-A with probability 1 or dominant-D with probability 1. If given the cutoff, buyers choose to join platform A, then all buyers and sellers rationally expect that dominant-A will be played with probability 1. The opposite case occurs when given the cutoff buyers choose joining platform D.

The concept of α-coordination bias has several intuitive features, already mentioned above. First, as we show in Section **??**, it defines a unique equilibrium with rational expectations. Second, this concept provides an intuitive measure, α, of the advantage platform A has in the market when it comes to agents' coordination on joining the same platform. This coordination advantage translates into access fee advantage (for given quality difference). The larger the coordination bias, the more surplus the disadvantaged platform (platform D) needs to provide to the agents to overcome the bias and convince them to join. A third important property of the α-coordination bias is that the well-known "favorable beliefs" concept is a special case, in which $\alpha = 1$.

4 Equilibrium

To solve for the equilibrium outcome, we use standard backward induction. We start by finding the agents' optimal choice of platforms given (F_B^A, F_S^A), (F_B^D, F_S^D). Then, we solve for the equilibrium access fees and business models that the platforms choose, knowing how (F_B^A, F_S^A), (F_B^D, F_S^D) affect the agents' choices.

4.1 Decisions of Buyers and Sellers

In the last stage, buyers and sellers observe the posted fees, (F_B^A, F_S^A), (F_B^D, F_S^D), and simultaneously decide which platform to join. Not joining leaves an agent with payoff of 0.

Every buyer receives the same payoff: joining platform A with n^A sellers yields $U_B(n^A) - F_B^A + Q$, and joining platform D with n^D sellers yields $U_B(n^D) - F_B^D$. Hence, they all make the same decision:[15] either they all join platform A, or they all join platform D.[16]

The payoff of a seller decreases with the number of other sellers: joining platform i ($i = A, D$) with all N_B buyers and n^i sellers yields each seller a payoff of $N_B\big(p(n^i) - k\big) - F_S^i$. Sellers join a platform only until the payoff is 0. Each additional seller would earn negative payoff. Hence, if $n^i > 0$ join a platform, this number depends on F_S^i and is uniquely characterized by $N_B\big(p(n^i) - k\big) - F_S^i = 0$. Thus, even though a priori identical, in equilibrium sellers make different participation decisions.

There exists dominant-D equilibrium when following conditions are satisfied:

$$N_B(p(n^D) - k) - F_S^D = 0 \qquad \text{and} \qquad U_B(n^D) - F_B^D \geq \min\{0, -F_B^A + Q\}\,. \tag{2}$$

But for some fees conditions for both dominant-D and dominant-A are satisfied. Dominant-A exists when

$$N_B(p(n^A) - k) - F_S^A = 0 \qquad \text{and} \qquad Q + U_B(n^A) - F_B^A \geq \min\{0, -F_B^D\}\,. \tag{3}$$

When all conditions in (**??**) and (**??**) are satisfied, then both equilibria are possible. In such a case, we use coordination bias principle to determine which equilibrium occurs.

There are three situations where indifference plays a role. We resolve it by applying following

[15] The only exception may be when the buyers are indifferent. We consider this case in analysis, but platforms always want to avoid the case when the buyers are indifferent. Hence we abstract from it for clarity of exposition.

[16] There is also a third potential equilibrium, in which both sides do not join either platform. We assume that if there is such an equilibrium in addition to the two equilibria above, then agents will not play this equilibrium. Intuitively, we focus on a market in which agents believe that the market eventually will succeed in attracting the two sides, so the only question is which platform is going to be successful.

tie-breaking rules. First, we assume that if buyers' coordination bias makes them exactly indifferent between joining platforms A or D—i.e., the difference in the buyers' access fees exactly equals to the cutoff value defined in Definition **??**—then all buyers join platform A, expecting that all other buyers will do the same.[17] Second, notice that if $F_S^i = -K$ and all N_B buyers join platform i, at least $\hat{n}$ sellers will join, and any additional sellers above $\hat{n}$ will be indifferent between joining and not joining platform i. As our second tie-breaking rule, we assume that in such a case, only $\hat{n}$ sellers will join platform i in the dominant-i equilibrium. We make this assumption because a platform will never want to accommodate more than $\hat{n}$ sellers, and each of these sellers cannot make positive profit from joining platform i anyways.[18] The third indifference case is when $F_S^i = -K$ and no buyer joins platform i—the dominant-j equilibrium, in which all buyers join the competing platform j. In this case all sellers are indifferent between joining and not joining platform i, because platform i fully subsidizes their entry cost but at the same time buyers join the competing platform. As the third tie-breaking rule, we assume that in such a case, $\hat{n}$ sellers will join platform i.

4.2 Choice of a Business Model and Access Fees

Consider now the stage where the two platforms choose their business models and their access fees, (F_B^A, F_S^A), (F_B^D, F_S^D), taking into account that agents are aware of coordination bias. We focus on a sequential move game, in which the winning platform chooses its business model and access fees slightly before the competing platform. For the winning platform, we identify its equilibrium business model. For the losing platform, we identify its optimal business model that the winning platform needs to prevent. That is, the winning platform has to make sure that given that the losing platform were to respond by setting its optimal business model, it will not be able to profitably win the market.

[17] The profits of the two platforms will be similar, up to a negligible epsilon, if instead we assume that all buyers join platform D, or that with probability α they all join A while with probability $1-\alpha$ they all join D.

[18] In real life platforms can control the number of sellers they subsidize. The example in the introduction of Microsoft hosting 850 sessions to developers is consistent with this assumption, as Microsoft could obviously control the number of sessions it held.

We focus our exposition on equilibria where platform D moves first, i.e., profitably wins the market.[19] Using backward induction, we first find platform A's best response to (F_B^D, F_S^D).

In the situation when both dominant-A and dominant-D are possible, let $U_B^D(F_S^D, \alpha)$ denote the buyer's expected utility (i.e., gains from trade) from joining platform D under coordination bias α in favor of platform A. Notice that by our analysis in Section **??** this expected utility depends only on the access fee charged to the sellers by platform D and on α, as those variables determine the number of sellers joining platform D.

***Sellers-pay* business model.** The first option for platform A is to set $F_S^A > 0$. If the platform charges positive access fee to the sellers, they find it worthwhile to join the platform only if the buyers are joining as well. Then, in a dominant-A equilibrium, n^A sellers join platform A, where n^A is determined by

$$N_B\, p(n^A) - K - F_S^A = 0\,. \tag{4}$$

Given coordination bias, the condition for buyers to join is constructed as if sellers would join platform A with probability α (and platform D with probability $1 - \alpha$). The buyer's expected utility from joining platform A in such a case would be $Q + \alpha U_B(n^A) + (1 - \alpha)U_B(0) - F_B^A$. Thus, buyers join platform A when

$$Q + \alpha\, U_B(n^A) - F_B^A \geq U_B^D(F_S^D, \alpha) - F_B^D\,. \tag{5}$$

Condition (**??**) selects a unique equilibrium with rational beliefs. Whenever the left-hand-side of (**??**) is equal or higher than the right-hand-side, then each buyer plays dominant-A, expecting that other buyers and sellers will play dominant-A as well. Therefore, all buyers and sellers play dominant-A. If the inequality in (**??**) were violated, each buyer would have played dominant-D,

[19] Later, we show that the order of play—whether platform A plays before or after platform D—does not affect the optimal business models.

expecting that other buyers and sellers will play dominant-D as well.

Platform A wants to keep F_B^A as high as possible, while assuring that condition (**??**) holds. Hence, the platform sets F_B^A such that condition (**??**) holds with equality. With F_S^A and F_B^A identified by (**??**) and (**??**), platform A's profit under *sellers-pay* business model, $\Pi^A_{\textit{sellers-pay}} = n^A F_S^A + N_B F_B^A$, can be expressed as a function of n^A:

$$\Pi^A_{\textit{sellers-pay}}(n^A) = N_B \left(\pi^A_{\textit{sellers-pay}}(n^A) + Q - U_B^D(F_S^D, \alpha) + F_B^D\right) , \tag{6}$$

where

$$\pi^A_{\textit{sellers-pay}}(n^A) = n^A\big(p(n^A) - k\big) + \alpha U_B(n^A) \, . \tag{7}$$

Let n^{A^*} denote the number of sellers that maximizes (**??**) (and therefore (**??**)). While we assume that platforms compete by setting access fees, it is more convenient to solve directly for the optimal number of sellers that platform A wishes to attract, n^A.

Equation (**??**) reveals that when choosing n^A to maximize its profit, platform A internalizes all the sellers' gains from trade, but only a fraction α of the buyers' gains from trade. In this sense, platform A is oriented towards capturing the revenues from the sellers' side, and as we show below, use F_B^A as the only tool for competing with platform D. Also, because platform A internalizes only fraction α of the benefits that sellers provide to buyers, *sellers-pay* involves attracting fewer sellers than the first-best (trade-maximizing level).

***Buyers-pay* business model.** Next, we turn to platform A's optimal best response given that it chooses seller's access fee $F_S^A \leq 0$. Notice first that it is never optimal to set $F_S^A < -K$, because the platform can saturate with $\hat{n}$ sellers by setting $F_S^A = -K$. Moreover, notice that it is never optimal for platform A to set $0 \geq F_S^A > -K$. This is because for any $F_S^A > -K$, sellers do not cover their entry costs unless buyers join platform A, which forces platform A to compete in attracting buyers by setting a low F_B^A. Given that it does so, platform A might as well charge a high F_S^A to capture the sellers' profit, by using a *sellers-pay* business model. Therefore, platform A sets $F_S^A = -K$.

In a dominant-A equilibrium where all buyers join platform A, setting $F_S^A = -K$ attracts $\hat{n}$ sellers to join platform A, because for any $n^A < \hat{n}$, $p(n^A) > 0$ and therefore more sellers would like to join.[20] In dominant-D equilibrium, our third tie-breaking rule implies that $n^A = \hat{n}$ sellers will still find it optimal to join platform A. Intuitively, as sellers are fully compensated for their entry costs, a seller bear no risk of losing money from joining into an "empty" platform, which occur if buyers play dominant-D. The seller may earn positive profits if buyers were to play dominant-A.

Let us turn now to the buyers side under *buyers-pay* business model. Given coordination bias, the condition for buyers to join is constructed as if sellers would play dominant-A with probability α (and dominant-D with probability $1 - \alpha$). Since sellers join platform A in both of these equilibria, the buyer's expected utility from joining platform A in such a case would be $Q + \alpha U_B(\hat{n}) + (1 - \alpha)U_B(\hat{n}) - F_B^A$. Thus, buyers join platform A when

$$Q + U_B(\hat{n}) - F_B^A \geq U_B^D(F_S^D, \alpha) - F_B^D \, . \tag{8}$$

Condition (**??**) selects a unique equilibrium with rational beliefs. Whenever the inequality in (**??**) holds, all buyers and sellers play dominant-A, expecting all other agents to play it as well. Therefore, dominant-A occurs. When the inequality in (**??**) is violated, each agent would play dominant-D, expecting all other agents to play dominant-D as well. Notice that here α does not appear on the left-hand-side, because the buyer knows that by subsidizing sellers, platform A guarantees sellers participation in both equilibria.

To keep F_B^A as high as possible, while assuring that (**??**) holds, platform A sets F_B^A such that condition (**??**) holds with equality. Then platform A's profit under *buyers-pay* business model is $\Pi^A_{\textit{buyers-pay}} = \hat{n}F_S^A + N_B F_B^A$, or

[20] By our second tie-braking assumption, no more than $\hat{n}$ sellers will enter.

$$\Pi^A_{\textit{buyers-pay}} = N_B\left(\pi^A_{\textit{buyers-pay}} + Q - U^D_B(F^D_S, \alpha) + F^D_B\right)\,, \tag{9}$$

where

$$\pi^A_{\textit{buyers-pay}} = U_B(\hat{n}) - \hat{n}\,k\,. \tag{10}$$

Equation (**??**) reveals that now platform A fully internalizes the buyers' gains from trade, but does not collect any gains from trade to the sellers' side (because $p(\hat{n}) = 0$). In this sense, platform A is oriented towards creating maximal value to the buyers side, and capturing all of it. From now onwards we refer to this business model as *buyers-pay*.

Notice that when platform A loses the market, it will not subsidize sellers, as doing so would result in a loss.

Optimal business model for platform A. By comparing (**??**) and (**??**)—maximal profit under each business model—we find that platform A prefers to adopt the *sellers-pay* business model if $\pi^A_{\textit{sellers-pay}}(n^{A*}) > \pi^A_{\textit{buyers-pay}}$, and prefers to adopt the *buyers-pay* business model if $\pi^A_{\textit{sellers-pay}}(n^{A*}) < \pi^A_{\textit{buyers-pay}}$. Notice that both n^{A*} and $\pi^A_{\textit{sellers-pay}}(n^{A*})$ depend on α, while $\pi^A_{\textit{buyers-pay}}$ does not. Notice also that both n^{A*} and $\pi^A_{\textit{sellers-pay}}(n^{A*})$ are independent of platform D's access fees. Therefore, platform A's optimal business model (and consequently F^A_S) is independent of whether platform A moves first or second.

For the convenience of exposition, let $\pi^A \equiv \max\{\pi^A_{\textit{sellers-pay}}(n^{A*}), \pi^A_{\textit{buyers-pay}}\}$. Then the maximal profit that platform A can achieve is $\Pi^A = N_B\left[\pi^A + Q - U^D_B(F^D_S, \alpha) + F^D_B\right]$. Suppose that the second mover platform enters only if it makes positive profit. When $\Pi^A \leq 0$, platform A chooses a strategy equivalent to not entering the market (e.g., high access fees).

Optimal business model for platform D. Given those strategies by platform A (second-mover), platform D wins the market when it sets such access fees to prevent the competitor's entry, i.e., so that

$$N_B\left[\pi^A + Q - U_B^D(F_S^D,\alpha) + F_B^D\right] = 0 \implies N_B F_B^D = N_B\left[U_B^D(F_S^D,\alpha) - \pi^A - Q\right] \tag{11}$$

With this constraint, platform D decides whether to adopt *sellers-pay* or *buyers-pay* business model.[21] If platform D adopts a *buyers-pay* business model, then it attracts the same number of sellers, $\hat{n}$, as platform A's *buyers-pay* business model. From now onward we can define $\pi_{\textit{buyers-pay}} \equiv \pi^D_{\textit{buyers-pay}} = \pi^A_{\textit{buyers-pay}}$. If platform D adopts *sellers-pay*, it attracts n^{D*} which maximizes $\pi^D_{\textit{sellers-pay}}(n^D) \equiv (1-\alpha)U_B(n^D) + n^D[p(n^D) - k]$.

Platform D chooses *sellers-pay* when $\pi_{\textit{sellers-pay}}(n^{D*}) > \pi^D_{\textit{buyers-pay}}$, and *buyers-pay* otherwise. It must be, however, that $\max\{\Pi^D_{\textit{sellers-pay}}(n^{D*}), \Pi^D_{\textit{buyers-pay}}\} \geq 0$. Otherwise, platform D would not want to play either of those strategies. Let $\pi^D \equiv \max\{\pi^D_{\textit{sellers-pay}}(n^{D*}), \pi_{\textit{buyers-pay}}\}$. Then $\Pi^D = N_B\left[\pi^D - \pi^A - Q\right]$ and $\Pi^D > 0 \iff \pi^D - \pi^A > Q$. Notice that the choice of the optimal business model does not depend on whether the platform moves first or second.[22]

Lemmas **??** and **??** summarize the properties of each business model.

Lemma 1 (features of *sellers-pay* business model) *If platform $i = A, D$ chooses a* sellers-pay *business model, then it charges a positive access fees from the sellers, $F_S^i > 0$, and uses the buyers' access fee as the exclusive tool for competing with the other platform. Platform i attracts fewer sellers than the trade-maximizing level, $n^{i*}(\alpha) < n^*$ for all $\alpha < 1$. Moreover,*

(i) for platform A, $n^{A*}(\alpha)$ is increasing with α and $n^{A*} = n^*$ for $\alpha = 1$;

(ii) for platform D, $n^{D*}(\alpha) < n^{A*}(\alpha)$ for any α, and $n^{D*}(\alpha)$ is decreasing with α.

Proof. See Appendix.

[21] The logic behind this decision is very similar to decision of platform A above, and we defer formal analysis to Appendix **??**.

[22] We explicitly analyze it in Appendix **??**.

Lemma 2 (features of *buyers-pay* business model) *If platform $i = A, D$ chooses a* buyers-pay *business model, then it charges a negative access fees from the sellers, $F_S^i = -K < 0$, and a positive access fee form the buyers, $F_B^i > 0$. The platform attracts $\hat{n}$ sellers, which is more than the trade-maximizing level, $\hat{n} > n^*$ for all α.*

Proof. See Appendix.

The lemmas show that under *sellers-pay* business model, a platform attracts fewer sellers than the trade-maximizing level, while under *buyers-pay*, a platform attracts more sellers than the trade-maximizing level. This result differs from Hagiu (2006) that shows that an incumbent platform which benefits from a full coordination bias advantage (corresponding to platform A in our model) does not distort its level of trade while the competing entrant (corresponding to platform D) distorts the level of trade downwards. These results also differ from Halaburda and Yehezkel (2013) which show that both platforms distort the level of trade downward regardless of whether they attract the buyer of the seller. For business strategy, Lemmas **??** and **??** show that a platform's business model also indicates whether a platform should "oversupply" or "undersupply" applications.

Business models in equilibrium. Since the optimal business model for each platform is independent of whether it plays first or second, we can therefore solve the equilibrium in two steps. First, regardless of the sequence of play, we can compare between $\pi_{buyers\text{-}pay}$, $\pi^D_{buyers\text{-}pay}$ and $\pi^A_{buyers\text{-}pay}$, and derive the platforms' optimal business models. In equilibrium, the winning platform will implement its optimal business model, while making sure that the losing platform cannot profitably win the market with its own optimal business model. In the second step, we solve for the identity of the wining platform in a sequential equilibrium, using the optimal business models that we derived in the first step.

Starting with the first step, Figure **??** shows the optimal business models for platforms A and D given α and k. The figure reveals that there are three regions: (Ω_{BB}) both platforms adopt a *buyers-pay*, (Ω_{SS}) both platforms adopt *sellers-pay*, (Ω_{SB}) platform A adopts *sellers-pay* and platform D adopts *buyers-pay*. Proposition **??** describes the characteristics of each region.

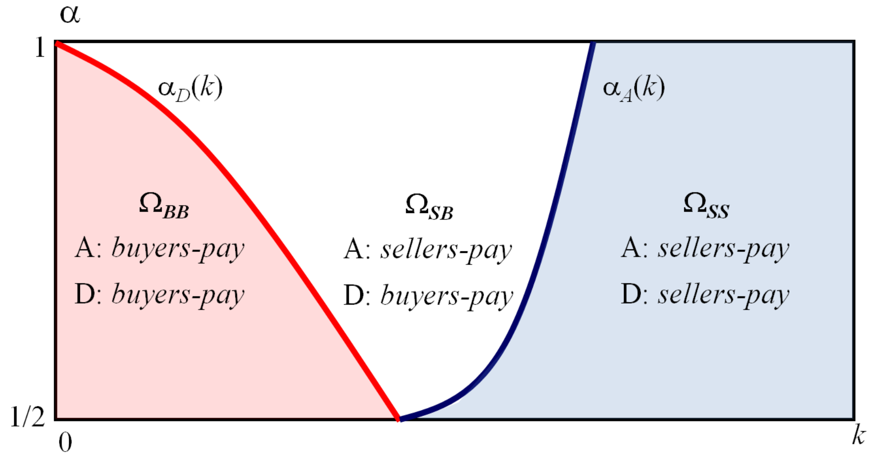


Figure 1: The three subsets, Ω_{BB}, Ω_{SB} and Ω_{SS}

Proposition 1 (equilibrium choice of business model) *For any* $\alpha \in \left[\frac{1}{2}, 1\right]$, *and any* $k \in [0, u'_B(0)]$, *a pair* $(\alpha,\, k)$ *belongs to exactly one of three regions:*

$\Omega_{SS} = \left\{(\alpha, k)|\, \pi^{A}_{\text{sellers-pay}}(n^{A^*}) > \pi^{D}_{\text{sellers-pay}}(n^{D^*}) > \pi_{\text{buyers-pay}}\right\}$, *where both platforms adopt* sellers-pay *business model;*

$\Omega_{BB} = \left\{(\alpha, k)|\, \pi_{\text{buyers-pay}} > \pi^{A}_{\text{sellers-pay}}(n^{A^*}) > \pi^{D}_{\text{sellers-pay}}(n^{D^*})\right\}$, *where both platforms adopt* buyers-pay *business model; or*

$\Omega_{SB} = \left\{(\alpha, k)|\, \pi^{A}_{\text{sellers-pay}}(n^{A^*}) > \pi_{\text{buyers-pay}} > \pi^{D}_{\text{sellers-pay}}(n^{D^*})\right\}$, *where platform* A *adopts* sellers-pay *and platform* D *adopts* buyers-pay *business model.*

The thresholds between those regions are characterized by $\alpha_A(k)$ *and* $\alpha_D(k)$, *where*

$\alpha_A(k)$ *is uniquely defined by* $\pi^{A}_{\text{sellers-pay}}(n^{A^*}) = \pi_{\text{buyers-pay}}$; *moreover,* $\alpha_A(0) = 1$, $\alpha'_1 < 0$ *and* $\alpha''_A > 0$; *also, there is a point* k_1 *such that* $\alpha_A(k_1) = \frac{1}{2}$, *where* $0 < k_1 < u'_B(0)$.

$\alpha_D(k)$ *is uniquely defined by* $\pi^{D}_{\text{sellers-pay}}(n^{D^*}) = \pi_{\text{buyers-pay}}$; *moreover,* $\alpha_D(k_1) = \frac{1}{2}$, $\alpha'_D > 0$ *and* $\alpha''_D > 0$; *also, there is a point,* k_2, *such that* $\alpha_D(k_2) = 1$, *where* $k_1 < k_2 < u'_B(0)$.

Proof. See Appendix.

In choosing which business model to adopt, platforms are facing the following tradeoff. If a platform attracts buyers (*sellers-pay*), the platform can fully collect the sellers' surplus from trading with buyers, but internalizes only part of the buyers' surplus from trading with sellers, depending on the degree of the coordination bias. When attracting sellers (*buyers-pay*), the platform internalizes the buyers' surplus from trade with sellers, regardless of α, but at the cost of giving up on the sellers' surplus from trading with buyers. Therefore, the platforms' choices of business models depend on two effects. First, on how the joint surplus from trade is divided between sellers and buyers. Second, on the degree of coordination bias, α.

The first effect is determined according to $k = K/N_B$. Given an access fee for sellers above $-K$, as k increases, fewer sellers will join the platform, implying that sellers that do join the platform compete less aggressively for buyers, and sellers (buyers) earn higher (lower) payoff from trading. Therefore, as k increases, both platforms have more of an incentive to adopt *sellers-pay* business model, where they collect the sellers' payoff from trading with buyers, while giving up some of the buyers' payoff from trading with sellers, by lowering the buyers' access fees to make the platform more attractive.

The second effect, through α, affects each platform in the opposite direction. As α increases, platform A (D) has more (less) of an incentive to adopt *sellers-pay*, because it becomes increasingly cheaper for platform A to attract buyers (in order to collect the revenue from the sellers), and increasingly more expensive for platform D. Hence, increasing α makes *sellers-pay* business model more appealing to platform A, while it makes *buyers-pay* business model more appealing to platform D.

The two platforms may choose the same business model. If they choose different business models, it is possible that platform A adopts the *sellers-pay* business model, while platform D

adopts *buyers-pay*, but not the other way around. This is because it is always cheaper for platform A than for platform D to attract the buyers and collect the revenue on the sellers' side.

In Figure **??**, we can clearly see that increase in α motivates platform A to switch from *buyers-pay* business model to *sellers-pay*. Platform D may be motivated to switch in the opposite direction when α increases. As k increases, both platforms are motivated to switch from *buyers-pay* to *sellers-pay* business model.

When $\alpha = \frac{1}{2}$, the platforms are symmetric in the market coordination bias, and none has an advantage over the other in attracting the buyers. Hence, both platforms choose the same business model. For k lower than k_1, intensive entry and price competition between sellers implies that buyers earn most of the gains from trade with sellers. As a result, both platforms subsidize the sellers and collect the buyers' payoffs, by adopting *buyers-pay* business model. For k higher than k_1, the high entry cost implies less entry and softer price competition between sellers. Therefore, both platforms prefer to collect the sellers' payoff and compete by attracting buyers, i.e., adopting a *sellers-pay* business model. As α increases and the platforms become more asymmetric in the market coordination bias they are facing, they are more likely to adopt different business models.

As α increases, it becomes cheaper for platform A to attract buyers. When α increases above α_A (for $k < k_1$), the effect is strong enough that platform A finds it optimal to switch its business model from *buyers-pay* to *sellers-pay.*

For platform D it is the exact opposite: As α increases, it becomes more expensive for platform D to attract the buyers. Hence, if for $k < k_1$ platform D subsidized the sellers in *buyers-pay* business model for $\alpha = \frac{1}{2}$, it continues to do so for any larger α. However, for $k \in (k_1, k_2)$ when α increases above α_D, competing on buyers becomes more expensive for platform D then subsidizing sellers, and the platform finds it optimal to switch its business model from *sellers-pay* to *buyers-pay.* For $k > k_2$ giving up on the sellers' payoff from trading with buyers by adopting *buyers-pay* is too costly for both platforms. Even the disadvantaged platform, D, for such high k prefers to bear the

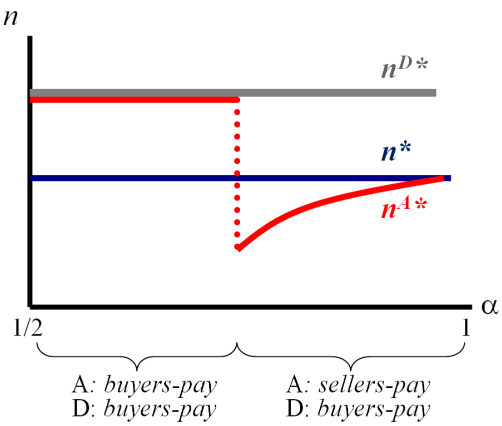


Figure 2: The equilibrium number of sellers as a function of α, for $k < k_1$

cost of attracting the buyers and sticks to *sellers-pay* for any α. The corollary below summarizes this discussion.

Corollary 1 *Small change in α may lead a platform to choose a different business model:*

(i) For $k < k_1$, an increase in α motivates platform A to switch from buyers-pay *to* sellers-pay *business model, and switch from oversupplying to undersupplying sellers.*

(ii) For $k_1 < k < k_2$, an increase in α motivates platform D to switch from sellers-pay *to* buyers-pay *business model, and switch from undersupplying to oversupplying sellers.*

(iii) For $k > k_2$, an increase in α has no effect on platform's optimal business models.

The results above show that the relative position in the market—as measured by the strength of the coordination bias—has a significant effect on the choice of a business model. The respective choices of the business models in turn affect the platforms' pricing decisions, and whether the oversupply or undersupply sellers, in comparison with the trade-maximizing number of sellers. We illustrate parts (i) and (ii) of Corollary **??** in Figures **??** and **??**.

Figure **??** shows the equilibrium number of sellers that platforms attract, as a function of α, for $k < k_1$. The figure reveals that while platform D always oversupply sellers, platform A first

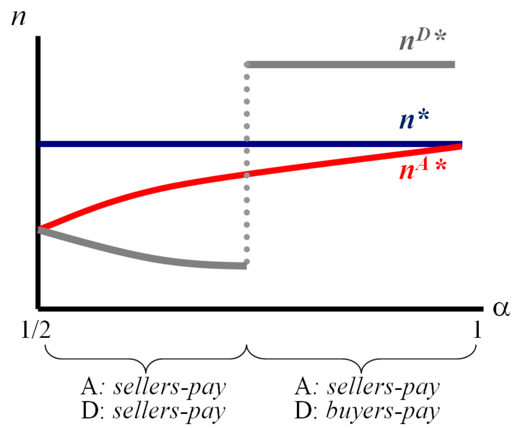


Figure 3: The equilibrium number of sellers as a function of α, for $k_1 < k < k_2$

oversupply, and then undersupply when an increase in α motivate the platform to switch from *buyers-pay* to *sellers-pay* business models. Figure **??** shows the equilibrium number of sellers that platforms attract, as a function of α, for $k_1 < k < k_2$. Now, platform A always undersupply, but platform D first undersupply, and then oversupply when an increase in α motivate the platforms to switch from *sellers-pay* to *buyers-pay*.

Winning platform. We now turn to showing which platform wins the market in equilibrium.[23] Suppose that platform i plays slightly before platform j. Let $Q^i = Q$ if $i = A$ and $Q^i = -Q$ if $i = D$. Recall that $\pi^i = \max\{\pi^i_{\textit{sellers-pay}}(n^{i*}), \pi_{\textit{buyers-pay}}\}$. To win the market, platform i needs to set F^i_B such that platform j cannot profitably win the market. Using equation (**??**) (and a similar one for platfrom A), this implies that platform i sets

$$F^i_B = U^i_B(Q^i + F^i_S, \alpha) - \pi^j \,, \tag{12}$$

Platform i earns $\Pi^i = n^i F^i_S + N_B F^i_B$, or

[23] Again, it is important to emphasize that in real-life situation, more than one platform can gain positive market share because of horizontal product differentiation. We analyze such case in Section **??**.

$$\Pi^i = \left[N_B\, U_B^i(F_S^i, \alpha) + F_S^i n^i\right] - N_B \pi^j + N_B Q^i\,, \tag{13}$$

Platform i will choose the business model that maximizes the term inside the square brackets. From the analysis of the platforms' optimal business models, the maximum term inside the brackets is $N_B\, \pi^i$ and platform i earns $\Pi^i = N_B(\pi^i - \pi^j + Q^i)$. We can conclude that platform i can profitably win the market if and only if $Q^i > \pi^j - \pi^i$. If however $Q^i < \pi^j - \pi^i$, platform j could profitably win the market if it were to move slightly before platform i.

To identify the winning platform, in Lemma **??** we define the cutoff level $\overline{Q}$, such that there is a sequential equilibrium in which platform A moves first and wins the market for $Q > \overline{Q}$, and platform D moves first and wins the market otherwise. The threshold indicates extend to which higher quality relates to winning the market.

Lemma 3 (winning platform) *Let*

$$\overline{Q} = \begin{cases} \pi^D_{\text{sellers-pay}}(n^{D*}) - \pi^A_{\text{sellers-pay}}(n^{A*}); & (\alpha, k) \in \Omega_{SS}; \\ \pi_{\text{buyers-pay}} - \pi^A_{\text{sellers-pay}}(n^{A*}); & (\alpha, k) \in \Omega_{SB}; \\ 0; & (\alpha, k) \in \Omega_{BB}. \end{cases}$$

Then, platform A wins the market if and only if $Q > \overline{Q}$, and earns $\Pi^A = (Q - \overline{Q})N_B$. Platform D wins the market if and only if $Q < \overline{Q}$, and earns $\Pi^D = (\overline{Q} - Q)N_B$.

Notice that the threshold $\overline{Q}$ depends on α. Moreover, $\overline{Q} \leq 0$, which means that platform A may win the market even when it is of lower quality than platform D.[24] This is because the coordination bias favors platform A. The following proposition describes how $\overline{Q}$ depends on α.

Proposition 2 (the effect of α on $\overline{Q}$) *For all regions, if $\alpha = \frac{1}{2}$, then $\overline{Q} = 0$. When $\alpha > \frac{1}{2}$:*

[24]Recall that we treat α and Q as independent of each other. In Section **??** we investigate how higher quality may lead to larger coordination bias advantage. We examine how correlation between α and Q affects the results at the end of this section.

(i) For regions Ω_{SS} and Ω_{SB}, $\overline{Q} < 0$. Moreover, $\overline{Q}$ and Π^D are decreasing with α, and Π^A is increasing with α.

(ii) For Ω_{BB}, $\overline{Q} = 0$, and Π^A and Π^D are independent of α.

Proof. See Appendix.

Proposition **??** shows that when there is no coordination bias (i.e., $\alpha = \frac{1}{2}$), then the platform with higher quality wins the market, regardless of the business model that each platform adopted. Intuitively, without coordination bias, the platforms are symmetric except for their qualities. Hence the quality is the only source of competitive advantage, and it determines the identity of the winning platform.

For region Ω_{BB}, quality alone determines the identity of the winning platform for all $\alpha > \frac{1}{2}$. Both platforms adopt *buyers-pay* business model and subsidize sellers to collect highest possible revenue from the buyers. Given the subsidy to the sellers, coordination bias does not play a role, as each platform assures $\hat{n}$ sellers. Consequently, the platform with the highest quality wins the market. In this region the profits are also determined solely by Q.

In the other two regions, i.e., when at least one platform adopts *sellers-pay* business model, the coordination bias plays a role in determining which platform wins, and how large are the profits of the winning platform. Larger coordination bias gives larger competitive advantage to platform A. Therefore, this platform can win the market even if it offers lower quality ($\overline{Q} < 0$). This is because with larger α, it can command higher access fee (or lower subsidy) from the buyers. However, if it offers lower quality, it limits the access fee it can command from the buyers. Therefore, platform D can profitably win the market if its quality advantage is sufficiently large. The higher is α, the larger quality difference platform D needs to win the market, in order to compensate for coordination bias in favor of platform A ($\overline{Q}$ is decreasing in α). We also find that the negative effect of α on $\overline{Q}$ is stronger when both platforms adopt *sellers-pay* business models, than when only platform A

does so.

Positive correlation between Q and α. So far, we have considered the platforms' quality difference and the degree of coordination bias as two separate variables. In real life, it is natural to expect that the two variables are positively correlated—if the quality difference between the two platforms increases in favor of one of the platforms, buyers would place a higher coordination bias in favor of that platform.

As we show in the base model, when $\alpha(Q)$ is independent of Q, the platforms' business models are not affected by Q. This is because of our simplifying assumption that buyers' utilities are separable in quality. If however $\alpha(Q)$ is increasing with Q, then the platforms' business model will be affected by Q, indirectly through $\alpha(Q)$. In particular, an increase in Q can motivate platform A to switch from subsidizing sellers to attracting buyers (for low values of k), and motivate platform D to switch from attracting buyers to subsidizing sellers (for intermediate values of k).

Platforms should therefore take into account that an increase in the quality of the service that they offer to buyers may also require them to adjust their business models, or motivate their competitors to adjust their own business model. In particular, an increase in the platform's quality will have two potential effects on the platform's profit. First, the direct effect of increasing buyers' willingness to pay, coming from the positive effect that Q has on buyers' utilities. Second, the indirect effect of increasing the buyers' coordination bias, that provides the platform with a stronger competitive advantage. This second effect holds when at least one of the platforms competes by attracting buyers. If however both platforms compete by subsidizing sellers (the case of low development costs), second effect vanishes, because platforms' profits do not depend on the degree of coordination bias.

Business models in a simultaneous move game. Here we discuss the robustness of our results to the assumption that platforms select their strategies sequentially. As our analysis reveals, the platforms' optimal business models are not affected by the order of play. Therefore, the winning platform in a simultaneous move game chooses the same business model as we identify in Proposition **??**. For the losing platform, its ability to implement a *buyers-pay* business model in a simultaneous move game depends on whether sellers indeed play the equilibrium in which they join the losing platform, if they are only just compensated for their development costs. If the losing platform expects that sellers will join it in such a case, it will not be able to implement a *buyers-pay* business model because doing so would result in a loss. If it expects that sellers will stay out, then the losing platform can implement the *buyers-pay* business model as in Proposition **??**.

5 Heterogeneous Buyers

Our analysis so far focused on homogeneous buyers. In this section we consider heterogeneous buyers by assuming that each platform has certain "loyal" buyers that will either join it or not join a platform at all. We ask how the proportion of loyal buyers affects the platforms' response to coordination bias. The main result of this section is that the presence of loyal buyers motivates both platforms to compete by attracting sellers (*buyers-pay* business model) for levels of coordination bias under which platforms compete by attracting buyers (*sellers-pay* business model) in the absence of loyal buyers. Moreover, when platform A has more loyal buyers than platform D and the degree of coordination bias is low (i.e., α is close to 1/2), there can be an equilibrium in which platform A attracts sellers and platform D attracts buyers. Such equilibrium does not emerge with homogeneous buyers.

To keep the analysis tractable, we make the following simplifying assumptions:

Interaction between buyers and sellers. Suppose that the total mass of consumers is 1, i.e., $N_B = 1$. A buyer values each application at $v > K$ and demands at most $\hat{n}$ units. That is,

$u_B(n) = nv$ for $n \leq \hat{n}$ and $u_B(n) = v\hat{n}$ for $n > \hat{n}$.[25] When buyers and sellers meet to trade, we use Nash bargaining solution where the seller makes an offer (and captures the whole surplus) with probability γ, and the buyer makes an offer with probability $1-\gamma$. In the former case the price of an application will be v, and in the latter it will be 0. As we will show, even though the interaction between buyers and sellers is different than in our base model, it will not change the main results of Figure **??**. The introduction of buyers' heterogeneity, however, will have a qualitative effect on the results.

Buyers' heterogeneity. To model buyers' heterogeneity, we follow Narasimhan (1988) by assuming that there are d_i buyers that are "loyal" to platform i, where $0 < d_D \leq d_A < 1$ and $d_D + d_A < 1$. Buyers that are loyal to platform i, want to buy only from platform i (or not buy at all).[26] Non-loyal buyers, with a mass $1 - d_D - d_A > 0$, view the two platforms as substitutes, as in our base model. We continue to assume that there is α-coordination bias in favor of platform A, and that this is common knowledge. The presence of loyal buyers can emerge from subjective tastes in favor of the features of one of the platforms. For example, some smartphone consumers may have a strong preference towards Apple's iPhone, because of Apple's brand image and product design. Other consumers may not care about product image and design, and may view smartphone manufacturers as close substitutes. Loyal buyers can also emerge from previous experience. For example, consumers that used iPhone in the past, may be accustomed to its iOS operating system and may therefore strictly prefer it over unfamiliar operating systems. Notice that if $d_A = d_D \equiv d$, where $0 < d < 1/2$, then d measures the degree of horizontal differentiation. If d is close to 0,

[25] We make the assumption that buyers' marginal utility from sellers is constant (instead of decreasing as in the base model) because otherwise the first and second order conditions for the platforms equilibrium number of sellers could not be solved analytically. As we show, under the simplifying assumptions of this section, the case of homogeneous buyers is qualitative similar to the results in the base model. Therefore, we expect that these simplifying assumptions do not drive the differences between the homogeneous and the heterogeneous cases that this section finds.

[26] Loyal buyers have fully favorable beliefs towards their preferred platform. That is, if after the access fees are set there is an equilibrium in which all loyal buyers to platform i join it, then indeed they will do so. However, as we will show, the degree of coordination bias will still affect the decision of the loyal buyers, when a platform is competing for the non-loyal buyers.

the two platforms are close substitutes. As d approaches 1/2, the two platforms becomes two monopolies.

Timing. As in the base model, the platforms move sequentially in setting their access fees.[27] With the presences of both loyal and non-loyal buyers, both platforms will be active in the market with positive market share. We therefore focus on equilibria in which platform A moves first, and wins the non-loyal buyers. In equilibrium, Platform A attracts its own loyal buyers and wins the non-loyal buyers. Platform D only attracts its own loyal buyers. The opposite case, in which platform D plays first and wins the non-loyal buyers can be obtained by replacing α and d_A with $1-\alpha$ and d_D.

Second mover's strategy. Suppose that platform A chose its access fees, and that those fees are not prohibitively high.[28] Given these fees, platform D, moving second can either focus on capturing its loyal buyers only, or aim to capture also the non-loyal segment.

Platform D focuses on its loyal buyers only. In equilibrium, platform D attracts all of its loyal buyers, d_D, and $\hat{n}$ sellers. Since loyal buyers do not have a coordination bias, if there is an equilibrium in which $\hat{n}$ sellers and all loyal buyers join platform D, they play this equilibrium, expecting that sellers and loyal buyers do the same. Since sellers make an offer to the buyers with probability γ, the expected payoff of loyal buyers and sellers, gross of the access fees, are $(1-\gamma)v\hat{n}$ and $-K+d_D\gamma v$, respectively. Therefore, platform D charges the buyers access fee of $F_B^D=(1-\gamma)v\hat{n}$, and the sellers the fee of $F_S^D=-K+d_D\gamma v$. Then the platform's profit is

$$\Pi_{loyal}^D = d_D F_B^D + \hat{n} F_S^D = \hat{n}(d_D v - K)\,.$$

[27] We make this assumption because as Narasimhan (1988) shows, in a setting with loyal consumers there is no pure-strategy equilibrium in a simultaneous game.

[28] As is shown below, no buyer ever joins platform A if F_B^A is higher than $(1-\gamma)v\hat{n}$. And no seller joins if F_S^A is higher than $-K+(1-d_A)\hat{n}$. When platform A sets such prohibitive fees, it in fact leaves the market.

Suppose that $d_D v > K$. Otherwise, in equilibrium platform D does not gain a positive market share, as in our base model.

Platform D captures the non-loyal segment. An alternative option for platform D is to compete with platform A to attract the non-loyal buyers. To this end, the platform can choose one of two strategies, attracting buyers (*sellers-pay*) or attracting sellers (*buyers-pay*).

When attracting buyers, the platform charges sellers a high access fee such that sellers join platform D only if they believe that both loyal and non-loyal buyers join. That is,

$$F_S^D = -K + (1 - d_A)\gamma\hat{n}\,.$$

Then, there exist two equilibria: in one $\hat{n}$ sellers and $1 - d_A$ buyers join platform D, and in the other no buyer and no seller joins platform D. Given that both equilibria exist, the α-coordination bias implies that agents play the equilibrium where non-loyal segment joins platform D—expecting that others will play this equilibrium as well—when

$$-F_B^D + (1-\alpha)(1-\gamma)v\hat{n} > Q + U_B^A(F_S^A, \alpha) - F_B^A\,. \tag{14}$$

Notice that due to the network externalities, the degree of coordination bias is relevant for the loyal buyers of platform D. If α is large such that (**??**) holds in the opposite direction, loyal buyers do not join platform D as they know that sellers expect that non-loyal buyers would not join it.

Satisfying (**??**)[29] yields platform D's profits

$$\Pi^D_{\textit{sellers-pay}} = (1-d_A)F_B^D + \hat{n}F_S^D = \hat{n}v\big[(1-\alpha)(1-\gamma)(1-d_A) + \gamma(1-d_A)\big] - \hat{n}K - (1-d_A)\left(Q + U_B^A(F_S^A, \alpha) - F_B^A\right)\,.$$

Alternatively, platform D may aim to capture the non-loyal segment by attracting the sellers. When attracting the sellers, platform D charges sellers a low access fee such that sellers join

[29] As before, for the convenience of exposition we solve (**??**) as if it were equality.

platform D even if only loyal buyers join. That is,

$$F_S^D = -K + d_D \gamma \hat{n}\,.$$

Again, there may exist two equilibria (depending on the strategy of platform A), one in which non-loyal buyers join platform D, and another in which non-loyal join platform A. Notice that since platform D charges sellers a low access fee such that sellers join platform D even if only loyal buyers join, in the first equilibrium $\hat{n}$ sellers and $1-d_A$ buyers join platform D, and in the second equilibrium $\hat{n}$ sellers but only d_D buyers join platform D, while non-loyal buyers join platform A.[30] Since in both of these equilibria, $\hat{n}$ sellers join platform D, the expected buyers' utility from joining platform D is $-F_B^D + (1-\gamma)v\hat{n}$ regardless of α. Therefore, when the two equilibria exist, the α-coordination bias implies that agents play the equilibrium where non-loyal buyers join D, expecting that others will play this equilibrium as well, when

$$-F_B^D + (1-\gamma)v\hat{n} > Q + U_B^A(F_S^A, \alpha) - F_B^A\,. \tag{15}$$

Platform D's profit is then

$$\Pi^D_{\textit{buyers-pay}} = \hat{n}v\big[(1-\gamma)(1-d_A) + \gamma d_D\big] - \hat{n}K - (1-d_A)\,\left(Q + U_B^A(F_S^A, \alpha) - F_B^A\right)\,.$$

By comparing $\Pi^D_{\textit{sellers-pay}}$ and $\Pi^D_{\textit{buyers-pay}}$ notice that the two options differ in the terms inside the square brackets. Intuitively, when platform D attracts buyers, the term inside the squared brackets is negatively affected by α. This effect becomes stronger the higher is the proportion of the sum of buyers that are loyal to platform D and non-loyal buyers. This is because as we explained earlier, both loyal and non-loyal buyers are affected by the degree of coordination bias. When platform D attracts sellers, the term inside the squared brackets is affected (positively) by d_D and independent

[30] Those equilibria also differ in the number of sellers joining platform A.

of α. Comparing the two terms, we can see that platform D prefers *sellers-pay* business model (i.e., attracting buyers) when

$$\alpha < \alpha_D = \frac{\gamma(1-d_D-d_A)}{(1-\gamma)(1-d_A)}\,.$$

Otherwise, it prefers *buyers-pay* business model. Notice that α_D is independent of $\hat{n}$, v and K.

For the convenience of exposition, let $X \equiv \max\{(1-\alpha)(1-\gamma)(1-d_A)+\gamma(1-d_A),\ (1-\gamma)(1-d_A)+\gamma d_D\}$. Then platform D's profit from capturing non-loyal buyers is expressed by

$$\Pi^D_{non-loyal} = \hat{n}vX - \hat{n}K - (1-d_A)\left[Q + U^A_B(F^A_S,\alpha) - F^A_B\right].$$

First mover's strategy. Platform A wins the non-loyal market segment, if it sets its access fees such that it is optimal for platform D to focus on attracting its loyal buyers only, i.e., $\Pi^D_{non-loyal} \leq \Pi^D_{loyal}$, which is equivalent to

$$0 \,\leq\, \hat{n}v(d_D - X) + (1-d_A)[Q + U^A_B(F^A_S,\alpha) - F^A_B]\,. \tag{16}$$

To capture the non-loyal market segment, platform A chooses between attracting buyers (*sellers-pay*) and attracting sellers (*buyers-pay*). The analysis of platform A's business models is qualitatively similar to that of platform D, replacing α with $1-\alpha$ and d_D with d_A. In Appendix **??** we show that platforms A's profits from adopting *sellers-pay* and *buyers-pay* business models are

$$\Pi^A_{sellers\text{-}pay} = \frac{1-d_D}{1-d_A}\hat{n}v(d_D-X) + (1-d_D)\,Q - \hat{n}K + \hat{n}v\big[(1-d_D)(1-\gamma)\alpha + (1-d_D)\gamma\big]\,,$$
$$\Pi^A_{buyers\text{-}pay} = \frac{1-d_D}{1-d_A}\hat{n}v(d_D-X) + (1-d_D)\,Q - \hat{n}K + \hat{n}v\big[(1-d_D)(1-\gamma) + d_A\gamma\big]\,.$$

Comparing $\Pi^A_{sellers\text{-}pay}$ with $\Pi^A_{buyers\text{-}pay}$, notice that the profits under the two strategies differ in the terms inside the square brackets. In particular, when platform A attracts buyers, the term inside the square brackets is positively affected by α. This effect becomes stronger the higher is the proportion of the sum of buyers that are loyal to platform A and non-loyal buyers. When platform A attracts sellers, the term inside the square brackets is affected (positively) by d_A and independent of α. Comparing the two terms, we can see that platform A prefers *sellers-pay* business model (i.e., attracting buyers) when

$$\alpha > \alpha_A = \frac{(1-\gamma)(1-d_D) - \gamma(1-d_A-d_D)}{(1-\gamma)(1-d_D)}.$$

Notice that α_A is independent of $\hat{n}$, v and K. Finally, for this to be an equilibrium, the maximum profit that platform A earns from competing on the non-loyal buyers should be higher than its profit from serving its loyal buyers only. When attracting loyal buyers only, platform A ignores constraint (**??**), sets $F_B^A = (1-\gamma)v\hat{n} + Q$, $F_S^A = -K + d_A\gamma v$ and earns

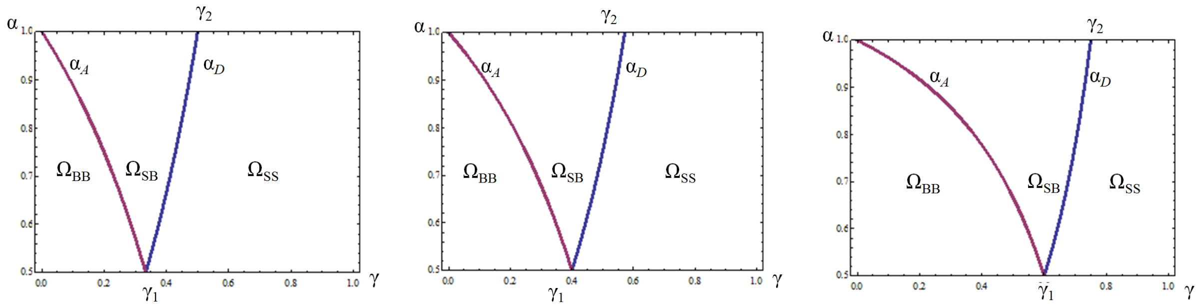
$$\Pi^A_{loyal} = d_A F_B^A + \hat{n} F_S^A = d_A\, Q + \hat{n}(d_A v - K)\,.$$

Since $d_A + d_D < 1$, $\max\{\Pi^A_{\textit{sellers-pay}}, \Pi^A_{\textit{buyers-pay}}\} - \Pi^A_{loyal}$ is an increasing function of Q. Therefore, $\max\{\Pi^A_{\textit{sellers-pay}}, \Pi^A_{\textit{buyers-pay}}\} - \Pi^A_{loyal} > 0$ if Q is sufficiently high. In particular, we find that if $d_A = d_D$, then $\max\{\Pi^A_{\textit{sellers-pay}}, \Pi^A_{\textit{buyers-pay}}\} - \Pi^A_{loyal} > 0$ for all $Q > 0$.[31] Therefore, competing for the non-loyal buyers brings higher profits for A than serving its loyal buyers only.

Now we turn to analyzing the effects of loyal buyers on the platforms' equilibrium business models. Consider first the case where $d_A = d_D = d$. Then, the parameter d, $0 < d < 1/2$, measures the degree of horizontal differentiation. If d is close to 0, most buyers are non-loyal as in our base model. As d increases, the two platforms are more differentiated in that there are more loyal buyers. As d becomes closer to $1/2$, the two platforms become monopolies.

Consider first the benchmark case of $d = 0$ (no horizontal differentiation). Since α_A and α_D are independent of $\hat{n}$, v and K, we can substitute $d_A = d_D = 0$ into α_A and α_D and show in panel (a)

[31] For the full analysis of this issue see the online appendix.



(a) $d = 0$ (b) $d = 0.2$ (c) $d = 0.4$

Figure 4: The three subsets, Ω_{BB}, Ω_{SB} and Ω_{SS} with heterogeneous buyers

of Figure **??**, α_A and α_D (and the resulting business models) as a function of γ. The parameters γ_1 and γ_2 are the values of γ that solve $\alpha_A = 1/2$ and $\alpha_D = 1$, respectively. The figure reveals that the results are similar to that of our base model, with the exception that now the business models are affected by γ instead of K. Although in this extension the interaction between buyers and sellers within the platform is different than in our base model, the main results hold because the parameter γ in the extension has a similar effect as K in the base model on the agents' ex-post payoff from trading. Recall that as K in the base model increases, fewer sellers enter a platform given any access fee above $-K$, and each seller earns a higher share of the joint surplus from trade with buyers. In this extension, as γ increases, sellers have a higher bargaining power, which again enables them to earn a higher share of the joint surplus from trade, v. As in our base model, the higher is the sellers' ex-post gains from trading with buyers, the more the platforms tend to attract buyers.

Next, suppose that $d > 0$. We obtain the following result:

Proposition 3 *Suppose that $d_A = d_D = d \geq 0$. Then, an increase in the proportion of loyal buyers increases the cutoff value of coordination bias from which onwards platform A switches from attracting sellers to attracting buyers, and decreases the cutoff value of coordination bias from which onwards platform D switches from attracting buyers to attracting sellers. That is, α_A is increasing with d while α_D is decreasing with d. Moreover, γ_1 and γ_2 are increasing with d, and $\gamma_1 = \gamma_2 = 1$*

if $d = 1/2$.

Proof. See Appendix.

To illustrate Proposition **??**, panels (b) and (c) of Figure **??** show the equilibrium business models as d increases, for $d = 0.2$ and $d = 0.4$. The figure shows that as d increases, γ_1 and γ_2 increase, implying that both platforms tend to attract sellers (*buyers-pay*), the more they are horizontally differentiated. As Proposition **??** implies, if $d \to 1/2$, such that the two platforms are almost two monopolies, then they both adopt *buyers-pay* for all α and γ. In such a case, the *buyers-pay* business model converges to the monopoly outcome. Intuitively, recall that when attracting buyers, a platform has to rely on the coordination bias for attracting both its own loyal and non-loyal buyers, and the effect of coordination bias becomes stronger the higher is the sum of the platform's loyal and non-loyal buyers. In contrast, when attracting sellers, a platform collects the sellers' payoff from serving its loyal buyers only. Consequently, the more loyal buyers a platform has, the more it becomes profitable for the platform to rely on these loyal buyers in attracting sellers.

Consider now the case where platform A has more loyal buyers than platform D: $d_A > d_D$. Following the intuition above, platform A may now have a stronger incentive to attract sellers than platform D. To show this, let $\tilde{\gamma}_1$ denote the solution to $\alpha_D = 1/2$. We therefore have the following result:

Proposition 4 *If platforms have the same proportion of loyal buyers,* $d_A = d_D \geq 0$*, then for all levels of coordination bias, there is no region in which platform A attracts sellers while platform D attracts buyers:* $\gamma_1 = \tilde{\gamma}_1$*. If however platform A has more loyal buyers than platform D,* $d_A > d_D \geq 0$*, then for low values of coordination bias and intermediate values of the sellers' bargaining power, there is a region in which platform A attracts sellers while platform D attracts buyers:* $\tilde{\gamma}_1 < \gamma_1$*.*

Proof. See Appendix.

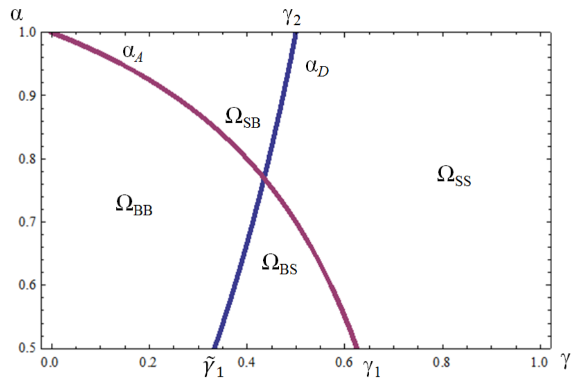


Figure 5: Four subsets, Ω_{BB}, Ω_{SB}, Ω_{SS}, and Ω_{BS} with heterogeneous buyers, for $d_A = 0.7$, $d_D = 0$, where Ω_{BS} defines parameter space where A adopts *buyers-pay* and D adopts *sellers-pay*

Figure **??** illustrates the case where $d_A > d_D$. The figure shows that now, a new region emerges, for low values of α and intermediate values of γ, in which platform A attracts sellers while platform D attracts buyers. Intuitively, recall that in our base model, platform A has a stronger incentive than platform D to attract buyers, because of its advantage in coordination bias: $\alpha > 1/2$. Therefore, there is no region in which platform A attracts sellers while platform D attracts buyers. Here, however, platform A may have a stronger incentive than platform D to attract sellers because it has more loyal buyers. If α is low (close to $1/2$), then this second effect dominates, and now platform A attracts sellers while platform D still attracts buyers. Notice that the two regions in which the two platforms choose different business models occurs for intermediate values of γ, because then both sides of the market have similar abilities to collect the joint benefit from trade, implying that the two platforms do not have a strong preferences towards attracting a particular side.

6 Adjustment of Coordination Bias Along Time

One potential explanation for coordination bias is that the advantaged platform enjoys the advantage because it was successful in attracting buyers and sellers in previous rounds. Given the history of successes, each agent expects that the two sides are more likely to continue joining the platform.

In this extension we consider the case where coordination bias can endogenously adjust along time in that it is positively affected by the platform's winning history. We ask how α-bias can converge over time to the full coordination bias (i.e., $\alpha = 1$), and how the rate of convergence depends on the business model that each platform chooses. We find that convergence to the full coordination bias is faster, on average, when both platforms adopt a *sellers-pay*, than in the case where one or both platforms adopt a *buyers-pay*.

To this end, suppose that the two sides and the two platforms play repetitively the static model described above, where coordination bias adjusts along time. In particular, suppose that in time t, the coordination bias is

$$\alpha_t = \begin{cases} \min\{\alpha_{t-1} + \varepsilon, 1\}\,, & \text{if } A \text{ won in } t-1\,, \\ \max\{\alpha_{t-1} - \varepsilon, 0\}\,, & \text{if } D \text{ won in } t-1\,. \end{cases}$$

That is, if a platform won in the previous period, the coordination bias is increasing in its favor by some $\varepsilon > 0$. A notable limitation of our analysis is that we assume that platforms are static players: platforms do not internalize the long-term effect of increasing their coordination bias advantage while setting their current-period strategies. This assumption enables us to obtain closed-form solutions and to provide general predictions regarding the adjustment process of the coordination bias. We discuss the robustness of our results to this limitation at the end of this section.

Suppose that in each period, platform A's quality advantage, Q, is drawn independently from the uniform distribution with support $[-q, q]$. Let $\overline{Q}_t$ denote the cutoff $\overline{Q}$ (as defined in Lemma **??**), evaluated at α_t, such that platform A wins in period t if $Q > \overline{Q}_t$. This means that each platform has a positive probability of winning the market in period t if $-q < \overline{Q}_t < q$.

Suppose that the market starts at the symmetric case of $\alpha_0 = \frac{1}{2}$, such that $\overline{Q}_0 = 0$. As the two platforms are initially symmetric, we can define platform A as the platform that enjoys coordination bias in its favor at time t: $\alpha_t > \frac{1}{2}$. The identity of platform A can therefore change along time. For simplicity, we focus on the case where $\alpha_t > \frac{1}{2}$ (the opposite case is symmetric).

Suppose that evaluated at $\alpha_t = 1$, $\overline{Q}_t < -q$. This assumption implies that there is a cutoff of α, $\overline{\alpha}$, such that once α_t crosses this cutoff, platform A is going to win all coming periods with probability 1, and coordination bias converges to a steady state of a full coordination bias, $\alpha_t = 1$. Intuitively, this assumption implies that the stochastic variations of Q are sufficiently small such that even with the worst realization of $Q = -q$, platform D cannot overcome platform A's full coordination bias.

By the law of large numbers, coordination bias is going to adjust to a steady state as long as the number of periods is large enough. We therefore ask how the rate of adjusting to $\alpha_t = 1$ depends on the equilibrium business models. Let $\rho_t = \Pr(Q > \overline{Q}_t)$ denote the probability that platform A wins in period t. As ρ_t increases, coordination bias adjusts faster, because platform A has a higher probability to win and consequently increase the coordination bias in its favor.

The following corollary follows directly from Proposition **??**.

Corollary 2

(i) For k and α_t s.t. $(\alpha_t, k) \in \Omega_{BB}$, $\rho_t = \frac{1}{2}$.

(ii) For k and α_t s.t. $(\alpha_t, k) \in \Omega_{SS} \cup \Omega_{SB}$, $\rho_t > \frac{1}{2}$ and ρ_t is increasing with α_t. Moreover, if q is sufficiently low, there is a cutoff, $\overline{\alpha}$, such that coordination bias adjusts to a steady state if $\alpha_t > \overline{\alpha}$.

Corollary **??** indicates that the process of adjusting coordination bias along time is faster, on average, for $k > k_1$, then for $k < k_1$. For $k < k_1$, even if platform A benefits from a certain degree of coordination bias such that $\alpha_t > \frac{1}{2}$, this advantage is fragile because in period t each platform has equal probability of winning the market and coordination bias can adjust upward or downward with equal probabilities. This implies that at $k < k_1$, when coordination bias starts at

$\alpha_0 = \frac{1}{2}$, they are likely to fluctuate around $\alpha_t = \frac{1}{2}$ with a different platform winning each period, until finally one of the platforms obtains a sufficiently large coordination bias to shift α_t to region Ω_{SB}. For $k > k_1$, or for $k < k_1$ but with a high enough coordination bias such that $(\alpha_t, k) \in \Omega_{SB}$, platform A has a higher probability of winning than platform D, which implies a higher probability of coordination bias adjustment in favor of platform A. Moreover, the probability that platform A wins is increasing with α_t, and eventually there is a cutoff, $\overline{\alpha}$, such that once $\alpha_t > \overline{\alpha}$, platform A is going to win all periods and coordination bias will converge to a study state of a full coordination bias, with platform A being the dominant platform for all realizations of Q.

These results indicate that the adjustment process of coordination bias is faster, on average, for high values of k, when both platforms initially adopt a *sellers-pay* business model, than for low values of k, when both platforms adopt a *buyers-pay*. In the former case, however, coordination bias can start to adjust faster whenever the accumulated bias motivates platform A to switch to a *sellers-pay*.

We obtain the results of this section with the simplifying assumption that platforms do not take into account the effect of winning the market has on future coordination bias. This assumption is suitable in two cases. First, when the process of adjusting coordination bias is very slow: ε is sufficiently small. In this case, winning in period t has only a marginal effect on coordination bias in period $t+1$, implying that platforms will not be willing to sacrifice profits in period t, just so they can affect future coordination bias. Second, when the platforms' discount factor is sufficiently high, such that platforms do not place a high weight on future profits. If these two conditions do not hold, platforms will have an inventive to compete more aggressively and sacrifice current profits for obtaining coordination bias in the future. This in turn will result in lower profits in the early periods than the profits predicted by our model, and a faster convergence to a steady state. However, notice that our result that $\rho_t = \frac{1}{2}$ whenever both platforms adopt *buyers-pay*, while $\rho_t > \frac{1}{2}$ and increasing with α_t whenever both platforms adopt *sellers-pay*, is independent of dynamic considerations by platforms.

7 Conclusion

Our paper considers platform competition in a two-sided market that includes buyers and sellers. One of the platforms, the advantaged platform, benefits from coordination bias, in that for this platform it is less costly than for the competing disadvantaged platform to convince customers that the two sides will coordinate on joining it. The two platforms may also differ in their qualities. In the base model, customers are homogeneous in their preferences for the two platforms. We study how platforms compete in the face of coordination bias. This research question is important for an advantaged platform, for deciding how to translate its advantage in agents' coordination into a competitive advantage, and for the disadvantage platform, for deciding how to overcome the unfavorable coordination bias and win the market.

We establish the following main results. First, we find that each platform chooses between two distinctive business models. It is important to emphasize that we do not restrict the platforms to choose one of these two business models. Instead, we find that this is what platforms do as an equilibrium outcome. The first business model is *sellers-pay* business model, in which the platform competes aggressively in attracting buyers and use the sellers as its main source of revenue. A platform that chooses this business model has an incentive to increase the sellers' gross revenue and therefore attracts fewer sellers than is socially optimal. This way, the platform restricts competition between sellers and increases their gross profits, which it can then collect through its access fee. The second business model is *buyers-pay* business model, in which the platform subsidizes the sellers and collects revenues from buyers. Under this business model, the platform has an incentive to increase the buyers' gross utility and therefore attracts more sellers than is socially optimal.

We find that the equilibrium choice of a business model depends on the strength of the coordination bias towards the advantaged platform and on the sellers' development costs. If development costs are small and no platform benefits from a substantial coordination bias, then both platforms adopt a *buyers-pay* business model. In such a case, both platforms find it more profitable to attract sellers by subsidizing the sellers' development costs, instead of relying on the coordination bias. If the coordination bias increases, the advantaged platform takes advantage of the favorable bias by switching from *buyers-pay* to *sellers-pay* business model. Intuitively, increase in the favorable coordination bias makes it easier for the advantaged platform to attract buyers, as buyers expect sellers to join the advantaged platform even when the platform does not subsidize the sellers. This implies that the advantaged platform undersupplies sellers for small coordination bias, and oversupplies for large coordination bias. If the sellers' development costs are high and the coordination bias is small, then both platforms adopt a *sellers-pay* business model. If the coordination bias increases, it is the disadvantaged platform that switches to a *buyers-pay* business model, in which the platform attracts sellers without relying on the coordination bias. In this case, the disadvantaged platform switches from undersupplying sellers to oversupplying them.

In an extension to our base model, we consider the case where buyers are heterogeneous in their preferences over the platforms, such that some buyers are "loyal" to one of the platforms. We find that the presence of loyal buyers provides platforms with a stronger incentive to adopt the business model in which they subsidize sellers. If the advantaged platform has more loyal buyers than the disadvantaged, then for some parameter values there is an equilibrium in which the advantaged platform subsidizes sellers while the disadvantaged platform competes by attracting buyers. Such an equilibrium never emerges in the base model with homogeneous buyers.

Our model suggests how important it is for a platform to pinpoint the correct business model. For example, in 2010, HP acquired Palm's operating system, WebOS, with the purpose of entering into the market for tablets, dominated by Apple's iPad. HP's tablet was superior to the iPad in some aspects.[32] However, HP found itself suffering from a coordination disadvantage as each side

[32] Amoth (2011) reports that HP's tablet garnered praise for its screen quality, audio features, and operating system, but stumbled when it came to running too many programs at once. It's also slightly thicker and heavier than even the first-generation iPad.

of the market did not expect that the other side will join it.[33] At first, HP subsidized the buyers (*sellers-pay* business model) by cutting the price of its tablets between $50 and $160.[34] In contrast, our model suggests that in the presence of a strong coordination disadvantage, an entrant platform should focus on offering substantial subsidies to developers (*buyer-pay* business model), unless development costs are prohibitively high.[35] Sales remained low because HP could not convince developers that buyers will indeed join the new platform.[36] HP then turned its operating system to an open source software to attract developers.[37] At that stage, the shift in HP's business model came too late.[38] Eventually, with no focused entry strategy, HP forgone the use of the WebOS operating system.[39]

In contrast, Microsoft seems to have a focused strategy of attracting sellers when entering the market for tablets. Consistent with our model, Microsoft is offering development tools and information for application developers, as well offering developers of popular applications discounts on store fees.[40] At the same time, the introductory price of the Microsoft tablet was relatively high.[41] While Microsoft managed to gain a foothold in the tablet market, to date, it did not capture a wide market share. In particular, current subsidies to developers are insufficient to induce the provision of large number of applications.[42] As our model shows, adopting the buyers-pay business

[33] For example, Amoth (2011) mentions that one of the weaknesses of HP's tablet is that it only counted around 300 TouchPad-specific apps at launch."

[34] Amoth (2011)

[35] Amoth (2011) argued that This price cut is a smart move on HP's part, as it seemingly demonstrates that the company understands how important it is to just get people in the door and using the platform. The TouchPad could probably even stand to have another $50 lopped off to really get people on board.... However, our model suggests that since a significant price cut to buyers is needed to overcome coordination disadvantage, entrants should focus attention on subsidizing sellers.

[36] Menn (2011) reports that "While praised by critics, webOS has suffered for failing to get as many programmers working on applications as Apple has for iOS and Google has with Android."

[37] See HP's Press Release (912/2011). In their press release, HP also announced that "HP will engage the open source community to help define the charter of the open source projectHP also will contribute ENVO, the application framework for webOS, to the community in the near future."

[38] Menn (2011) argued "It may prove too late to generate momentum..."

[39] Gupta (2013) reports that HP sold its webOS operating system to LG, for using it in LG's smart TV.

[40] App Developer Agreement for Windows Store specifies "The Store Fee for Apps made available in the Windows Store is thirty percent (30%) of Net Receipts, unless and until your App takes in total Net Receipts of USD$25,000, after which time the percentage is 20% for that App." (available at https://appdev.microsoft.com/StorePortals/en-us/document/05b50199-1d5b-49f3-8046-46e2a2baf8d8).

[41] Musil (2013)

[42] King and Bass (2013)

model is ineffective if only small subsidies are provided by the platform. Only a substantial subsidy, that makes it worthwhile to developers to join even in the absence of buyers, can make the business model effective.[43]

In addition to selecting the right business model, a platform needs to implement it by choosing its appropriate size, i.e., the number of available products. When a new platform selects a *sellers-pay* business model, it needs to undersupply sellers. In contrast, when a new platform selects a *buyers-pay* business model, it needs to oversupply sellers. For example, Claussen, Kretschmer and Mayrhofer (2011) illustrate the latter case with the example of applications on Facebook: "Facebook encouraged entry of as many developers as possible. The company offered strategic subsidies to third-party developers by providing open and well-documented application programming interfaces, multiple development languages, free test facilities, as well as support for developers through developer forums and conferences" (p. 5). In result more than 30,000 applications had been developed within a year of lunching the service. However, not all applications have been adopted by users, and of those that have been installed, not all had been actively used. This suggests that consistent with our model, the platform was oversupplying applications. Eventually, Facebook has succeeded in maintaining the dominant position (Olson 2014).

The concept of coordination bias can be extended to other models of platform competition and coordination games. In the context of our model, we have formalized coordination bias on the gap between the buyers' access prices only. This is because our model has the feature that buyers are the bottleneck side, along the definition of Alexandrov, Deltas and Spulber (2011). Since all buyers join a platform, they decide which platform to join based on the gap in the buyers' access prices. Sellers, however, either join the winning platform or do not join at all, and their decision is not affected by the gap in the sellers' access prices. Suppose instead that both sides of the market were bottlenecks. That is, all buyers and sellers join a platform and that their decisions are affected by the gap in

[43] Jackson (2014) reports that in a recent move for attracting developers, Microsoft open source its WinJS JavaScript library. Consequently, "developers can use it to build and design Windows-like Web applications for other browsers and platforms, including Chrome, Firefox, Android, and iOS."

their access prices. In such a model, it is possible to formalize coordination bias according to a cutoff in the buyers' access prices, sellers' access prices, or both. Doing so can provide a framework for solving coordination problems in a variety of models in platform competition. We leave this extension for future research.

Another natural extension of our paper for future research would be to analyze platform competition in a fully dynamic perspective. Our analysis of a static model is a first step, as it is more direct and straightforward, while already providing rich results. In the second extension to our base model, we consider the case where the coordination bias adjusts along time in favor of the platform that won the market in the previous period. We find that beliefs can converge to a full coordination bias, in which the disadvantaged platform cannot win the market. The convergence process is, on average, faster when both platforms adopt a *sellers-pay*, than in the case where they adopt a *buyers-pay* business model.

In real-life situations, it is possible to think of other factors that might affect the coordination bias. One such factor, that we do not model, is advertising. Platforms can advertise in order to enhance coordination in favor of their platform. For example, when Apple advertises "There is an app for that," Apple signals to buyers that application developers are likely to join Apple, and therefore users should also join. This in turn convinces developers to join as they expect users to join as well, resulting in a stronger coordination bias in favor of Apple. The results of our model suggest that platforms will have an incentive to invest in such advertising. However, the effect of such advertising on welfare might be inconclusive, as it may increase or decrease the number of sellers a platform attracts. Moreover, it is unclear whether a platforms' ability to advertise increases or decreases the coordination bias. This is because both platforms can potentially advertise, making it unclear whether competing advertising campaigns affect the coordination bias or just cancel each other out. Another factor that may affect the coordination bias are certifiers, who provide reviews and recommendations as to which platform is more likely to be successful. For example, PC magazines can provide a recommendation that a certain tablet or smarthphone is more likely to attract more users and application developers in the future than others. Such a recommendation may enhance a platform's coordination bias. As in the previous example, our model suggest that certifiers may increase or decrease welfare, depending on how they affect the platforms' business models. We leave these issues for future research.

Appendix

A Proofs

Proof of Lemma ??.

Since $U_B(n) = u_B(n) - n\,u'_B(n)$ and $p(n) = u'_B(n)$, we can write the first-order conditions that determine n^*, n^{A*} and n^{D*}, respectively, as:

$$u'_B(n^*) - k = 0 \tag{17}$$

$$u'_B(n^{A^*}) - k + (1-\alpha)\left[n^{A^*} \cdot u''_B(n^{A^*})\right] = 0 \tag{18}$$

$$u'_B(n^{D^*}) - k + \alpha\left[n^{D^*} \cdot u''_B(n^{D^*})\right] = 0 \tag{19}$$

(**??**) follows directly from maximization problem in (**??**). (**??**) follows from equation (**??**), and (**??**) follows from the fact that n^{D^*} maximizes $\pi^D_{\textit{sellers-pay}}(n^D) \equiv (1-\alpha)U_B(n^D) + n^D[p(n^D) - k]$.

Since by assumption, $u''_B < 0$, the terms in the squared brackets in (**??**) and (**??**) are negative. Since $\frac{1}{2} < \alpha < 1$, it follows from the above equations that $n^* > n^{A^*} > n^{D^*}$. Moreover, (**??**) and (**??**) imply that as α increases, n^{A^*} increases and n^{D^*} decreases, with $n^{A^*} = n^*$ for $\alpha = 1$.

The second order conditions are:

$$u_B''(n^*) < 0\,,$$
$$u_B''(n^{A*}) + (1-\alpha)\left[n^{A*} \cdot u_B'''(n^{A*}) + u_B''(n^{A*})\right] < 0\,,$$
$$u_B''(n^{D*}) + \alpha\left[n^{D*} \cdot u_B'''(n^{D*}) + u_B''(n^{D*})\right] < 0\,,$$

which are satisfied by assumptions of $u_B''(n) < 0$ and $u_B'''(n) < -\frac{u_B''(n)}{n}$.

Proof of Lemma ??.

Recall that $\hat{n}$ is the solution to $u_B'(\hat{n}) = 0$. Comparing $u_B'(\hat{n}) = 0$ with (**??**) yields that $\hat{n} > n^*$ for $k > 0$. (If we allowed for $k = 0$, then $\hat{n} = n^*$.)

Proof of Proposition ??.

To prove the characteristics of $\alpha_A(k)$ and $\alpha_D(k)$, we use the following claims

Claim: There is at most one α, $\alpha_A(k)$, that solves $\pi^A_{\textit{sellers-pay}}(n^{A*}) = \pi_{buyers-pay}$, such that if $\frac{1}{2} \leq \alpha_A(k) \leq 1$. Moreover, $\pi^A_{\textit{sellers-pay}}(n^{A*}) \;>(<)\; \pi_{buyers-pay}$ for $\alpha >\; (<)\; \alpha_A(k)$.

Proof: $\pi^A_{\textit{sellers-pay}}(n^{A*})$ is strictly decreasing with α while $\pi_{buyers-pay}$ is independent of α, thus $\pi^A_{\textit{sellers-pay}}(n^{A*})$ can intersect $\pi_{buyers-pay}$ only once, and $\pi^A_{\textit{sellers-pay}}(n^{A*}) >\; (<)\; \pi_{buyers-pay}$ for $\alpha >\; (<)\; \alpha_A(k)$.

Claim: $\alpha_A(0) = 1$.

Proof: To prove the claim we need to show that evaluated at $(\alpha, k) = (1, 0)$, $\pi^A_{\textit{sellers-pay}}(n^{A*}) = \pi_{buyers-pay}$. Lemmas **??** and **??** show that at $(\alpha, k) = (1, 0)$, $n^{A*} = \hat{n} = n^*$. Substituting $n^{A*} = \hat{n}$ and $\alpha = 1$ into $\pi^A_{\textit{sellers-pay}}(n^{A*})$ yields:

$$\pi^A_{\textit{sellers-pay}} = U_B(\hat{n}) + \hat{n}\left(p(\hat{n}) - k\right) = U_B(\hat{n}) - k\,\hat{n} = \pi_{buyers-pay}\,,$$

where the second equality follows because $p(\hat{n}) = u'_B(\hat{n}) = 0$, and the last equality follows from the definition of $\pi_{buyers-pay}$.

Claim: $\alpha'_A(0) = 0$, $\alpha'_A(k) < 0$ and $\alpha''_A(k) > 0$.

Proof: Since $\alpha_A(k)$ is the solution to $\pi^A_{\textit{sellers-pay}}(n^{A*}) = \pi_{\textit{buyers-pay}}$, we have:

$$\frac{d\,\alpha_A(k)}{d\,k} = -\frac{\frac{d\,(\pi^A_{\textit{sellers-pay}}(n^{A*}) - \pi_{\textit{buyers-pay}})}{d\,k}}{\frac{d\,(\pi^A_{\textit{sellers-pay}}(n^{A*}) - \pi_{\textit{buyers-pay}})}{d\,\alpha}}. \tag{20}$$

The nominator of (**??**) is:

$$\begin{aligned}\frac{d\,(\pi^A_{\textit{sellers-pay}}\left(n^{A*}\right) - \pi_{buyers-pay})}{d\,k} &= \frac{\partial\,\pi^A_{\textit{sellers-pay}}\left(n^{A*}\right)}{d\,k} + \frac{\partial\,\pi^A_{\textit{sellers-pay}}\left(n^{A*}\right)}{\partial\,n}\frac{\partial\,n^{A*}}{\partial\,k} - \frac{d\,\pi_{buyers-pay}}{d\,k} \\ &= -\left(n^{A*} - \hat{n}\right), \end{aligned} \tag{21}$$

where the last equality follows from the envelope theorem and from the definitions of $\pi^A_{\textit{sellers-pay}}(n^{A*})$ and $\pi_{\textit{buyers-pay}}$. The denominator of (**??**) is:

$$\frac{d\,(\pi^A_{\textit{sellers-pay}}\left(n^{A*}\right) - \pi_{\textit{buyers-pay}})}{d\,\alpha} = \frac{\partial\,\pi^A_{\textit{sellers-pay}}\left(n^{A*}\right)}{d\,\alpha} + \frac{\partial\,\pi^A_{\textit{sellers-pay}}\left(n^{A*}\right)}{\partial\,n}\frac{\partial\,n^{A*}}{\partial\,\alpha} - \frac{d\,\pi_{\textit{buyers-pay}}}{d\,\alpha} = U_B(n^{A*}), \tag{22}$$

where the equality follows from the envelope theorem and from the definitions of $\pi^A_{\textit{sellers-pay}}(n^{A*})$ and $\pi_{buyers-pay}$. Substituting (**??**) and (**??**) back into (**??**) yields:

$$\frac{d\,\alpha_A(k)}{d\,k} = -\frac{\hat{n} - n^{A*}}{U_B(n^{A*})}.$$

Now, for $(\alpha, k) = (1, 0)$, $n^{A*} = \hat{n}$, implying that $\alpha'_1(0) = 0$. As k increases, $\hat{n}$ remains constant but n^{A*} decreases, implying that $\alpha'_A(k) < 0$ and $\alpha''_A(k) > 0$.

Remark: Since $\alpha'_A(k) < 0$ and $\alpha''_A(k) > 0$, it has be that there is a k such that $\alpha_A(k) = \frac{1}{2}$. We define the solution to $\alpha_A(k) = \frac{1}{2}$ as k_1. As $\alpha_A(0) = 1$, it has to be that $k_1 > 0$, but we still need to prove that $k_1 < u'_B(0)$. It would be convenient for us to do this for the subsequent proof of characteristics of $\alpha_D(k)$.

Claim: There is at most one α, $\alpha_D(k)$, that solves $\pi^D_{\textit{sellers-pay}}(n^{D^*}) = \pi_{buyers-pay}$, such that if $\frac{1}{2} \leq \alpha_D(k) \leq 1$. Moreover, $\pi^D_{\textit{sellers-pay}}(n^{D^*}) > (<) \, \pi_{buyers-pay}$ for $\alpha < (>) \, \alpha_D(k)$.

Proof: $\pi^D_{\textit{sellers-pay}}(n^{D^*})$ is strictly decreasing with α while $\pi_{buyers-pay}$ is independent of α, thus $\pi^D_{\textit{sellers-pay}}(n^{D^*})$ can intersect $\pi_{buyers-pay}$ only once, with $\pi^D_{\textit{sellers-pay}}(n^{D^*}) > (<) \, \pi_{buyers-pay}$ for $\alpha < (>) \, \alpha_D(k)$.

Claim: $\alpha_D(k_1) = \frac{1}{2}$.

Proof: Recall that k_1 is the solution to $\alpha_A(k) = \frac{1}{2}$, thus evaluated at $(\alpha, k) = (\frac{1}{2}, k_1)$, $\pi^A_{\textit{sellers-pay}}(n^{A^*}) = \pi_{buyers-pay}$. To prove that it is also the solution to $\alpha_D(k_1) = \frac{1}{2}$, we need to show that evaluated at $(\alpha, k) = (\frac{1}{2}, k_1)$, $\pi^D_{\textit{sellers-pay}}(n^{D^*}) = \pi_{buyers-pay}$, which holds if $\pi^D_{\textit{sellers-pay}}(n^{D^*}) = \pi^A_{\textit{sellers-pay}}(n^{A^*})$. To see that, notice that (**??**) and (**??**) imply that at $\alpha = \frac{1}{2}$, $\pi^D_{\textit{sellers-pay}}(n^{D^*}) = \pi^A_{\textit{sellers-pay}}(n^{A^*})$.

Claim: $\alpha'_D(k) > 0$ and $\alpha''_D(k) > 0$.

Proof: Using the envelope theorem, and applying similar calculations as in (**??**), (**??**) and (**??**) yields:

$$\frac{d\alpha_D(k)}{dk} = \frac{\hat{n} - n^{D^*}}{U_B(n^{D^*})}. \tag{23}$$

From Lemmas **??** and **??**, $n^{D^*} < \hat{n}$, hence $\alpha'_D(k) > 0$. Moreover, as α increases, $\hat{n}$ remains constant, while n^{D^*} decreases, thus (**??**) increases.

Claim: There is a point, k_2, such that $\alpha_D(k_2) = 1$, where $0 < k_1 < k_2$.

Proof: Since $\alpha'_D(k) > 0$ and $\alpha''_D(k) > 0$, there is a k such that $\alpha_D(k) = 1$. Also, as $\alpha_A(0) = 1$ and $\alpha'_A(k) < 0$, it has to be that $0 < k_1$, while as $\alpha'_D(k) > 0$, it has to be that $k_1 < k_2$.

Claim: $k_2 < u'_B(0)$.

Proof: To show that $k_2 < u'_B(0)$, it is sufficient to show that evaluated at $k = u'_B(0)$, it is always the case that $\pi^D_{\textit{sellers-pay}}(n^{D*}) > \pi_{buyers-pay}$. This is because if at $k = u'_B(0)$, $\pi^D_{\textit{sellers-pay}}(n^{D*}) > \pi_{buyers-pay}$ for all α, it has to be that $\alpha_D(k)$ is always to the left-hand side of the vertical line defined by $k = u'_B(0)$. To show that, notice that (**??**) implies that if $k = u'_B(0)$, then $n^{D*} = 0$. This in turn implies that at $k = u'_B(0)$, $\pi^D_{\textit{sellers-pay}}(n^{D*}) = 0$. Turning to $\pi_{buyers-pay}$, evaluating $\pi_{buyers-pay}$ at $k = u'_B(0)$ yields:

$$\begin{aligned}
\pi_{buyers-pay} &= u_B(\hat{n}) - \hat{n}\, u'_B(\hat{n}) - \hat{n}\, k \\
&= u_B(\hat{n}) - \hat{n} \cdot 0 - \hat{n}\, u'_B(0) \\
&= \int_0^{\hat{n}} \big(u'_B(n) - u'_B(0)\big)\, dn \; < 0\,,
\end{aligned}$$

where the first equality follows because $u'_B(\hat{n}) = 0$ and $k = u'_B(0)$, the second equality follows because $u_B(0) = 0$, and the last inequality follows because $u'_B(n)$ is decreasing in n. We therefore have that evaluated at $k = u'_B(0)$, $\pi^D_{\textit{sellers-pay}}(n^{D*}) = 0 < \pi_{buyers-pay}$.

Proof of Proposition ??.

Consider first the effects of α. From Lemma **??**, if $\alpha = \frac{1}{2}$ then $n^{A*} = n^{D*}$, implying that $\pi^D_{\textit{sellers-pay}}(n^{D*}) = \pi^A_{\textit{sellers-pay}}(n^{A*})$ and therefore $\overline{Q} = 0$. Using the envelope theorem, the derivatives of Π^A, Π^D and $\overline{Q}$ with respect to α, in region Ω_{SS}, are

$$\frac{d\,\Pi^A}{d\,\alpha} = U_B(n^{A*}) + U_B(n^{D*}) > 0, \qquad \frac{d\,\Pi^D}{d\,\alpha} = \frac{d\,\overline{Q}}{d\,\alpha} = -\Big(U_B(n^{A*}) + U_B(n^{D*})\Big) < 0.$$

In region Ω_{SB}, the derivatives are:

$$\frac{d\,\Pi^A}{d\,\alpha} = U_B(n^{A^*}) > 0, \qquad \frac{d\,\Pi^D}{d\,\alpha} = \frac{d\,\overline{Q}}{d\,\alpha} = -U_B(n^{D^*}) < 0.$$

In region Ω_{BB}, it is straightforward to see that α does not affect Π^A, Π^D and $\overline{Q}$.

Proof of Proposition ??.

Substituting $d_A = d_D = d$ into α_A and α_D yields

$$\alpha_A = \frac{(1-\gamma)(1-d) - \gamma(1-2d)}{(1-\gamma)(1-d)}, \alpha_D = \frac{\gamma(1-2d)}{(1-\gamma)(1-d)}\,.$$

The derivatives of α_A and α_D with respect to d are:

$$\frac{\partial \alpha_A}{\partial d} = \frac{\gamma}{(1-\gamma)(1-d)^2} > 0, \frac{\partial \alpha_D}{\partial d} = -\frac{\gamma}{(1-\gamma)(1-d)^2} < 0\,.$$

Substituting $d_A = d_D = d$ into α_A and solving $\alpha_A = \frac{1}{2}$ for γ yields:

$$\gamma_1 = \frac{1-d}{3-5d}\,.$$

Straightforward calculations show that $\frac{\partial \gamma_1}{\partial d} = \frac{2}{(3-5d)^2} > 0$ and $\gamma_1(d = \frac{1}{2}) = 1$. Next, substituting $d_A = d_D = d$ into α_D and solving $\alpha_D = 1$ for γ yields:

$$\gamma_2 = \frac{1-d}{2-3d}\,.$$

Straightforward calculations show that $\frac{\partial \gamma_2}{\partial d} = \frac{1}{(2-3d)^2} > 0$ and $\gamma_2(d = \frac{1}{2}) = 1$.

Proof of Proposition ??.

Solving $\alpha_A = \frac{1}{2}$ and $\alpha_D = \frac{1}{2}$ for γ_1 and $\tilde{\gamma}_1$ respectively, yields

$$\gamma_1 = \frac{1-d_D}{3-3d_D-2d_A}, \tilde{\gamma}_1 = \frac{1-d_A}{3-3d_A-2d_D}.$$

Therefore

$$\gamma_1 - \tilde{\gamma}_1 = (d_A - d_D)\frac{(1-d_D-d_A)}{(3-3d_D-2d_A)(3-3d_A-2d_D)}.$$

Notice that $3-3d_i-2d_j > 0, i, j = d_A, d_D$, because $3-3d_i-2d_j > 3(d_i+d_j)-3d_i-2d_j = d_j > 0$, where the first inequality follows because $1 > d_D + d_A$. Therefore, the term in the denominator is positive. The term in the numerator equals 0 if $d_A = d_D$ and positive if $d_A > d_D$.

B Formal analysis of business model choice

Optimal business model for platform D when moving first. Given the strategies by platform A (second-mover) described in Section **??**, platform D wins the market when it sets such access fees to prevent the competitor's entry, i.e., so that

$$N_B\left[\pi^A + Q - U_B^D(F_S^D,\alpha) + F_B^D\right] = 0 \implies N_B F_B^D = N_B\left[U_B^D(F_S^D,\alpha) - \pi^A - Q\right] \tag{24}$$

Under *sellers-pay* business model, platform D sets F_S^D above 0. In the dominant-D equilibrium n^D sellers join platform D, where n^D is determined by $N_B p(n^D) - K - F_S^D = 0$. Then, sellers do not join platform D in the dominant-A equilibrium, in which buyers join platform A. Given the coordination bias, we can substitute $U_B^D(F_S^D,\alpha) = (1-\alpha)U_B(n^D)$ in conditions (**??**) and (**??**). Then,

$$\Pi^D_{\textit{sellers-pay}}(n^D) = N_B\left[\pi^D_{\textit{sellers-pay}}(n^D) - \pi^A - Q\right],$$

where $\pi^D_{\textit{sellers-pay}}(n^D) \equiv (1-\alpha)U_B(n^D) + n^D[p(n^D) - k]$ and is maximized by n^{D*}.

Under *buyers-pay* business model, $F_S^D = -K$ and buyers join when $U_B(\hat{n}) - F_B^D \geq U_B^A(F_S^A,\alpha) +$

$Q - F_B^A$.[44] Then, $\hat{n}$ sellers join platform D in both dominant-A and dominant-D. Given the coordination bias, we can substitute $U_B^D(F_S^D, \alpha) = U_B(\hat{n})$ in conditions (**??**) and (**??**), which yields

$$\Pi^D_{\textit{buyers-pay}} = N_B \left[\pi^D_{\textit{buyers-pay}} - \pi^A - Q\right] \,,$$

where $\pi^D_{\textit{buyers-pay}} = U_B(\hat{n}) - k\hat{n}$. Notice that if platform D adopts a *buyers-pay* business model, then it attracts the same number of sellers, $\hat{n}$, as platform A's *buyers-pay* business model. From now onward we can define $\pi_{\textit{buyers-pay}} \equiv \pi^D_{\textit{buyers-pay}} = \pi^A_{\textit{buyers-pay}}$.

Platform D chooses *sellers-pay* when $\pi_{\textit{sellers-pay}}(n^{D*}) > \pi^D_{\textit{buyers-pay}}$, and *buyers-pay* otherwise. We need to check, however, that $\max\{\Pi^D_{\textit{sellers-pay}}(n^{D*}), \Pi^D_{\textit{buyers-pay}}\} \geq 0$. Otherwise, platform D would not want to play either of those strategies. Let $\pi^D \equiv \max\{\pi^D_{\textit{sellers-pay}}(n^{D*}), \pi_{\textit{buyers-pay}}\}$. Then $\Pi^D = N_B\left[\pi^D - \pi^A - Q\right]$ and $\Pi^D > 0 \iff \pi^D - \pi^A > Q$.

Platform A moves first. For the case when platform A moves first and platform D second the analysis is very similar. Knowing (F_B^A, F_S^A), platform D may decide not to enter the market and receive 0 profit. If it decides to enter the market it chooses between *sellers-pay* and *buyers-pay* business models. Under *sellers-pay*, the platform charges sellers a high fee $F_S^D = N_B\, p(n^D) - K > 0$ and buyers join when

$$(1-\alpha)U_B(n^D) - F_B^D > Q + U_B^A(F_S^A, \alpha) - F_B^A \,. \tag{25}$$

[44] Notice that if platform A also subsidizes the sellers, then (10) implies that the profits of both platforms are independent of α, because in such a case both platforms do not rely on buyers' expectations concerning sellers' decisions, and instead subsidize the sellers.

Under this business model, platform D may achieve profit of[45]

$$\Pi^D_{\textit{sellers-pay}}(n^{D^*}) = N_B\left[\pi^D_{\textit{sellers-pay}}(n^{D^*}) - Q - U^A_B(F^A_S,\alpha) + F^A_B\right] .$$

Under *buyers-pay*, the platform subsidizes sellers $F^D_S = -K$ and buyers join when $U_B(\hat{n}) - F^D_B > Q + U^A_B(F^A_S,\alpha) - F^A_B$. Thus, the platform achieves the profit of

$$\Pi^D_{\textit{buyers-pay}} = N_B\left[\pi_{\textit{buyers-pay}} - Q - U^A_B(F^A_S,\alpha) + F^A_B\right] .$$

Platform D chooses to stay out of the market when $\max\{\Pi^D_{\text{buyers-pay}}(n^{D^*}), \Pi^D_{\textit{sellers-pay}}\} < 0$. Otherwise it choses *sellers-pay* when $\pi^D_{\textit{sellers-pay}}(n^{D^*}) > \pi_{\textit{buyers-pay}}$, and *buyers-pay* otherwise. Notice that this is the same decision rule whether platform D moves first or second.

C Formal analysis of first mover's strategy under heterogeneous buyers

To capture the non-loyal market segment, platform A (the first mover) chooses between attracting buyers (*sellers-pay*) and attracting sellers (*buyers-pay*).

Platform A, moving earlier, sets its access fees to prevent platform D from profitably entering the market, i.e.,

$$N_B(\pi^D - Q - U^A_B(F^A_S,\alpha) + F^A_B) \leq 0 \implies N_B F^A_B = N_B\left[Q + U^A_B(F^A_S,\alpha) - \pi^D\right] .$$

By similar arguments as above, platform A chooses *sellers-pay* when $\pi^A_{\textit{sellers-pay}}(n^{A^*}) > \pi_{\textit{buyers-pay}}$, and *buyers-pay* otherwise. Notice that this decision rule is the same whether platform A moves as

[45]We have assumed that when agents are indifferent between joining platform A and platform D, they join platform A. Therefore, platform D sets access fees so that (**??**) holds with *slight* inequality. However, for the convenience of exposition, we solve the reminder of analysis as if it were an equality. This overestimates the profits platform D can achieve by negligible amount, and does not change any qualitative results.

first or as second.

When attracting buyers, platform A charges sellers a high access fee such that sellers will join platform A only in an equilibrium in which both loyal and non-loyal buyers join. That is,

$$F_S^A = -K + (1 - d_D)\gamma v\,.$$

Then, if platform D decides to compete for the non-loyal buyers (such that either condition (**??**) or (**??**) holds), in the equilibrium in which non-loyal buyers join platform D, no seller will join platform A. Thus, buyers' expected utility from joining A given the two equilibria and α-coordination bias is

$$U_B^A(F_S^A, \alpha) = \hat{n}v(1-\gamma)\alpha\,.$$

Notice that the degree of coordination bias is relevant to the loyal buyers of platform A, when deciding whether to join platform A. Since F_S^A is such that sellers join platform A only if both loyal and non-loyal buyers join, if α is small such that non-loyal buyers do not join platform A, buyers that are loyal to platform A do not join it either, as they correctly expect that sellers would not join it.

Thus, to assure that condition (**??**) is satisfied, platform A needs to set

$$(1-d_A)F_B^A \;=\; \hat{n}v(d_D - X) + (1-d_A)\big(\hat{n}v(1-\gamma)\alpha + Q\big)\,,$$

which yields profit

$$\begin{aligned}
\Pi^A_{\textit{sellers-pay}} &= (1-d_D)F_B^A + \hat{n}F_S^A \\
&= \frac{1-d_D}{1-d_A}\hat{n}v(d_D - X) + (1-d_D)\,Q - \hat{n}K + \hat{n}v\big[(1-d_D)(1-\gamma)\alpha + (1-d_D)\gamma\big]\,.
\end{aligned}$$

Alternatively, platform A may aim to win the non-loyal buyers by attracting the sellers. Then, it charges sellers a low access fee such that sellers join platform A even if there is only an equilibrium in which loyal buyers join. That is,

$$F_S^A = -K + d_A \gamma v \,.$$

Then, if platform D decides to compete for the non-loyal buyers (such that either condition (**??**) or (**??**) holds), in the equilibrium in which non-loyal buyers join platform D, $\hat{n}$ sellers still join platform A. Consequently, buyers' expected utility from the two equilibria, given the α-coordination bias, is

$$U_B^A(F_S^A, \alpha) = \hat{n} v (1-\gamma) \,.$$

Condition (**??**) takes the form

$$(1-d_A) F_B^A \,\leq\, \hat{n} v (d_D - X) + (1-d_A)\big[\hat{n} v (1-\gamma) + Q\big] \,,$$

yielding platform's profit

$$\Pi^A_{\textit{buyers-pay}} = \frac{1-d_D}{1-d_A} \hat{n} v (d_D - X) + (1-d_D)\, Q - \hat{n} K + \hat{n} v \big[(1-d_D)(1-\gamma) + d_A \gamma\big] \,.$$

References

[1] Alexandrov, Alexei, George Deltas and Daniel F. Spulber, "Antitrust and Competition in Two-Sided Markets," Journal of Competition Law and Economics, Vol. 7 (2011), pp. 775–812.

[2] Amoth, Doug, "One Month Later, HP Cuts Price of TouchPad Tablet by $50," Time (2011). Available at: http://techland.time.com/2011/08/02/one-month-later-hp-cuts-price-of-touchpad-tablet-by-50/

[3] Austen, Ian, "BlackBerry 10 Prototype Is Given to Developers," New York Times (2012). Available at: http://www.nytimes.com/2012/05/02/technology/research-in-motions-blackberry-10-is-unveiled.html

[4] Bunton, Cam. "BlackBerry Q10 vs. iPhone 5 Hardware Comparison." Today's iPhone (2013). Available at: http://www.todaysiphone.com/2013/07/blackberry-q10-vs-iphone-5-hardware-comparison/

[5] Caillaud, Bernard and Bruno Jullien, "Competing Cybermediaries," European Economic Review, Vol. 45 (2001), pp. 797–808.

[6] Caillaud, Bernard and Bruno Jullien, "Chicken & Egg: Competition among Intermediation Service Providers," RAND Journal of Economics, Vol. 34. (2003), pp. 309–328.

[7] Casadesus-Masanell, Ramon and Joan Enric Ricart, "From Strategy to Business Models and onto Tactics," Long Range Planning, Vol. 43 (2010), pp. 195-215.

[8] Casadesus-Masanell, Ramon and Feng Zhu, "Strategies to Fight Ad-Sponsored Rivals," Management Science, Vol. 56 (2010), pp. 1484-1499.

[9] Casadesus-Masanell, Ramon, and Feng Zhu, "Business Model Innovation and Competitive Imitation: The Case of Sponsor-Based Business Models," Strategic Management Journal 34, no. 4 (April, 2013): 464–482.

[10] Claussen, Jorg, Tobias Kretschmer and Philip Mayrhofer, "Incentives for Quality over Time—The Case of Facebook Applications," mimeo, December 2011.

[11] Colon, Alex. "BlackBerry Z10 vs. Apple iPhone 5: Spec Showdown." PC Magazine, (2013). Available at: http://www.pcmag.com/article2/0,2817,2414915,00.asp

[12] Faughnder, Ryan and Adam Satariano, “Apple iPhone 5 Pre-Orders Top 2 Million, Doubling Record,” Bloomberg (2012). Available at: http://www.bloomberg.com/news/2012-09-17/apple-iphone-5-pre-orders-top-2-million-double-prior-record-1-.html

[13] Ghemawat, Pankaj, Commitment: The Dynamic of Strategy. Free Press, New York 1991.

[14] Gupta, Poornima, HP sells webOS operating system to LG Electronics, Reuters (2013). Available at: http://www.reuters.com/article/2013/02/25/us-hp-webos-idUSBRE91O0R820130225

[15] Hagiu, Andrei, “Pricing and Commitment by Two-Sided Platforms,” RAND Journal of Economics, Vol. 37 (2006), pp. 720–737.

[16] Hagiu, Andrei and Hanna Halaburda, “Responding to the Wii?” Harvard Business School Case Study No. 709-448 and Teaching Note No. 709-481 (2009).

[17] Hagiu, Andrei and Daniel Spulber, “First-Party Content and Coordination in Two-Sided Markets,” 2013, Management Science, Volume 59 (4), April, pp. 933-949.

[18] Halaburda, Hanna and Yaron Yehezkel, “Platform Competition under Asymmetric Information,” American Economic Journal: Microeconomics, 5, no. 3, pp. 22–68.

[19] Holly, Russell. ”BlackBerry Z10 vs iPhone 5: Does BB10 stand a chance?” Geek.com, (2013). Available at: http://www.geek.com/review/blackberry-z10-vs-iphone-5-does-bb10-stand-a-chance-1537941/

[20] Hossain, Tanjim, Dylan Minor and John Morgan, “Competing Matchmakers: An Experimental Analysis,” Management Science; Issue: 57(11); 2011; Pages: 1913–1925.

[21] Hossain, Tanjim and John Morgan, “When Do Markets Tip? A Cognitive Hierarchy Approach,” Marketing Science; Issue: 32(3); 2013; Pages: 431-453.

[22] HP Press Release. HP to Contribute webOS to Open Source, December 09, (2013) Available at: http://www8.hp.com/us/en/hp-news/press-release.html?id=1148201

[23] Jackson, Joab, "Microsoft open sources Windows Library for JavaScript," PCWrold, (2014). Available at: http://www.pcworld.com/article/2139480/microsoft-open-sources-windows-library-for-javascript.html

[24] Jullien, Bruno and Alessandro Pavan, "Platform Competition under Dispersed Information," (2013).

[25] Jullien, Bruno, "Competition in Multi-Sided Markets: Divide-and-Conquer," American Economic Journal: Microeconomics, Vol. 3 (2011), pp. 1–35.

[26] Katz, Michael and Karl Shapiro, "Network Externalities, Competition and Compatibility," American Economic Review, Vol. 75 (1985), pp. 424–440.

[27] King, Ian and Diana Bass, "Microsoft's Surface Tablet Is Said to Fall Short of Predictions," Bloomberg (2013). Available at: http://www.bloomberg.com/news/2013-03-14/microsoft-s-surface-tablet-is-said-to-fall-short-of-predictions.html

[28] Lopez, Angel and Patrick Rey, "Foreclosing Competition through Access Charges and Price Discrimination." IDEI Working Paper, n. 570, June 2009.

[29] Menn, Joseph, "HP to make webOS software open-source," Financial Times (2011). Available at: http://www.ft.com/cms/s/2/e301eb7c-228f-11e1-8404-00144feabdc0.html

[30] Musil, Steven, "Microsoft cuts Surface Pro tablet prices by $100," CNET (2013). Available at: http://www.cnet.com/news/microsoft-cuts-surface-pro-tablet-prices-by-100/

[31] Olson, Michael, "Social Login Trends Across the Web for Q4 2013," Janrain (2014). Available at: http://janrain.com/blog/social-login-trends-across-web-q4-2013/

[32] Ovide, Shira and Ian Sherr, ”Microsoft Banks on Mobile Apps,” Wall Street Journal, (2012). Available at: http://online.wsj.com/article/SB10001424052702304750404577321933818976966.html

[33] Rochet, Jean-Charles and Jean Tirole. “Platform Competition in Two-sided Markets.” Journal of the European Economic Association, Vol. 1 (2003), pp. 990-1029.

[34] Speigler, Ran, “Extracting Interaction-Created Surplus,” Games and Economic Behavior, Vol. 30 (2000), pp. 142–162.

[35] Spulber, Daniel F., “Market making by price setting firms,” Review of Economic Studies, Vol. 63 (1996), pp. 559–580.

[36] Spulber, Daniel F., Market Microstructure: Intermediaries and the Theory of the Firm, Cambridge University Press, New York 1999.

[37] Zhu, Feng and Marco Iansiti, “Entry into Platform-Based Markets,” Strategic Management Journal 33, no. 1 (2012), pp. 88–106.