Pricing and Commitment by Two-Sided Platforms[*]

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Abstract

This paper studies pricing and commitment by platforms in two-sided markets with the following characteristics: i) platforms are essential bottleneck inputs for buyers and sellers transacting with each other; ii) sellers arrive before buyers; iii) platforms can charge both fixed fees and variable fees (royalties). We show that a monopoly platform may prefer not to commit to the price it will charge buyers at the same time it announces its seller price if it faces unfavorable seller expectations. With competing platforms commitment makes the existence of an exclusive equilibrium (in which sellers register only with one platform) less likely, but has no impact on multihoming equilibria (in which sellers support both platforms) whenever these exist.

Keywords: Two-Sided Markets, Platforms, Commitment, Indirect Network Effects.

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1. Introduction

Most of the recent literature on two-sided markets has modelled the two "sides" or categories of agents as arriving at the same time and therefore playing a simultaneous coordination game. While no one would argue that all agents in such markets arrive at the same time in a literal sense, the idea is that the equilibria of the simultaneous-move game represent the equilibria which would arise in a more realistic, sequential-move game. This is true as long as agents of the two sides arrive in a "sufficiently" alternated fashion. Some two-sided markets fit this description: credit cards (merchants and consumers); yellow page directories, TV, newspapers (advertisers and viewers/readers); real-estate agents and other intermediaries (buyers and sellers), etc.

However, there are several prominent categories of two-sided markets, for which this stylized representation does not seem particularly well-suited, because there is a natural and well-defined order of arrival of the two sides, in the sense that *most* members of one side of the market arrive before *most* members of the other side. For example, in the software and videogame markets, most application and game sellers join platforms (operating systems and game consoles) before most buyers do. This is for technological reasons: application and game development are long and costly processes, therefore platform vendors in these markets have to start courting sellers more than a year before the platform is ready to go on the market, in order to ensure that enough application support will be available for it at launch. An operating system or game console can not be launched simultaneously to both buyers and sellers, because no buyers would purchase it without enough applications or games and by the time any become available, buyers would be gone to another platform.

In this paper we depart from previous literature by focusing on the strategic issues arising in two-sided markets in which the two sides arrive in a clear and well-defined order.

The key issues which arise are whether platforms find it profitable to credibly commit to the price they will charge the side arriving later when trying to attract the side arriving earlier and how multihoming on one side of the market - i.e. the possibility that its members support more than one platform - affects the pricing and commitment decisions.

We propose a model for studying Bertrand competition among platforms in two-sided markets with the following characteristics: i) platforms are essential bottleneck inputs for buyers (buyers) to access the products offered by sellers (sellers); ii) sellers arrive before buyers; iii) only sellers can multihome; iv) platforms can charge fixed fees on both sides and variable fees (royalties) on each buyer-seller transaction.

Perhaps the main characteristic of two-sided markets is the presence of bilateral indirect network effects giving rise to a "chicken-and-egg" problem. However, in our case, since sellers arrive before buyers, this implies that indirect network effects are asymmetric: once sellers have decided which platform to support, the coordination problem on the buyer side vanishes. Buyers will simply adopt the platform offering the largest surplus, taking into account the price it charges and the number of supporting sellers. Thus, the only coordination game is played by sellers. It would then seem natural that platforms should concentrate all their efforts on attracting sellers, or, in other words, on capturing "chicken". This is however not necessarily true when credible commitment to buyer prices is feasible, since then platforms have the option to commit to attract a large share of buyers *ex-post* by announcing a low buyer price *ex-ante*, which enables them at the same time to charge higher seller prices. For example, as illustrated by the quote at the beginning of the paper, it is common for videogame console manufacturers to announce (attractive) price tags for their upcoming consoles well in advance of their actual release, in order to attract the support of independent game developers (and justify charging them around $8 royalties per game sold).

Commitment and the determination of variable fees (royalties) are interdependent in our model. Royalties link the pricing game for sellers and the subsequent pricing game for buyers. Specifically, positive royalties announced in the first stage act as negative "marginal costs" for platforms when they compete for buyers in the second stage. There are two conflicting effects of royalties: on the one hand, *absent commitment* to buyer prices, high royalties put platforms in a better position vis-a-vis buyers in the second stage by allowing them to price more aggressively, but on the other hand, from an *ex ante* (i.e. prior to stage one) perspective, a platform expecting to extract most of the surplus created by sellers' products has an incentive to set low royalties in order to maximize this surplus by curbing seller market power over buyers.

Although there is full and complete information in our model, we show that even a monopoly platform can sometimes find it optimal *not* to commit to buyer prices at the time it announces prices for sellers. This result is rather counterintuitive: one would be inclined to believe that commitment does always weakly better in the absence of uncertainty, since then one can always commit to the action would end up choosing anyway. The reason for why this is not necessarily true here is the two-sidedness of the pricing problem, i.e. the interdependencies between buyers' and sellers' platform adoption decisions. If for instance sellers always coordinate on not adopting the platform whenever this is an equilibrium given the prices announced, the platform finds it optimal not to commit. This credibly communicates to sellers that the platform will attract all buyers irrespective of seller support since the platform has the flexibility to price low enough to buyers *if* seller support is not forthcoming. But then sellers will in fact sign up, so that the platform can subsequently extract all the buyer surplus created, whereas commitment would have forced it to set a much lower buyer price.

With competing platforms under symmetric seller expectations, when commitment is not feasible a pricing equilibrium always exists. If sellers cannot multihome (i.e. have to support only one platform) then the only possible equilibrium involves exclusivity with either platform. If multihoming is possible, then a multihoming (respectively exclusive) equilibrium exists if and only if it is constrained socially optimal. Introducing the possibility for platforms to commit makes the existence of exclusive equilibria less likely but has no bite on the multihoming equilibria whenever the latter exist.

The paper is organized as follows. The next section sets up the modelling framework and section 3 is devoted to the analysis of the monopoly platform case. The fourth section analyzes platform competition in a duopoly with symmetric seller expectations. Section five concludes.

Related literature

Our paper belongs to the very recent literature on two-sided markets, pioneered by Armstrong (2002) (hereafter A), Rochet and Tirole (2003) (hereafter RT) and Caillaud and Jullien (2003) (hereafter CJ). RT and A emphasize the role of relative price elasticities of demand on the two sides of the market in determining platform pricing structures. However, they assume demand is elastic on both sides and agents always coordinate on the interior solution (i.e. with positive adoption on both sides) to the two-equation system determining demands on each side. The paper closest in spirit to ours is CJ: they study competition among intermediaries with homogeneous populations on both sides of the market and the sustainability of dominant platform and market sharing equilibria, which arise endogenously as a consequence of indirect network effects. However, in all of these papers the *volume of transactions between two agents (one from each side* of the market) is not directly affected by platforms' prices: RT and A essentially assume that each member of one side interacts with an exogenously given proportion of members on the other side, whereas in CJ, each member of one side interacts with only one member of the other side (in case matching is succesful). In our model the variable fees charged by the platform (royalties) play a central role, because they affect the prices and volumes of trade between sellers and buyers and therefore social welfare. On the other hand the allocation of the royalties among the two sides is largely inconsequential in our model.

Our solution and equilibrium concept are directly adapted from CJ; we also borrow their terminology for pricing strategies, in particular *divide-and-conquer*. However, in their model the two sides are essentially symmetric from all points of view and are assumed to arrive and coordinate simultaneously, therefore timing or commitment issues do not arise. By contrast, we assume sequential arrival (sellers arrive before buyers).

Lastly, our paper is related to Bernheim and Whinston (1998), who study pricing and exclusivity clauses in a game involving two manufacturers competing for access to a retailer. In particular, the method we use to determine the pricing equilibrium with competing platforms is also related to their solution concept, with our platforms corresponding to their manufacturers and our sellers corresponding to their retailer. Two-sidedness and the possibility of commitment strategies render our setting potentially much more complex than theirs. We do simplify things somewhat however by assuming that the possibility of seller multihoming is exogenously given, not endogenously determined.

2. Modelling Set-Up

The platforms we have in mind serve two categories of customers, which we call buyers and sellers, indexed by B and S: they can only interact if they have joined the same platform. There is a continuum [0,1] of buyers and a continuum [0,1] of sellers. All buyers, respectively all sellers, are *identical ex-ante* (i.e. before adopting the platform) and the interaction between a buyer and a seller generates *ex-ante expected surplus* $u^B(r)$ for the buyer and $u^S(r)$ for the seller[1], where $u^B(.)$ and $u^S(.)$ are both *decreasing* and non-negative functions[2] and r is a transaction fee (or royalty) that the platform might levy on each buyer-seller transaction[3].

This formulation encompasses several applications. In the simplest one, to which we will refer throughout the paper, each buyer has a demand $d(p)$ for each seller's product, where p is the price charged by the seller ($d(.)$ is assumed to be continuous and bounded). Then we have[4]:

$$u^S(r) = (p(r) - r)\, d(p(r))$$

$$u^B(r) = \int_{p(r)}^{\infty} d(\rho)\, d\rho$$

where $p(r) = \arg\max_p (p - r)\, d(p)$.

Another application are the constrained efficient bargaining processes studied by Myerson and Satterthwaite (1983) and also used by Rochet and Tirole (2005).

There are positive indirect network effects between buyers and sellers in the following

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[1] That is, we assume that buyers (respectively sellers) can solely be differentiated by a parameter b^B (b^S) which is revealed only *ex-post*, i.e. after they (buyers and sellers) have adopted the platform. Then, denoting by F^B (respectively F^S) the cdf of b^B (b^S), we have:

$$u^i(r) = \int_{b^B}\int_{b^S} u^i\left(b^B, b^S, r\right) dF^B\left(b^B\right) dF^S\left(b^S\right)$$

where $u^i\left(b^B, b^S, r\right)$ is the realized net surplus for agent i from interacting with agent j ($i, j \in \{B, S\}$, $i \neq j$) when the buyer's "type" is b^B and the seller's type is b^S.

This is similar to the formulation found in Rochet and Tirole (2005), except that we assume away the *ex-ante* heterogeneity for simplicity.

[2] This is because buyers or sellers can always opt out of interactions which give them negative utility.

[3] Thus, we assume that the split of the royalty between buyers and sellers (r^B and r^S) is irrelevant and only the total $r = r^B + r^S$ matters. This is true for a wide range of two-party economic interactions, including bargaining with symmetric or asymmetric information and price-setting by one party. See Rochet and Tirole (2005).

[4] It is easily verified that the expressions that follow are independent of the exact allocation of r between buyers and sellers.

sense. Any seller joining a platform which is adopted by N^B buyers and charges sellers an access price[5] P^S derives net surplus:

$$u^S(r)\,N^B - P^S - f$$

where f is the fixed cost for a seller of making her product "work" on the platform (it can be for example the development cost of a game for a console).

We allow for economies of scale in making seller products available on several platforms (*seller multihoming)* in that we assume the fixed cost of making the product available on any *additional* platform is only a fraction γf of the fixed cost f of supporting the first platform, where $\gamma < 1$.

Conversely, any buyer joining a platform supported by N^S sellers and charging buyers an access price P^B derives net surplus[6]:

$$u^B(r)\,N^S - P^B$$

Denoting by $n(r)$ the *ex-ante expected* number of transactions between a buyer and a seller on a platform charging a royalty rate r[7] and access prices P^S and P^B, the expression of total platform profits when it is adopted by N^B buyers and N^S sellers is:

$$\Pi^P = N^S P^S + N^B N^S n(r)\,r + N^B P^B$$

Implicit in the expression above is the simplifying assumption that all the costs incurred

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[5] Throughout the paper we assume platforms cannot price-discriminate among sellers. This means they cannot offer a low price to the first sellers in order to create a cascade effect and then raise prices for the subsequent sellers.

[6] We assume buyers have no fixed cost of adopting platforms.

[7] In the price-setting example above $n(r) = d(p(r))$.

by the platform are equal to 0 (these include fixed costs per buyer and per seller and variable costs for each transaction taking place between buyers and sellers).

Further notation and assumptions

We denote by $W(r)$ the total social surplus created by a buyer-seller interaction on a platform charging royalty r (gross of the seller's development cost f):

$$W(r) = u^B(r) + u^S(r) + rn(r)$$

We also define two functions which will play an important role in what follows:

$$\begin{aligned} \Phi^B(r) &= u^B(r) + rn(r) \\ \Phi^S(r) &= u^S(r) + rn(r) \end{aligned}$$

$\Phi^B(r)$ is the sum of buyer surplus and platform royalty net revenues per buyer-seller and similarly, $\Phi^S(r)$ is the sum of seller surplus and platform net royalty revenues per buyer-seller.

We make the following assumptions:

Assumption 1 *$W(r)$ is continuous and strictly decreasing for $r \in [r^*, r^{\max}]$, $W(r) = W(r^*)$ for $r \leq r^*$ and $W(r) = 0$ for $r \geq r^{\max}$,* where $r^* < 0 < r^{\max}$.

This assumption simply says that when the tax on interactions r increases, the negative impact on total surplus due to lowered incentives for agents to interact outweighs the positive effect of higher "tax revenues" for the platform. For r high enough, agents do not interact anymore and therefore there are no transactions and no surplus, whereas for r low enough (negative) total surplus stops increasing[8].

Assumption 2 $\Phi^B(.)$ *and* $\Phi^S(.)$ *are single-peaked on* $[r^*, r^{\max}]$.

Let then $r_B = \arg\max_r \Phi^B(r)$ and $r_S = \arg\max_r \Phi^S(r)$.

Assumption 3 *There exists* $r_0 \in (r^*, 0)$ *such that* $\Phi^B(r_0) = 0$*,* $\Phi^B(r) < 0$ *if and only if* $r < r_0$*.*

These three assumptions simplify the exposition considerably but our main results do not depend on them. In the appendix, we illustrate and justify these assumptions using the example introduced earlier, in which each seller sets a price to buyers.

The following figure shows the typical shapes of some of the functions defined by breaking down $W(r)$ into $u^S(r) + \Phi^B(r)$.

Timing

As explained in the introduction, we are interested in two-sided settings in which one side enters the market before the other. Here, we assume sellers make their platform adoption decisions before buyers. The justification is that they might need significant time to make their products available for the platforms they have decided to support.

In this context, platforms may have two strategic options. One is to first announce only the prices concerning sellers, i.e. P^S and r, observe sellers' adoption decisions and only then announce prices for buyers P^B. The second option is to commit to the price for buyers P^B from the beginning (if there exists a way to credibly commit), i.e. at the same time when announcing P^S and r. These two possibilities lead to different pricing games. Therefore the timing of the games we analyze in the paper is as follows:

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[8] This hinges on our simplifying assumption that platform variable costs are equal to 0. See following footnote for an alternative example.

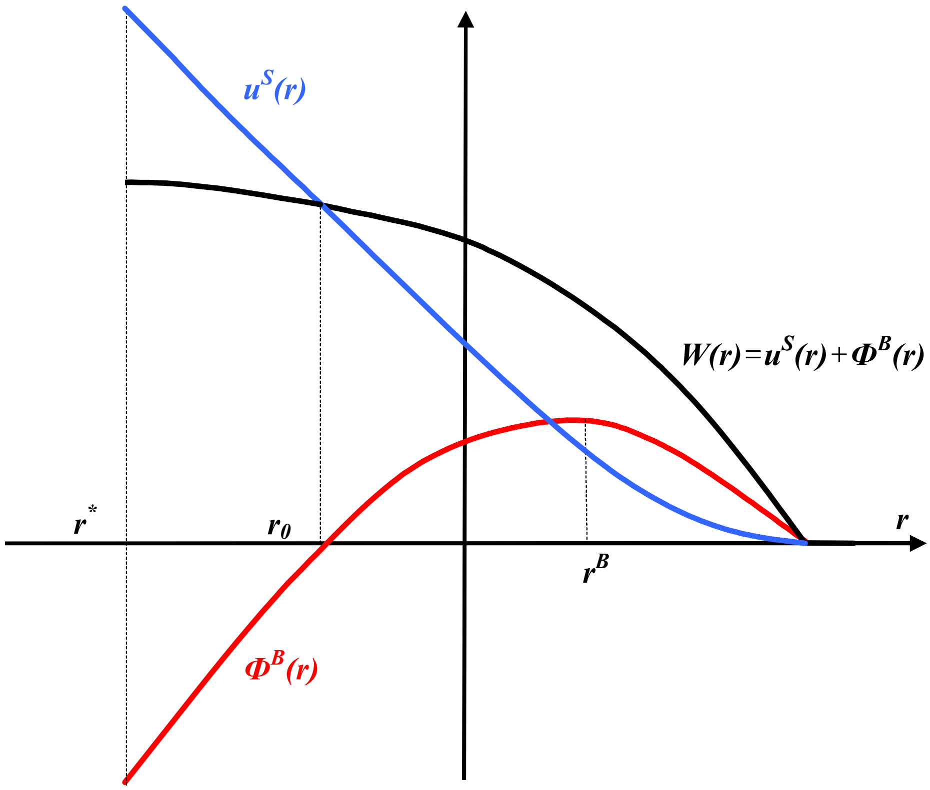

Figure 2.1:

Stage 1 Platforms announce prices P^S and r and those who decide to commit also announce P^B. In either case, sellers make their platform adoption decisions.

Stage 2 Platforms which have not committed announce P^B. Buyers make platform adoption decisions.

We assume there is full information at every stage of the game.

The key implication of this timing is that although there are positive indirect network effects on both sides of the market (i.e. more buyers on a platform attract more sellers and viceversa), the only coordination game with network effects is played by sellers. Once they have made up their minds, buyers will simply go with the platform offering them the highest surplus, taking into account number of sellers and buyer access price.

3. Monopoly Platform

The analysis of the case with a single monopoly platform allows us to derive several key insights regarding the interplay between indirect network effects and commitment strategies, in particular, the non-intuitive result that in spite of full and complete information no commitment may turn out to be the profit-maximizing strategy for the monopoly platform even when it has the option to commit.

The price P^B charged to buyers is either determined from stage 1 in the commitment pricing game, in which case the platform has no strategic variables to choose in the second stage, or it is the only strategic variable that the platform can set in stage 2 in case it has not committed. In order to capture both of these possibilities, denote by $\mathbf{P}$ the vector of prices announced by the platform in the first stage. If $\mathbf{P} = \left(P^B, r, P^S\right) \in \mathbb{R}^3$ then the platform has chosen to commit to buyer prices and we are in the commitment pricing subgame. If not, $\mathbf{P} = \left(r, P^S\right) \in \mathbb{R}^2$ and we are in the no-commitment sub-game. In both cases, sellers decide whether or not to adopt the platform based on $\mathbf{P}$ and on their expectations of N^B, the number of buyers who will adopt the platform in the second stage, which in turn depends on $\mathbf{P}$ (whether P^B is announced in stage 1 or 2) and N^S, the number of sellers who end up adopting in the first stage.

Let us first make clear our equilibrium concept for the adoption game played by sellers, buyers and the platform given $\mathbf{P}$. In equilibrium, we require all actors (buyers, sellers and the platform) to make the decision(s) that maximize(s) their individual utilities at every stage of the game in which they have one or several decisions to make, given their expectations of the future realizations of the variables which impact their utility; and we also require that expectations are rational, i..e. fulfilled in equilibrium. Formally:

Definition 1 *An adoption equilibrium (with commitment) given* $\mathbf{P} = \left(P^B, r, P^S\right)$ *is a pair* $\left(N^S, N^B\right)$ *such that* $N^S = 1_{\{N^B u^S(r) - P^S - f \geq 0\}}$ *and* $N^B = 1_{\{N^S u^B(r) - P^B \geq 0\}}$[9].

An adoption equilibrium (with no-commitment) given $\mathbf{P} = \left(r, P^S\right)$ *is a pair* $\left(N^S, N^B\right)$ *such that* $N^S = 1_{\{N^B u^S(r) - P^S - f \geq 0\}}$ *and* $N^B = 1_{\{N^S \Phi^B(r) \geq 0\}}$.

Embedded in the no-commitment adoption equilibrium definition is the implicit assumption that the platform sets P^B in the second stage to maximize its profits from that point on (once N^S is realized). Since maximum second stage profits are $N^S \max\left(\Phi^B(r), 0\right)$, the platform sets $P^B = N^S u^B(r)$ if $\Phi^B(r) \geq 0$ and $P^B = \infty$ if $\Phi^B(r) < 0$.

Also, note that if the platform does not commit, the royalty rate r it sets in the first stage has to satisy $\Phi^B(r) \geq 0$ or, equivalently, $r \geq r_0$ by assumption 3. Indeed, no seller will ever sign up to a royalty rate such that $r < r_0$ because they correctly anticipate in

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[9] We assume that when indifferent between adopting and not, both buyers and sellers adopt. For buyers, this holds even when there are no sellers and the platform charges $P^B = 0$: the interpretation is that the platform may offer some standalone utility, which for simplification purposes we have normalized to 0. And similarly for sellers.

this case that the platform will set a prohibitively high buyer price in the second stage in order to make 0 sales and avoid having to *pay* the costly royalties it has announced (they are negative). When the platform has credibly committed however, it no longer faces this constraint and its second stage profits may well turn out to be negative[10].

Due to the timing of the adoption game - sellers decide before buyers -, given $\mathbf{P}$, any adoption equilibrium is in fact uniquely characterized by the equilibrium number of sellers N^S, which then uniquely determines $N^B\left(\mathbf{P}, N^S\right) = 1_{\{N^S u^B(r) - P^B \geq 0\}}$ in the commitment case and $N^B\left(\mathbf{P}, N^S\right) = 1_{\{N^S \Phi^B(r) \geq 0\}}$ in the no commitment case. We can then define:

Definition 2 *A seller demand function is a mapping* $N^S(.)$*, which associates to each price vector* $\mathbf{P}$ *an adoption equilibrium number of sellers* $N^S(\mathbf{P})$ *supporting the platform*[11]*.*

Definition 3 *An equilibrium of the overall pricing game is a pair* $\left(\mathbf{P}, N^S(.)\right)$ *where* $N^S(.)$ *is a seller demand function and* P *maximizes the profits of a platform facing* $N^S(.)$*.*

The key observation is that the two-sided indirect network effects between sellers' and buyers' adoption decisions (apparent from definition 1), combined with the fact that sellers decide first, give rise to strategic complementarities among individual sellers' adoption decisions. This means that for any given price vector $\mathbf{P}$ announced by the platform in the first stage there may be several possible adoption equilibria and consequently that in general there exist multiple seller demand functions. Our equilibrium concept can therefore be interpreted as a *rational expectations equilibrium*, in which, given $\mathbf{P}$, each infinitesimal seller has expectations about all sellers' adoption decisions, namely the fraction choosing to support the platform, and in equilibrium expectations are common and fulfilled.

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[10] They are presumably outweighed by positive revenues from fixed fees charged to sellers in the first stage.

[11] Note that this definition is general enough to include both the commitment and the no-commitment pricing games.

Using this interpretation, we focus here on two polar seller demand functions, stemming from two types of seller expectations.

The first one stems from *favorable seller expectations*: each individual seller expects all other sellers to support the platform, as long as they obtain non-negative profits by doing so at the prices announced by the platform. This type of expectations may arise for example if the platform in question is a long-standing incumbent or benefits from outstanding reviews in specialized magazines; it could be Microsoft's Windows, Sony's Playstation, Palm, etc. Formally[12]:

$$N^S(\mathbf{P}) = 1_{\{N^B(\mathbf{P},1)u^S(r)-P^S-f\geq 0\}}$$

It follows that the platform sets $\mathbf{P}$ in order to maximize its profits subject to the seller participation constraint, which in this case is:

$$P^S \leq u^S(r)\,N^B(\mathbf{P},1) - f \tag{3.1}$$

Therefore, if the platform does not commit, it can extract the full surplus from sellers in the first stage by charging[13] $P^S = u^S(r) - f$. Sellers rationally anticipate that the platform will attract all buyers in the second stage, which it does by charging $P^B = u^B(r)$. Total platform profits are then $W(r) - f$, which it maximizes subject to the constraint $\Phi^B(r) \geq 0$. This yields $r = r_0$ and $\Pi^P = W(r_0) - f$.

If on the other hand the platform commits, it can do so to the price it would have charged buyers anyway, i.e. $P^B = u^B(r)$. The seller access fee remains the same, i.e. $P^S = u^S(r) - f$: given favorable seller expectations, sellers rationally coordinate on platform

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[12] It is easily verified that $N^S(\mathbf{P})$ thus defined and $N^B = N^B\left(\mathbf{P}, N^S(\mathbf{P})\right)$ form an adoption equilibrium for any $\mathbf{P}$.

[13] Recall that the total numbers of buyers and sellers are normalized to 1.

adoption anticipating all buyers will adopt in the second stage, which is in fact what happens given the price P^B to which the platform has committed. The platform is therefore able once again to extract the full surplus $W(r) - f$ from both sides, only now credible commitment to P^B makes the $r \geq r_0$ constraint disappear, so that the platforms sets $r = r^*$ for profits $\Pi^P = W(r^*) - f > W(r_0) - f$. Thus commitment is a dominant strategy for a monopoly platform facing favorable seller expectations.

The second demand function we analyze stems from *unfavorable seller expectations*: each individual seller expects *no* seller will support the platform as long as this is consistent with the prices announced[14]. Formally:

$$N^S(\mathbf{P}) = 1_{\{N^B(\mathbf{P},0)u^S(r) - P^S - f \geq 0\}}$$

In this case, the platform sets $\mathbf{P}$ to maximize profits subject to:

$$P^S \leq u^S(r)\, N^B(\mathbf{P}, 0) - f \tag{3.2}$$

If the platform does not commit to the price it will charge buyers, then as long as $\Phi^B(r) \geq 0$, i.e. $r \geq r_0$, sellers still anticipate that it would attract all buyers in the second stage *even without any seller support*, by setting $P^B = 0$. Then the platform can charge $P^S = u^S(r) - f$ and attract all sellers, which enables it to attract all buyers in the second stage by setting $P^B = u^B(r)$. This yields the same profits as when expectations were favorable under no committment, i.e. $\Pi^P = W(r_0) - f$.

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[14] The type of expectations is exogenously assumed here in order to simplify the analysis. One could model them as endogenously arising from uncertainty regarding the platform's quality. Uncertainty may surround a platform if it is a new entrant and/or does not benefit from good reviews, as was the case with Palm's 1993 failure in the market for personal digital assistants with the Zoomer and IBM's failure to establish the OS/2 operating system for PCs as a viable competitor to Microsoft's Windows, etc.

Things change dramatically when the platform facing unfavorable expectations tries to commit. Commitment to any $P^B > 0$ requires it to set $P^S \leq -f$, since otherwise sellers coordinate on no adoption, which is justified *ex-post*, because then no buyer adopts either. Consequently, the platform has two options: give up buyer surplus and content itself with seller surplus by setting $P^B = 0$ and $P^S = u^S(r) - f$, or give up seller surplus and extract buyer surplus by setting $P^S = -f$ and $P^B = u^B(r)$. These two pricing options can be called (by analogy to Caillaud and Jullien (2003)) *divide-and-conquer* strategies. Each of them relies on pricing low on one side in order to secure its participation *irrespective* of the participation of the second side, and then extracting surplus from the latter. The first option yields profits equal to $\Phi^S(r) - f$, which are maximized by $r = r_S$, whereas the second option yields $\Phi^B(r) - f$, maximized by $r = r_B$.

In the price setting example with $n(r) = d(p(r))$, we have $\Phi^S(r) = p(r)\, d(p(r))$, so that $r^S = 0 > r_0$, and $\Phi^B(r_0) = 0$, so that $r^B > r_0$. Therefore, since $W(r) > \max\left(\Phi^S(r), \Phi^B(r)\right)$ for all r (including $r > r_0$) we have $W(r_0) > \max\left(\widehat{\Phi^S}, \widehat{\Phi^B}\right)$, so that no commitment is strictly preferred by the platform.

We have thus proven the following proposition.

Proposition 1 *Commitment to buyers prices is always the optimal equilibrium strategy for a monopoly platform if it faces favorable seller expectations, whereas no commitment can sometimes be optimal when seller expectations are unfavorable.*■

This result goes against the common intuition that in the absence of any information asymmetries and incompleteness commitment is always weakly better because one can always commit from the outset to the action one will take in the future. This is true only if the monopoly platform faces favorable seller expectations, i.e. benefits from the confidence of sellers, who coordinate on the "right" equilibrium. If however sellers are not confident in the success of the platform, then the latter strictly gains by not committing, because in this way it maintains the ability to adjust its buyer prices in order to attract buyers even in the event that sellers coordinate on the unfavorable equilibrium with 0 adoption. This flexibility allows it to charge higher prices to sellers.

4. Platform Competition

We now turn to the study of competition between two platforms. Throughout this section we assume the platforms are identical in the surplus they create for buyers and sellers transacting on them.

There is still a continuum [0,1] of identical sellers and a continuum [0,1] of identical buyers, however we assume that each platform has a fraction $a \in [0, \frac{1}{2})$ of buyers "captive", i.e. who always adopt that platform as long as they derive non-negative surplus from doing so[15]. The remaining $(1-2a)$ fraction of buyers is "free", i.e. they go with the platform offering the highest net surplus. This assumption might reflect situations in which some consumers have fixed *ex-ante* preferences over platforms. We also assume platforms can distinguish the free buyers from captive buyers[16] and can price discriminate in access fees between them, so that they always extract the full surplus from captive buyers (they do not face any competition for them). However, we assume platforms are constrained to charge the same royalty to all buyers and sellers. This is justified for instance if platforms levy the royalty on sellers and can only observe total sales, but not the type of buyers sellers interact with, which is quite realistic. The videogame industry is a good illustration.

While buyers are assumed to adopt at most one platform throughout, we will analyze

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[15] We are grateful to an anonymous referee for suggesting this feature.

[16] This is quite plausible for instance if the platforms have a pre-existing relationship with the captive buyers.

both situations in which sellers are restricted to choosing only one platform and situations in which they can multihome, i.e. adopt both platforms.

Throughout this section, in order to render the discussion meaningful, we make the following assumption:

Assumption 4 $(1-a)\,W(r_0) \geq f$

This simply says that the maximum social surplus (and profits) created by a platform attracting all sellers, all of its captive buyers and the free buyers, and not committing to buyer prices, is non negative.

The Bertrand pricing game played in stage 2 (competition for buyers) is entirely determined by the outcome of stage 1, i.e. by sellers' adoption decisions. We therefore start by characterizing the outcome of the stage 2 pricing game. We will use this characterization in what follows in order to solve for the entire pricing game.

Let $\mathbf{N^S} = \left(N_{e_1}^S, N_{e_2}^S, N_m^S\right)$ be the distribution of developers among the two platforms at the beginning of stage 2. $N_{e_i}^S$ is the number of developers supporting platform i *exclusively* and N_m^S is the number of developers multihoming[17]. Let then $N_i^S = N_{e_i}^S + N_m^S$ be the total number of developers supporting platform i, $i = 1, 2$. For buyers, we denote by n_i^B the number of *free* buyers joining platform i, $0 \leq n_i^B \leq 1 - 2a$. Also, let $\mathbf{P} = \{\mathbf{P}_1, \mathbf{P}_2\}$ be the vector of prices announced by the platforms in the first stage. Since each platform i can price discriminate between free and captive buyers, the price for the latter will always be equal to $N_i^S u^B(r_i)$[18]. We therefore focus on the price P_i^B for free buyers.

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[17] Note that under exclusivity $N_m \equiv 0$ and $N_{e_1} + N_{e_2} = N$, whereas under multihoming $0 \leq N_{e_1} + N_{e_2}, N_m \leq N$.

[18] The only situation in which platform i's price for its captive buyers could be different than $N_i^S u^B(r_i)$ is when the platform has not committed and has set r_i such that $\Phi^B(r_i) < 0$. It would then have an incentive in the second stage to charge astronomical prices to all buyers in order to avoid attracting *any* at all. But such a royalty rate would not be credible as we argue below.

If platform i credibly commits to P_i^B in the first stage, then $\mathbf{P}_i = \left(P_i^B, r_i, P_i^S\right) \in \mathbb{R}^3$. If platform i attracts any buyers in the second stage, buyer rationality requires $P_i^B \leq N_i^S u^B\left(r_i\right)$. Platform i's second stage profits are then $aN_i^S \Phi^B\left(r_i\right) + n_i^B\left(P_i^B + N_i^S r_i n\left(r_i\right)\right)$. Note in particular that P_i^B may be lower than $-r_i N_i^S n\left(r_i\right)$, implying that platform i makes negative profits in the second stage.

If on the other hand platform i has not committed to its user price in the first stage then $\mathbf{P}_i = \left(r_i, P_i^S\right) \in \mathbb{R}^2$ and P_i^B is determined during the second stage Bertrand pricing game. However, in this case platform i will never price below the "marginal cost" $-N_i^S r_i n\left(r_i\right)$ for neither captive nor free buyers, meaning that, absent commitment to buyer prices, second stage platform profits - sum of income from royalties and from fixed fees charged to buyers - cannot be negative. Consequently, the highest utility platform i can offer a free buyer conditional on *not* having committed is $N_i^S\left(u^B\left(r_i\right) + r_i n\left(r_i\right)\right) = N_i^S \Phi^B\left(r_i\right)$. The highest profits platform i can earn in the second stage, obtained by setting $P_i^B = N_i^S u^B\left(r_i\right)$, are $(1-a)\, N_i^S \Phi^B\left(r_i\right)$. It follows that, just like in the case of a monopoly platform, the royalty rate announced to developers has to satisfy:

$$\Phi^B\left(r_i\right) \geq 0 \Longleftrightarrow r_i \geq r_0 \tag{4.1}$$

There are three possible scenarios to consider.

a) if both platforms have committed to buyer prices in the first stage then total buyer demand for platform i is:

$$N_i^B\left(\mathbf{P}, \mathbf{N^S}\right) = a + (1-2a)\, 1_{\left\{N_i^S u^B(r_i) - P_i^B \geq \max\left(0, N_j^S u^B(r_j) - P_j^B\right)\right\}}$$

b) If platform i has committed and platform j has not committed then buyer demand for platform i is:

$$N_i^B\left(\mathbf{P},\mathbf{N^S}\right)=a+(1-2a)\,1_{\left\{N_i^S u^B(r_i)-P_i^B\geq\max\left(0,N_j^S\Phi^B(r_j)\right)\right\}}$$

and for platform j:

$$N_j^B\left(\mathbf{P},\mathbf{N^S}\right)=a+(1-2a)\,1_{\left\{N_j^S\Phi^B(r_j)\geq\max\left(0,N_i^S u^B(r_i)-P_i^B\right)\right\}}$$

c) If neither platform has committed then buyer demand for platform i is:

$$N_i^B\left(\mathbf{P},\mathbf{N^S}\right)=a+(1-2a)\,1_{\left\{N_i^S\Phi^B(r_i)\geq\max\left(0,N_j^S\Phi^B(r_i)\right)\right\}}$$

With these characterizations in hand, we can now turn to the analysis of the full pricing game between two-competing platforms.

Just like in the monopoly platform case, but even more so with competing platforms, indirect network effects can give rise to many different equilibrium configurations of platform adoption by sellers given a single set of prices, depending on the nature of seller expectations.

In order to make our equilibrium concept clear, we adapt the definitions from Caillaud and Jullien (2003). Denote by $\mathbf{S}$ the set of strategies available to sellers: $\mathbf{S}=\{0,e_1,e_2\}$ if multihoming is not permitted and $\mathbf{S}=\{0,e_1,e_2,m\}$ if multihoming is feasible. Seller surplus from choosing strategy $s\in\mathbf{S}^D$ as a function of the vector of prices $\mathbf{P}=(\mathbf{P}_1,\mathbf{P}_2)$

and of the distribution of developers $\mathbf{N^S} = \left(N^S_{e_1}, N^S_{e_2}, N^S_m\right)$ is then:

$$U^S\left(s, \mathbf{P}, \mathbf{N^S}\right) = \begin{cases} u^S\left(r_i\right) N_i^B\left(\mathbf{P}, \mathbf{N^S}\right) - P_i^S - f & \text{if} \quad s = e_i \\ \sum_{i=1,2}\left(u^S\left(r_i\right) N_i^B\left(\mathbf{P}, \mathbf{N^S}\right) - P_i^S\right) - \left(1+\gamma\right) f & \text{if} \quad s = m \\ 0 & \text{if} \quad s = 0 \end{cases}$$

Then a distribution of sellers $\mathbf{N^S} = \left(N^S_{e_1}, N^S_{e_2}, N^S_m\right)$ is an equilibrium configuration given $\mathbf{P} = \left(\mathbf{P}_1, \mathbf{P}_2\right)$ if and only if:

$$N_s^S > 0 \Longrightarrow U^S\left(s, \mathbf{P}, \mathbf{N^S}\right) \geq \max_{\substack{s' \in \mathbf{S} \\ s' \neq s}} U^S\left(s', \mathbf{P}, \mathbf{N^S}\right)$$

A system of seller demand functions is a mapping $\mathbf{N^S}\left(.\right)$, which associates to every price vector $\mathbf{P}$ an equilibrium distribution of sellers $\mathbf{N^S}\left(\mathbf{P}\right)$.

Finally, an equilibrium is a pair $\left(\mathbf{N^S}\left(.\right), \mathbf{P}\right)$, where i) $\mathbf{N^S}\left(.\right)$ is a system of seller demand functions and ii) $\mathbf{P}$ is a Nash equilibrium of the reduced form pricing game induced by $\mathbf{N^S}\left(.\right)$.

This formulation makes it clear that because of indirect network effects, there exist potentially many equilibrium configurations, depending on seller expectations. Here we restrict attention to the case in which sellers have symmetric expectations about the two platforms. In other words, we assume sellers are able to coordinate on adopting the platform which offers the highest aggregate seller surplus. This is akin to the usual assumption in the network effects literature[19] that agents coordinate on the Pareto-optimal equilibrium. In our model this is strictly equivalent to a situation with a single seller of "size" 1.

Another interesting case is when one of the platforms is dominant in the sense that

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[19] See for example Katz and Shapiro (1985).

it benefits from biased favorable seller expectations against the other. In other words, the seller demand function $\mathbf{N^S}(.)$ is such for any given set of prices, if there are multiple seller configuration equilibria, sellers coordinate on the one yielding the highest market shares for the dominant platform on both sides of the market. This case is treated in the working paper version of this article (Hagiu (2005)): the main insight is that favorable seller expectations allow the dominant platform to sustain strictly positive profits even when sellers cannot multihome, however the analysis is quite complex, therefore we omit it here.

Focusing on the case of platform competition with symmetric seller expectations, we treat four cases in turn, according to whether platforms can commit to buyer prices or not and sellers can multihome or not.

4.1. Platforms cannot commit and sellers cannot multihome

This is by far the simplest case. Given the prices $\left(P_i^S, r_i\right)_{i=1,2}$ announced by the two platforms in the first stage, with $\Phi^B(r_1)$, $\Phi^B(r_2) \geq 0$, either all sellers support platform 1 exclusively or all sellers support platform 2 exclusively[20]. Then, in stage 2, the platform which captures sellers attracts both its captive buyers and the free buyers and extracts all their surplus. Denoting by E_i the seller surplus from adopting platform i when all sellers do the same, we have:

$$E_i = (1-a)\, u^S(r_i) - P_i^S - f$$

Assuming platform 1 attracts all sellers, we have $\Pi_1^P = P_1^S + (1-a)\,\Phi^B(r_1)$ and $\Pi_2^P = 0$.

Clearly, in the equilibrium of the pricing game, we must have $E_1 = \max(E_2, 0)$. Indeed,

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[20] Or all sellers support no platform at all - this cannot be an equlibrium however since there are strictly positive gains from trading on at least one platform.

first note that $E_1 \geq \max(E_2, 0)$, otherwise sellers would switch to platform 2 or not join platform 1 at all, and if $E_1 > \max(E_2, 0)$ then platform 1 could strictly increase its profits by increasing P_1^S.

Next, we must have $\Pi_1^P = 0$, otherwise platform 2 can profitably deviate by charging the same royalty as platform 1 and P_2^S slightly less than P_1^S. Thus $P_1^S = -(1-a)\,\Phi^B(r_1)$ and $E_1 = (1-a)\,W(r_1) - f$. This finally implies that $r_1 = r_0$, otherwise 2 could profitably deviate by setting $r_2 = r_0$ and $P_2^S = -(1-a)\,\Phi^B(r_0) + \varepsilon = \varepsilon$, with $\varepsilon > 0$ small enough.

We obtain:

Proposition 2 *When platforms cannot commit and sellers cannot multihome there always exists a unique exclusive equilibrium, in which each platform sets a royalty rate equal to r_0. Sellers register exclusively with either platform (they are indifferent). Equilibrium profits are 0 for each platform and all the surplus goes to sellers.*■

This result is quite natural: the Bertrand logic prevails, driving platform profits down to 0 (since they are identical) and ensuring that the constrained socially optimal royalty rate is chosen, i.e that which maximizes total social surplus subject to the credibility constraint $\Phi^B(r) \geq 0$. This surplus is then offered to sellers. The result is also easily understood in the terms of Bernheim and Whinston (1998): in the exclusive equilibrium platforms make 0 profits because they are identical.

4.2. Platforms cannot commit, sellers can multihome

There are two types of equilibria to consider in this case: an exclusive equilibrium in which one platform manages to attract all sellers exclusively and a multihoming equilibrium, in which sellers support both platforms. We study the existence of both equilibria in turn.

a) Exclusive equilibrium

Prices in the exclusive equilibrium with platform 1 must satisfy:

$$E_1 = (1-a)\,u^S(r_1) - P_1^S - f \geq (1-a)\,u^S(r_2) - P_2^S - f = E_2 \tag{4.2}$$

and

$$\underbrace{(1-a)\,u^S(r_1) - P_1^S - f}_{E_1} \;\geq\; \underbrace{au^S(r_1) + au^S(r_2) + (1-2a)\,u^S(r_k) - P_1^S - P_2^S - (1+\gamma)\,f}_{MH} \tag{4.3}$$

i.e. exclusivity with platform 1 must be preferred to both exclusivity with platform 2 and multihoming. In the expression of MH above:

$$k \in \{1,2\}\,,\; k = 1 \Longleftrightarrow \Phi^B(r_1) \geq \Phi^B(r_2)$$

In equilibrium platform profits are $\Pi_1^P = P_1^S + (1-a)\,\Phi^B(r_1) \geq 0$ and $\Pi_2^P = 0$ respectively, therefore we must have $E_1 = \max(E_2, 0) \geq MH$. To see this, note that platform 1 can increase P_1^S until the equality above holds, while maintaining the same difference between E_1 and MH. Note then that $E_1 = 0$ cannot be an equilibrium, otherwise platform 2 could profitably deviate by setting the same royalty rate as 1 and P_2^S slightly lower than P_1^S. Hence:

$$E_1 = E_2 \geq \max(MH, 0)$$

Consider now the following deviation by platform 2:

$$P_2^S = (1-a)\,u^S(r_2) - f - E_1 - \varepsilon$$

with $\varepsilon > 0$ very small. Then sellers prefer exclusivity with platfom 2 to exclusivity with platform 1: $E_2 = E_1 + \varepsilon$. If they choose exclusivity with platform 2, then the latter makes:

$$\Pi_2^P(E_2) = (1-a)W(r_2) - f - E_1 - \varepsilon$$

If sellers choose multihoming, then platform 2 makes:

$$\Pi_2^P(MH) = aW(r_2) + (1-2a)u^S(r_2) - f - E_1 - \varepsilon + (1-2a)\max\left(\Phi^B(r_2) - \Phi^B(r_1), 0\right)$$

It is easily seen that both expressions are decreasing in r_2, therefore the best such deviation for platform 2 involves $r_2 = r_0$. This yields profits $\Pi_2^P = (1-a)W(r_0) - f - E_1 - \varepsilon$[21], which are positive whenever $r_1 > r_0$ or $\Pi_1^P > 0$ because in equilibrium $\Pi_1^P + E_1 = (1-a)W(r_1) - f$. We must therefore have $r_1 = r_0$, $E_1 = (1-a)W(r_0) - f$ and $\Pi_1^P = 0$ in order for the above deviation by platform 2 to be unprofitable. Combined with the equilibrium condition $E_1 = E_2$ this implies $r_1 = r_2 = r_0$ and $P_1^S = -(1-a)\Phi^B(r_0) = 0 = P_2^S$. We obtain:

$$E_1 = E_2 = (1-a)W(r_0) - f$$

and

$$MH = W(r_0) - (1+\gamma)f$$

Thus, we have shown:

Proposition 3 *When platforms cannot commit but sellers can multihome, an exclusive equilibrium in which sellers only register with one platform exists if and only if* $aW(r_0) \leq \gamma f$. *If it does, then it involves 0 platform profits and a royalty rate equal to* r_0.■

Once again, Bertrand competition leaves platforms with 0 profits in the exclusive equi-

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[21] For $r_2 = r_0$ the two expressions above are equal.

librium, a result very similar (albeit in a two-sided rather than a one-sided context) to that of Bernheim and Whinston (1998) for manufacturers (corresponding to platforms in our case).

b) Multihoming equilibrium

The first necessary condition for sellers to prefer multihoming to exclusivity with either platform is:

$$MH \geq \max\left(E_1, E_2, 0\right)$$

where MH, E_1 and E_2 have the same expressions as in (4.2) and (4.3) above.

Platform i's profits in this case are:

$$\Pi_i^P = P_i^S + a\Phi^B\left(r_i\right) + (1-2a)\max\left(\Phi^B\left(r_i\right) - \Phi^B\left(r_j\right), 0\right)$$

It is then easily seen that in equilibrium we must have:

$$MH = \max\left(E_1, 0\right) = \max\left(E_2, 0\right) \tag{4.4}$$

Indeed, if $MH > \max\left(E_1, 0\right)$ for example, then platform 2 could profitably deviate by slightly increasing P_2^S.

Suppose without loss of generality that $\Phi^B\left(r_1\right) \geq \Phi^B\left(r_2\right)$. If $r_2 > r_0$, then platform 2 can deviate by decreasing r_2 to r_0 while keeping $au^S\left(r_2\right) - P_2^S$ constant, which ensures MH remains constant. If sellers continue to multihome, then platform 2's profits $P_2^S + a\Phi^B\left(r_2\right)$ strictly increase, whereas if sellers decide to switch to exclusivity with platform 2, its profits jump to $P_2^S + (1-a)\Phi^B\left(r_2\right)$, which is also strictly better. Thus, we must necessarily have $r_2 = r_0$.

Then platform 1's profits are $P_1^S + (1-a)\Phi^B\left(r_1\right)$ whether sellers multihome or choose exclusivity with platform 1. The latter can therefore decrease r_1 to r_0 while keeping $(1-a)\,u^S(r_1) - P_1^S$ constant, which strictly increases profits. Hence we must also have $r_1 = r_0$.

We obtain that in equilibrium P_1^S and P_2^S are necessarily simultaneously determined by the following two equations corresponding to (4.4):

$$P_1^S = W(r_0) - \max\left((1-a)\,W(r_0) + \gamma f, P_2^S + (1+\gamma)\,f\right) \tag{4.5}$$

$$P_2^S = W(r_0) - \max\left((1-a)\,W(r_0) + \gamma f, P_1^S + (1+\gamma)\,f\right) \tag{4.6}$$

Relegating the last part of the analysis in the appendix, we have:

Proposition 4 *If platforms cannot commit but sellers can multihome, a multihoming equilibrium exists if and only if* $aW(r_0) \geq \gamma f$.■

The main novelty of course is that now platforms make positive profits (whenever $aW(r_0) > \gamma f$). This is quite natural: seller multihoming relaxes platform competition and each platform is therefore able to extract some surplus. This equilibrium parallels the "common representation" equilibrium of Bernheim and Whinston (1998). In particular note that the condition for existence of this equilibrium $aW(r_0) > \gamma f$ parallels very closely their condition that total surplus under common representation exceeds total surplus under exclusive representation: it says that the constrained maximum social gains from introducing a second platform exceed the social costs thereof, which in this setting are simply equal to sellers' fixed costs of supporting it.

4.3. Platforms can commit, sellers cannot multihome

The first part of the analysis for this case is very similar to the one when neither commitment nor multihoming were feasible. The Bertrand logic prevails and drives profits down to 0. The only difference is that commitment allows both platforms to set the socially optimal royalty rate r^* by committing to $P_1^B = P_2^B = u^B(r^*)$ (they are no longer constrained to $\Phi^B(r_i) \geq 0$). This enables them to offer sellers the maximum total surplus equal to $(1-a)W(r^*) - f$ by charging $P_1^S = P_2^S = -(1-a)\Phi^B(r^*)$.

However, commitment opens up the possibility for a new deviation for either platform 1 or 2. Platform 2 for example can use a divide-and-conquer strategy targetted at buyers by committing to a price $P_2^B = 0$ [22]. Given that buyers do not multihome, this price ensures that all free buyers will go with platform 2 even when all sellers go with platform 1. Thus, the expressions of seller surplus from joining the platforms are changed to:

$$E_1 = au^S(r_1) - P_1^S - f = aW(r^*) + (1-2a)\Phi^B(r^*) - f$$

$$E_2 = (1-a)u^S(r_2) - P_2^S - f$$

The good news for platform 2 is that now it can charge a higher price to sellers, i.e.:

$$P_2^S = (1-a)u^S(r_2) - \max\left(f, aW(r^*) + (1-2a)\Phi^B(r^*)\right)$$

The optimal such deviation is therefore to set $r_2 = r_S$ for profits:

$$\Pi_2^{P\prime} = (1-a)\widehat{\Phi}^S - \max\left(f, aW(r^*) + (1-2a)\Phi^B(r^*)\right)$$

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[22] This is the only novel deviation introduced by the possibility to commit. Indeed, for commitment to the buyer access price to change the pricing game, it is necessary that $P_2^B \leq 0$, otherwise sellers know for sure that if they do not support platform 2, it will not attract any free buyers.

We obtain:

Proposition 5 *When platforms can commit but sellers cannot multihome, a pure strategy pricing equilibrium exists if and only if:*

$$(1-a)\widehat{\Phi}^S \leq \max\left(f, aW(r^*) + (1-2a)\Phi^B(r^*)\right)$$

If it does, then it involves both platforms committing to buyer prices extracting all the surpus from buyers and setting their royalty rates equal to r^* *and seller fixed prices equal to* $-(1-a)\Phi^B(r^*)$. *Platforms make 0 profits and all the available surplus* $(1-a)W(r^*)-f$ *goes to sellers.*■

Thus, unlike in the case when commitment was not feasible, an equilibrium may not exist. The condition for existence says that the maximum total of seller surplus and platform royalty revenues must not be too high, otherwise either platform is tempted to deviate by giving up buyer surplus and extracting seller surplus and royalties. Non-existence is due to the possibility platforms have of shifting surplus from one side to the other when commitment is feasible through two polar divide-and-conquer pricing strategies.

4.4. Platforms can commit, sellers can multihome

As in the no commitment case, we analyze the existence of both an exclusive and a multihoming equilibrium.

a) Exclusive equilibrium

Necessary conditions for exclusivity with platform 1 to be an equilibrium are again

(4.2) and (4.3); by the same argument as above, in equilibrium we must have:

$$E_1 = E_2 \geq \max\left(MH, 0\right)$$

If $r_1 > r^*$ or $\Pi_1^P > 0$ then platform 2 can profitably deviate by committing to $P_2^B = u^B\left(r^*\right)$, setting $r_2 = r^*$ and $P_2^S = \left(1-a\right)u^S\left(r^*\right) - f - E_1 - \varepsilon$. This deviation leads to $E_2 = E_1 + \varepsilon$, so that exclusivity with 1 is a strictly dominated choice for sellers. Depending on whether platform 2 attracts free buyers or not, its profits from the deviation are either:

$$\Pi_2^P = \left(1-a\right)W\left(r^*\right) - f - \varepsilon - E_1 = \left(1-a\right)W\left(r^*\right) - f - \varepsilon - \left(1-a\right)W\left(r_1\right) + f + \Pi_1^P > 0$$

or:

$$\Pi_2^P = \left(1-a\right)u^S\left(r^*\right) - f - \varepsilon - E_1 + a\Phi^B\left(r^*\right) > \left(1-a\right)W\left(r^*\right) - f - \varepsilon - E_1 > 0$$

for ε small enough.

Therefore, in equilibrium it must be that $\Pi_1^P = \Pi_2^P = 0$, platforms commit to $P_1^B = P_2^B = u^B\left(r^*\right)$, $r_1 = r_2 = r^*$ and $P_1^S = P_2^S = -\left(1-a\right)\Phi^B\left(r^*\right)$. This implies that a necessary condition for the equilibrium to exist is $aW\left(r^*\right) + \left(1-2a\right)\Phi^B\left(r^*\right) \leq \gamma f$, which says that sellers have to prefer exclusivity over multihoming (the fixed cost of supporting both platforms is not worth the benefits in terms of additional buyers reached).

However, just like in the previous case, either of the two platforms can deviate by employing a divide-and-conquer pricing strategy targetted at buyers, i.e. committing to a buyer price 0 and then extracting surplus from sellers. This strategy yields deviation profits equal to:

$$(1-a)\,\widehat{\Phi}^S - \max\left(f, aW\left(r^*\right) + (1-2a)\,\Phi^B\left(r^*\right)\right) = (1-a)\,\widehat{\Phi}^S - f$$

when the equilibrium exists[23]. Thus:

Proposition 6 *When platforms can commit and sellers can multihome, an exclusive equilibrium exists if and only if* $aW\left(r^*\right)+(1-2a)\,\Phi^B\left(r^*\right) \leq \gamma f$ and $(1-a)\,\widehat{\Phi}^S \leq f$. *In it both platforms commit to a buyer price equal to* $u^B\left(r^*\right)$, *make 0 profits and set the socially optimal royalty rate* r^*.■

There are two differences between the conditions for existence of this equilibrium and those for the exclusive equilibrium studied previously, when commitment was not feasible. The first one is the second condition which prevents the profitability of the new divide-and-conquer deviation. The second difference is that the condition $aW\left(r^*\right)+(1-2a)\,\Phi^B\left(r^*\right) \leq \gamma f$ is more lax than the socially optimal condition for existence $aW\left(r^*\right) \leq \gamma f$ (this tends to make the exclusive equilibrium exist too often)[24], whereas under no commitment the existence condition was constrained socially optimal, i.e. $aW\left(r_0\right) \leq \gamma f$.

b) Multihoming equilibrium

The same argument as in the analysis of the multihoming equilibrium when commitment was not feasible applies here so we must have:

$$MH = \max\left(E_1, 0\right) = \max\left(E_2, 0\right)$$

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[23] It does not matter whether the deviating platform attracts all sellers exclusively or they multihome, since it has already committed to a buyer price equal to 0, which guarantees it will get all free buyers no matter what.

[24] Recall indeed that $\Phi^B\left(r^*\right) < 0$.

or:

$$\begin{aligned} & au^S(r_1) + au^S(r_2) + (1-2a)\,u^S(r_k) - P_1^S - P_2^S - (1+\gamma)\,f && (4.7) \\ = \; & \max\big((1-a)\,u^S(r_1) - P_1^S - f, 0\big) && (4.8) \\ = \; & \max\big((1-a)\,u^S(r_2) - P_2^S - f, 0\big) && (4.9) \end{aligned}$$

Platform i's profits are:

$$\Pi_i^P = P_i^S + a\Phi^B(r_i) + (1-2a)\,1_{\{i=k\}}\big(P_i^B + r_i n(r_i)\big)$$

where $k = i$ if and only if i attracts all buyers.

Suppose then $k = 1$ and $r_2 > r^*$. Platform 2 can then commit to a price for buyers P_2^B prohibitively high so that it *never* attracts buyers, which implies that regardless of whether sellers sign up exclusively with 2 or continue to multihome, platform 2's profits are $\Pi_2^P = P_2^S + a\Phi^B(r_2)$. Then it can decrease r_2 and adjust P_2^S so that $au^S(r_2) - P_2^S$ stays constant (which implies $MH = (1-a)\,u^S(r_1) + au^S(r_2) - P_1^S - P_2^S - (1+\gamma)\,f$ remains constant) and therefore platform 2's profits strictly increase. In order for this deviation not to be possible we must therefore have $r_2 = r^*$. Consequently, since $\Phi^B(r^*) < 0$, platform 2 has no interest in attracting free buyers, hence, imposing trembling hand perfection requires that in equilibrium platform 2 commits to $P_2^B \geq u^B(r^*)$.

This in turn implies that in equilibrium $P_1^B = u^B(r_1)$ so that platform 1's profits are $\Pi_1^P = P_1^S + (1-a)\,\Phi^B(r_1)$. Then, if $r_1 > r^*$ platform 1 can deviate by decreasing r_1 while keeping $(1-a)\,u^S(r_1) - P_1^S$ constant. This maintains MH constant and platform 1's profits are $P_1^S + (1-a)\,\Phi^B(r_1)$ no matter whether sellers continue to multihome or switch to exclusivity with 1 (exclusivity with 2 is dominated by multihoming since both E_2

and MH remain unchanged). But $P_1^S + (1-a)\,\Phi^B(r_1)$ strictly increases when r_1 decreases and $(1-a)\,u^S(r_1) - P_1^S$ is fixed. Therefore we must also have $r_1 = r^*$.

Finally, we obtain the following two equations determining $\left(P_1^S, P_2^S\right)$ simultaneously:

$$P_1^S = u^S(r^*) - \max\left((1-a)\,u^S(r^*) + \gamma f, P_2^S + (1+\gamma)\,f\right) \tag{4.10}$$

$$P_2^S = u^S(r^*) - \max\left((1-a)\,u^S(r^*) + \gamma f, P_1^S + (1+\gamma)\,f\right) \tag{4.11}$$

The resolution is very similar to that of proposition 4 above[25] and we easily obtain:

Proposition 7 *When platforms can commit and sellers can multihome, a multihoming equilibrium exists if and only if $aW(r^*) \geq \gamma f$. In it both platforms set a royalty rate equal to the socially optimal rate r^* and make positive profits.*■

Note in particular that whenever it exists, this equilibrium cannot be destabilized by a divide-and-conquer pricing strategy targetted at buyers as the exclusive equilibrium could. This is because (4.10) and (4.11) imply $au^S(r^*) - P_i^S \geq \gamma f$ for $i = 1, 2$, which ensures that no platform can deviate and attract sellers exclusively. Also, this time the existence condition for the multihoming equilibrium is socially optimal.

Thus, when commitment to buyer prices is feasible, it is necessarily the preferred strategy for platforms competing under symmetric expectations. In the working paper version we show that no commitment can be preferred when one of the platforms benefits from biased favorable seller expectations over the other. Just like in the monopoly platform case, the nature of seller expectations has an important (and relatively non-intuitive) influence over the pricing and commitment strategies of our platforms.

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[25] The only difference is that now $\Pi_1^P = P_1^S + (1-a)\,\Phi^B(r^*)$ and $\Pi_2^P = P_2^S + a\Phi^B(r^*)$.

5. Conclusion

In this paper we have investigated pricing and commitment strategies by two-sided platforms operating in markets with two interdependent categories of agents, buyers and sellers, where sellers enter the market before buyers. In the case of a monopoly platform, we have shown that if sellers hold favorable expectations, i.e. always coordinate on platform adoption when this is an equilibrium given the prices announced by the platform, commitment to buyer prices at the same time when the platform announces seller prices is a dominant strategy. On the other hand, if seller expectations are unfavorable, i.e. if they coordinate on non-adoption whenever this is an equilibrium, then the platform may sometimes strictly prefer no commitment in order to avoid having to commit to the low buyer prices commitment would require for attracting sellers. An important insight of the model is that when sellers have market power over buyers, platforms find it optimal to charge sellers a negative royalty rate in order to counter that market power and extract the surplus created through fixed fees on both sides of the market.

With competing platforms, under symmetric seller expectations, commitment is always a dominant strategy for both platforms whenever feasible. Commitment also makes the existence of exclusive pricing equilibria less likely by introducing the possibility of an additional divide-and-conquer strategy. It has no bite however in a multihoming equlibrium, provided the latter exists. Moreover, as one would expect in a Bertrand setting with undifferentiated platforms, platform profits are 0 under seller exclusivity, but positive when sellers can multihome.

Although we have analyzed pricing and commitment in a highly stylized model which does not exactly reflect the reality of the industries we have in mind (computer software, videogames, etc.), the issues analyzed are real and the key insights we have drawn are robust to more general formulations. In particular, to the best of our knowledge, this is the first paper to tackle the issue of commitment in certain types of two-sided markets and we believe it is an important concept for research seeking to shed light on these industries. Promising avenues for further research include endogenizing exclusivity and multihoming clauses (for example by allowing platforms to charge different prices to agents who multihome from those who are exclusive), allowing for buyer multihoming and introducing uncertainty about product quality and/or buyer demand.

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6. Appendix

Illustration of assumptions 1-3

In the case in which each seller faces a buyer demand $d(p)$, total surplus has the following expression:

$$W(r) = p(r)\, d(p(r)) + \int_{p(r)}^{\infty} d(\rho)\, d\rho$$

and is clearly a decreasing function of $p(r)$ and hence of r.[26] This is because sellers have monopoly power over buyers and r acts as a marginal cost on sellers, therefore $p(r)$ is decreasing in r. Thus, $W(r)$ is maximized for $r = r^* < 0$, where r^* is uniquely defined by $p(r^*) = 0$. Also, there exists $r^{\max}$ such that $d(p(r)) = 0$ and hence $W(r) = 0$ for $r \geq r^{\max}$.

An intuitive explanation for the requirement that both $\Phi^B(.)$ and $\Phi^S(.)$ are single-peaked is the following. For very low (negative) royalty rates, $u^S(r)$ and $u^B(r)$ are high, however royalty revenue $rd(p(r))$ is low (negative), whereas for r too high, $p(r)$ also becomes too high, so that $u^B(r)$, $u^S(r)$ and $d(p(r))$ are low. Hence $\Phi^B(r)$ and $\Phi^S(r)$ are maximized for some intermediate values of r.

For instance, all 3 assumptions are satisfied for $d(p) = (1-p)^{\theta}$ and we have: $r^* = -\frac{1}{\theta}$, $r^{\max} = 1$, $r_0 = \frac{-\theta}{\theta^2+\theta+1}$, $r_B = \frac{1}{\theta^2+\theta+1}$.

■

Proof of proposition 4 All we have left to do is determine when equations (4.5) and (4.6) have a solution $\left(P_1^S, P_2^S\right)$ satisfying $P_1^S, P_2^S \geq 0$, so that both platforms make

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[26] If the platform incurred a variable cost c per buyer-seller transaction then we would have:

$$W(r) = (p(r) - c)\, d(p(r)) + \int_{p(r)}^{\infty} d(\rho)\, d\rho$$

which is maximized for $r^*(c)$ defined by $p(r^*(c)) = c$. $W(r)$ is then increasing for $r^*(0) \leq r \leq r^*(c)$ and decreasing for $r^*(c) \leq r \leq r^{\max}$.

non-negative profits in equilibrium (since $r_i = r_0$, $\Pi_i^P = P_i^S$, $i = 1, 2$), and to show that no platform can profitably deviate from the the equilibrium defined by $r_2 = r_1 = r_0$, (4.5) and (4.6).

Given the symmetry, there are three cases to consider.

a) $P_1^S = P_2^S = aW(r_0) - \gamma f$. This is a solution to (4.5) and (4.6) yielding non-negative profits for the two platforms if and only if $aW(r_0) \geq \gamma f$ and $(1-2a) W(r_0) \geq (1-\gamma) f$.

b) $P_1^S + P_2^S = W(r_0) - (1+\gamma) f$. This is a solution[27] to (4.5) and (4.6) yielding non-negative profits if and only if $W(r_0) \geq (1+\gamma) f$ and $(1-2a) W(r_0) \leq (1-\gamma) f$.

c) $P_1^S + P_2^S = W(r_0) - (1+\gamma) f$ and $P_2^S = aW(r_0) - \gamma f$, which imply that $P_1^S = (1-a) W(r_0) - f$. This is a solution to (4.5) and (4.6) yielding non-negative profits if and only if $aW(r_0) \geq \gamma f$; $(1-2a) W(r_0) \leq (1-\gamma) f$ and $(1-a) W(r_0) \geq f$, the latter being satisfied by assumption.

From (4.5) and (4.6) we have:

$$P_i^S \leq aW(r_0) - \gamma f = au^S(r_0) - \gamma f$$

for $i = 1, 2$, so that for any deviation by platform i, if platform j maintains its prices unchanged, sellers prefer multihoming to exclusivity with i. Hence no platform can profitably deviate from the equilibrium defined by (4.5), (4.6) and $r_2 = r_1 = r_0$.

Finally, note that since $(1-a) W(r_0) \geq f$ by assumption 4, whenever solution c) exists, solution b) exists as well. Thus, since $(1-2a) W(r_0) \leq (1-\gamma) f$ and $(1-a) W(r_0) \geq f$ imply $aW(r_0) \geq \gamma f$, we have proven that the multihoming equilibrium exists if and only if $aW(r_0) \geq \gamma f$.■

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[27] There is in fact a continuum of solutions here.