MANAGEMENT SCIENCE
Vol. 59, No. 4, April 2013, pp. 933–949
ISSN 0025-1909 (print) | ISSN 1526-5501 (online)

informs®
http://dx.doi.org/10.1287/mnsc.1120.1577

First-Party Content and Coordination in Two-Sided Markets

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The strategic use of first-party content by two-sided platforms is driven by two key factors: the nature of buyer and seller expectations (favorable versus unfavorable) and the nature of the relationship between first-party content and third-party content (complements or substitutes). Platforms facing unfavorable expectations face an additional constraint: their prices and first-party content investment need to be such that low (zero) participation equilibria are eliminated. This additional constraint typically leads them to invest more (less) in first-party content relative to platforms facing favorable expectations when first- and third-party content are substitutes (complements). These results hold with both simultaneous and sequential entry of the two sides. With two competing platforms—incumbent facing favorable expectations and entrant facing unfavorable expectations—and multi-homing on one side of the market, the incumbent always invests (weakly) more in first-party content relative to the case in which it is a monopolist.

Key words: two-sided platforms; platform strategy; technology; first-party content
History: Received October 23, 2011; accepted April 16, 2012, by Bruno Cassiman, business strategy. Published online in *Articles in Advance* September 21, 2012.

Content is king —Bill Gates, 1996

1. Introduction

The software, Internet, and mobile communications revolutions have created information distribution systems of unprecedented efficiency and vast markets for content (e.g., news, entertainment, data, software applications, games, articles, books, music, images, and video). Content is king because many firms use content as in-kind payments to attract customers. Market intermediaries—two-sided platforms—face a challenging coordination problem that consists of attracting both buyers and sellers. Because of cross-market benefits, market participation by buyers and sellers depends on their expectations of participation on the other side of the market.[1] To solve the coordination problem, many two-sided platforms provide content, known as *first-party content*, often for free or as part of a product bundle, which makes participation more attractive to one side (typically, buyers), sometimes independently of the presence of the other side (typically, sellers).

In this paper, we introduce investment in first-party content as a strategic variable for two-sided platforms and show the interplay with the platforms' pricing strategies. The main results of the analysis show how two-sided platforms' first-party content and pricing strategies are determined by two factors: the nature of buyer and seller expectations and the nature of the relationship between first-party content and seller participation.

Examples of platforms supplying first-party content include the following: e-commerce sites (Amazon, eBay, Alibaba) provide market information and customer ratings; search engines and Internet portals (Google, Bing, Yahoo!) provide search results (website links, maps, news, weather, entertainment, books, articles, images, video); social networks such as Facebook provide network information (news feeds, games, digital gifts, email notifications, friend suggestions, information sharing, ability to comment, notifications from fan sites, and virtual currency such as Facebook Credits); video game console manufacturers provide first-party games (Microsoft's Xbox 360 game *Halo*, Sony's Playstation 3 game *Gran Turismo*, Nintendo's *Wii Sports*); smart phone and tablet original equiment manufactureres provide first-party applications and e-commerce information (e.g., Apple's iPhone and iPad apps and App Store); and operating system vendors provide first-party software applications (Microsoft's Windows includes *Internet Explorer* and *Windows Media Player*

[1] Buyers and sellers derive cross-market benefits as a result of product variety and scale effects, market liquidity, and connectivity of communications networks (see Spulber 2010).

and Google's Android includes apps such as *Sky Map*, *Finance*, and *Places Directory*).

Platforms' first-party content is strategically significant because it is either a substitute for or complement to seller participation in buyer demand. First-party content and seller participation tend to be complements when the products and services offered by the platform enhance the value of those provided by sellers. For example, the market information provided by e-commerce platforms such as Amazon, eBay, or Alibaba are complements to the diverse products offered by sellers. Similarly, Microsoft's Xbox Live online gaming system is a complement to third-party developers' games for the Xbox console, in the sense that it enhances those games' value to users. In contrast, first-party content and seller participation tend to be substitutes when the platform's first-party content competes with the products offered by sellers. For example, the first-party games provided by video game console makers are substitutes for the games provided by independent game developers. In these cases, first-party content must provide indirect benefits to sellers through customer attraction that exceed the direct competitive displacement of sellers.

The principal insight of our analysis is that two-sided platform firms follow different content and pricing strategies depending on buyer and seller expectations. Buyer and seller participation in the platform is a coordination game, for which there are typically many Nash equilibria. The use of first-party content as a strategic instrument to induce buyer and seller participation builds on the discussion in Spulber (2010). We further build on the standard notion of unfavorable versus favorable expectations in two-sided markets (Caillaud and Jullien 2003, Hagiu 2006, Halaburda and Yehezkel 2011). If buyers and sellers coordinate on the equilibrium with the highest participation rates given the prices and first-party content chosen by a platform, we say that expectations are *favorable*. Conversely, if buyers and sellers coordinate on the equilibrium with the lowest (or zero) participation rates on both sides, expectations are said to be *unfavorable*.

Platforms facing favorable expectations choose their pricing and content strategy to solve a straightforward profit-maximization problem. However, platforms facing unfavorable expectations have an additional hurdle to overcome: their prices and content need to be such that the zero participation equilibrium is eliminated. With unfavorable expectations, platforms choose between two pricing strategies. The *seller subsidy strategy* compensates sellers to secure their participation irrespective of buyers' decisions and then extracts profits from buyers. The *buyer attraction strategy* charges low prices to buyers to secure sufficient demand even when no sellers join and then extracts rents from sellers. These two pricing strategies are common in practice (see Eisenmann et al. 2006) and standard in most analyses of two-sided platforms.

This has implications for the platform's first-party content strategy. When first-party content and seller participation are complements, the platform facing unfavorable expectations always invests less in content than the platform facing favorable expectations regardless of the pricing strategy. When first-party content and seller participation are substitutes, and the platform facing unfavorable expectations chooses the buyer attraction strategy, it invests more in first-party content than does the platform facing favorable expectations. When first-party content and seller participation are substitutes, and the platform facing unfavorable expectations chooses the seller subsidy strategy, it may still invest more than the platform facing favorable expectations under some conditions.

1.1. Literature Review

Our key contribution is to introduce first-party content as a strategic instrument chosen by two-sided platforms in addition to prices.[2] Accordingly, this paper contributes to the growing strategy and economics literature on two-sided platforms (Caillaud and Jullien 2003, Parker and Van Alstyne 2005, Spulber 2006, Armstrong 2006, Economides and Katsamakas 2006, Eisenmann et al. 2006, Rochet and Tirole 2006, Weyl 2010, Zhu and Iansiti 2012). Our work is related to recent efforts to expand the formal study of two-sided platforms beyond pricing (e.g., Boudreau 2010, Parker and Van Alstyne 2008, who study openness decisions). Our analysis also contributes to the ongoing debate regarding the source of highly skewed two-sided pricing strategies (see Schmalensee 2011 for a survey). In particular, the buyer attraction strategy (seller subsidy strategy) is preferred when first-party content is such that the surplus derived by sellers from the buyers's presence is *high* (*low*) relative to the surplus derived by buyers from sellers' presence. This is consistent with the classic two-sided pricing strategy insight that platforms should charge relatively less to (or even subsidize) the side that cares less about cross-market benefits (see Spulber 1999, Parker and Van Alstyne 2005, Armstrong 2006, Rochet and Tirole 2006, Hagiu 2009, Weyl 2010).

Our paper also adds to previous work on vertical integration into and tying of complements by platforms, in particular Carlton et al. (2010), Farrell

[2] Because of the two-sided platform implications, our analysis differs from research on bundling information goods, including studies of large numbers of information goods (Bakos and Brynjolfsson 1999, Geng et al. 2005, Fang and Norman 2006).

and Katz (2000), and Gawer and Henderson (2007). Our reduced-form model of buyer-seller interactions is consistent with the microfoundations of Carlton et al. (2010) and captures the negative effect of first-party content on sellers with substitute products that they consider. We do not, however, allow for strategic pricing of first-party content, so that first-party content is always "reversibly tied" to the platform in our model. Nor is our model meant to capture the more nuanced organizational mechanisms discussed in Gawer and Henderson (2007), which enable platforms to selectively enter some complementary markets, while still preserving third-party complementor innovation incentives. On the other hand, our model allows for many types of third-party content as opposed to just one, thereby adding genuine two-sidedness to the theoretical analysis of the interactions between platforms and complementors (in contrast to Carlton et al. 2010, Farrell and Katz 2000, and other tying models). Furthermore, our simplified treatment of the effect of first-party content on third-party sellers has the advantage of allowing us to study in a unified framework both the substitutes case and the complements case, the latter of which is novel. Finally, our focus is less on the impact of first-party content on independent complementors. Instead, we are primarily interested in how the relationship between the two (complementarity versus substitutability) affects platform incentives to invest in first-party content under different expectations regimes (favorable versus unfavorable).

The provision of first-party content can also be viewed as a form of diversification by two-sided platforms (see Kim and Kogut 1996). Business strategy studies of platforms have informally discussed the importance of providing first-party content as a tool to get platform adoption off the ground (Evans et al. 2006, Gawer 2009, Gawer and Cusumano 2002). Our formal model allows us to provide a more precise analysis of the role played by first-party content and link it to pricing decisions. Our work also extends the analysis of commitment by two-sided platforms facing sequential entry (Caillaud and Jullien 2003, Hagiu 2006). The insights we obtain here extend this discussion by introducing first-party content and by allowing for heterogeneous buyers.

2. Monopoly Model Setup

A monopoly two-sided platform firm connects a continuum of buyers i uniformly distributed over $[0, 1]$ and a continuum of sellers j uniformly distributed over $[0, M]$. The platform charges participation fees p to buyers and w to sellers. In addition, the platform can offer buyers an amount x of *first-party content.* The firm has costs of providing content $C(x)$, which is increasing and convex in x.[3] The nature of x is discussed in more detail below.

2.1. Buyers and Sellers

Buyers are heterogeneous, and buyer i's net benefit from joining the platform is

$$U_i(m, x, p) = u(m, x) - i - p.$$

The utility function $u(m, x)$ represents buyers' preferences over combinations of first-party content x and *seller participation* m on the platform, $m \in [0, M]$. Seller participation represents the products that sellers provide to buyers. Buyer i incurs a personal cost of adopting the platform equal to i, so that buyers have different willingness to pay for participation. Let the buyer's utility function $u(\cdot, \cdot)$ be increasing, twice continuously differentiable, and concave or linear in each of its arguments. Thus, as is natural, buyer utility is increasing in first-party content and seller products. A buyer joins the platform if and only if her expected net benefit is nonnegative.

Sellers are identical, and each seller's net benefit from joining the platform is

$$V(n, x, w) = \pi(x)n - w - \phi,$$

where $\pi(x) > 0$ is the profit per buyer made by each seller and $\phi > 0$ is a seller's fixed cost of "porting" his product to the platform. Let $n \in [0, 1]$ represent *buyer participatio*n on the platform, which indicates buyer consumption of sellers' products. The function $\pi(\cdot)$ can be increasing or decreasing depending on the relationship between first-party content and seller products, and ϕ is an exogenous parameter. A seller chooses to participate if expected benefits are nonnegative. We assume that ϕ is small enough so that no platform finds it profitable to be simply a content provider to buyers without any sellers, and platforms are profitable under all types of expectations.

2.2. First-Party Content

A key factor in our analysis is the relationship between first-party content, x, and seller participation, m. The nature of the platform determines whether first-party content and seller participation are complements or substitutes. For example, if the firm is an e-commerce, social networking, or matchmaking platform, then first-party content such as market information is usually complementary to seller

[3] We do not model the specific organizational mechanisms that enable a platform firm to acquire the necessary capabilities to provide first-party complements and signal them to the market (see Farrell and Katz 2000, Gawer and Henderson 2007). Nevertheless, $C(x)$ is meant to capture the cost of acquiring those capabilities. In §5 we specifically discuss the impact of this cost on pricing and first-party content strategies.

participation. If the firm is a hardware provider (computers, tablets, game consoles, mobile phones) or an operating system provider, then first-party content such as software applications are usually substitutes for seller participation.

Complementarity or substitutability of x and m is given exogenously. The precise definition of subtitutability and complementarity that we use throughout the paper is as follows:

DEFINITION 1. Content x and seller participation m are strong complements (substitutes) if $\partial^2 u/\partial m\partial x > 0$ and $d\pi/dx \geq 0$ (respectively, if $\partial^2 u/\partial m\partial x < 0$ and $d\pi/dx \leq 0$). They are independent if $\partial^2 u/\partial m\partial x = 0$ and $d\pi/dx = 0$.

Complementarity and substitutability as defined here are stronger notions than the ones commonly used. These terms usually refer to the relationship between x and m in the buyer utility function. As will become clear in the subsequent analysis, the two-sided nature of our setup requires a restriction on seller profit per buyer, $\pi(x)$. For strong complements (substitutes) we only require $d\pi/dx \geq 0$ (≤ 0) instead of strict inequality. Consequently, when sellers' profits per buyer are independent of x, first-party content and seller participation are strong complements (substitutes) if and only if they are strict complements (substitutes) in the usual sense.[4]

Sellers' profits per buyer are *independent* of x if, for example, sellers have an advertising-based business model; the advertising rates they receive per user are unlikely to be influenced by the platform's investments in first-party content. More generally, this would hold whenever sellers are unable to extract the increase in buyer surplus created by first-party content. With independence, first-party content serves only to attract buyers to the platform without affecting the benefits from consuming seller products.

In the three examples that follow, we always have $d\pi/dx = 0$. This restriction is used only for clarity of exposition: our results are stated generally and do not depend on this simplification.

EXAMPLE 1 (CONTENT AND SELLER PARTICIPATION ARE INDEPENDENT). Here, $u(m, x) = ms + x$, $\pi(x) = \pi$ and $C(x) = c(x^2/2)$. In this example, π and s are constants that result from the division of economic surplus created by a product between its seller and each participating buyer.

EXAMPLE 2 (STRONG COMPLEMENTS). Here, $u(m, x) = u_0 + msx$, $\pi(x) = \pi$ and $C(x) = c(x^2/2)$. In this example, u_0 is the (fixed) stand-alone utility offered by the platform to each buyer and seller's profit per buyer is a constant, π. Here, first-party content, x, enhances the value to buyers of seller participation. This can represent market information provided by platform firms.

EXAMPLE 3 (STRONG SUBSTITUTES). Here, $u(m, x) = ms(1 - x) + M_0 sx$, $\pi(x) = \pi$ and $C(x) = c(x^2/2)$. Here, $M_0 > M$ can be interpreted as the total number of product categories (e.g., applications, services) that can be potentially offered on the platform. The platform offers content in each available category (i.e., covers the entire spectrum $[0, M_0]$), each of which is of quality $x \leq 1$. In contrast, each seller offers one product in the range $[0, M]$ and sellers' products are of quality 1. Thus, for each product category, the content offered by the platform is an inferior substitute for the product offered by the corresponding seller. A buyer joining the platform obtains utility sx from each of the M_0 types of content offered by the platform and *additional* utility $s(1 - x)$ from each of the m products offered by sellers (this is consistent with the Carlton et al. 2010 model of reversible tying). Sellers' profits per buyer are constant and equal to π.

Some caveats regarding our modeling setup are in order. First, and most importantly, we have assumed that all buyers's preferences agree on benefits $u(m, x)$. This allows us to characterize differences in platform incentives to invest in first-party content depending on the nature of the relationship between m and x. It is otherwise difficult to find general regularity conditions that would guarantee our results when buyers have different marginal valuations. On the other hand, the assumptions of linear buyer demand (with respect to price) and inelastic seller demand are by no means restrictive: our analysis carries over (with more complicated calculations) to nonlinear buyer and seller demands. Second, we assume that π is independent of seller participation, m. Introducing competition among sellers (i.e., allowing π to be decreasing in m) would make the derivation of the various equilibria (favorable and unfavorable expectations) more difficult, but the nature of content and pricing strategies would remain unchanged.[5] Third, we only allow the platform to charge fixed participation fees on both sides. This turns out to be the richest scenario in our model. If the platform were to charge variable fees (royalties) to sellers instead of or in addition to fixed access fees, the set of its optimal pricing strategies would be identical or strictly smaller, resulting in identical or strictly lower profits. Fourth,

[4] We do not analyze the theoretically possible but unlikely scenarios in which $\partial^2 u/\partial m\partial x$ and $d\pi/dx$ have opposite signs. Although our framework does allow for the analysis of these cases, it seems reasonable to assume that when first-party content is complementary to seller participation in buyer demand, sellers should be no worse off when the platform increases its investment in first-party content (and vice versa with substitutes).

[5] Two-sided platform pricing with competition among members on at least one side has been studied at length elsewhere (see Belleflamme and Toulemonde 2009, Hagiu 2009, Nocke et al. 2007).

for analytical tractability reasons, we do not allow the platform to invest simulataneously in both types of content. Thus, although we can compare the effects of complementarity and substitutability on investment, our model cannot predict how a platform would optimally allocate its investment between the two types of content—statically or over time.

3. Monopoly Platform with Simultaneous Entry

The game with simultaneous entry of buyers and sellers has two stages. First, the profit-maximizing platform chooses the amount of first-party content x, as well as participation prices p and w for buyers and sellers, respectively: (p, w, x) are publicly announced and observed by all players. Second, individual buyers and sellers simultaneously choose whether or not to join the platform, based on the content and prices chosen by the firm and their expectations about total participation by agents on the other side of the market. There is no coordination among buyers or sellers and expectations are *fulfilled* in equilibrium.

The equilibrium of the full game consists of the first-stage choices of the platform, (p^*, w^*, x^*), and the resulting Nash equilibrium of buyer and seller participation decisions in the second-stage subgame, (n^*, m^*). As usual in the presence of network effects, for any vector (p, w, x) of platform choices there can be multiple, self-fulfilled participation equilibria. Indeed, buyer participation $n = n(x, p, w)$ and seller participation $m = m(x, p, w)$ solve the following two equations:

$$n = \max\{u(m, x) - p, 0\},$$

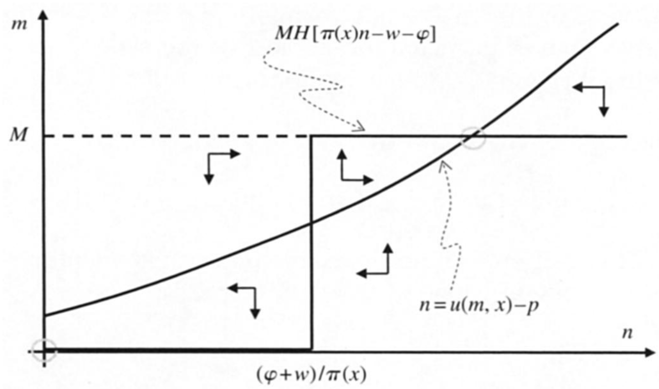
$$m = \begin{cases} M & \text{if } \pi(x)n - w - \phi \geq 0, \\ 0 & \text{if } \pi(x)n - w - \phi < 0. \end{cases}$$

In our model, the concavity of buyer benefits in seller participation and step-function shape of seller benefits in buyer participation narrow the number of possible *stable* equilibria to two: low participation and high participation. Given (p, w, x), the configuration of buyer and seller participation typically looks like Figure 1.

The circles identify the stable equilibria, with arrows indicating dynamic adjustment. Denote the low-participation Nash equilibrium (zero in this case) as the "unfavorable expectations" equilibrium and the high-participation equilibrium as the "favorable expectations" equilibrium—given prices and content (p, w, x).[6]

[6] In our model, there are at most three possible equilibria (n, m) for any triplet (p, w, x) and the highest equilibrium is always stable. Graphically, stability means that the curve $n = n(m, x, p)$ intersects the curve $m = m(n, x, w)$ from above in the (n, m) plane (see Figure 1).

Figure 1 Buyer and Seller Demands Given Prices and First-Party Content



The platform firm's profits are

$$\Pi(p, w, x) = pn(x, p, w) + wm(x, p, w) - C(x).$$

The firm chooses content x and prices p and w to maximize profits given the effects of its actions on the outcome of the participation subgame played by buyers and sellers. Note that content x changes the *shape* of each buyer's net benefit curve $u(m, x) - p$, while the price p simply shifts the net benefit curve up or down without altering its shape.

Even with at most two possible participation equilibria for any given prices and content vector (p, w, x), there can be an infinity of distinct, two-sided demand correspondences that (p, w, x) in participation decisions (m, n). For ease of presentation, we focus our analysis on two polar types of platforms, characterized by two specific demand correspondences:

Definition 2. A platform faces unfavorable expectations (UF platform) if for any (p, w, x), buyers and sellers *always* coordinate on the equilibrium with the lowest possible levels of participation on both sides. In contrast, a platform faces favorable expectations (F platform) if for any (p, w, x), buyers and sellers *always* coordinate on the equilibrium with the highest possible levels of participation on both sides.

Unfavorable expectations describe the problems faced by new entrants without established brands and name recognition. These can be either entrepreneurial firms or large companies entering a new space (e.g., Microsoft's Xbox in 2001). In contrast, *favorable expectations* apply to firms with well-known brands or established platform franchises. In some situations, platforms facing unfavorable expectations can overcome them by using "insulating tariffs" (see Weyl 2010). Nevertheless, they obtain lower profits relative to platforms benefitting from favorable expectations, even though they may be able to achieve the desired "market allocation."

3.1. Favorable Expectations and Profit Maximization

Consider first the F platform. It maximizes profits given buyer participation subject to the sellers' individual rationality (participation) constraint:

$$\max_{p,w,x} \{p[u(M,x)-p]+wM-C(x)\}$$
$$\text{subject to } \pi(x)[u(M,x)-p]-w-\phi \geq 0.$$

The constraint is binding, so the platform's maximization problem becomes

$$\max_{p,x} \Pi^F(p,x) = \max_{p,x} \{[p+M\pi(x)][u(M,x)-p]-C(x)-M\phi\}. \quad (1)$$

The first-order conditions determining the F platform's optimal choices of buyer price and first-party content (p_f, x_f) are

$$p_f = \frac{u(M,x_f)-M\pi(x_f)}{2}$$
$$\frac{[u_x(M,x_f)+M\pi_x(x_f)][u(M,x_f)+M\pi(x_f)]}{2} = C'(x_f), \quad (2)$$

where we have used the notation $u_x(m,x) \equiv (\partial u/\partial x)(m,x)$ and $\pi_x(x) \equiv (d\pi/dx)(x)$.

The price w_f to sellers is set to extract their entire surplus.

3.2. Unfavorable Expectations and Skewed Pricing

To have a chance of making positive profits, the UF platform must set its prices so as to eliminate the unfavorable expectations equilibrium. The corresponding seller participation condition is

$$\pi(x)\max[u(0,x)-p,0]-w-\phi \geq 0,$$

which means that prices must be such that an individual seller finds it profitable to join even when he or she expects the platform will atract no sellers. The resulting platform profits are

$$\max_{p,x}\{p[u(M,x)-p]+M\pi(x)\max[u(0,x)-p,0] - M\phi - C(x)\}. \quad (3)$$

The optimal buyer price p_{uf} and first-party content x_{uf} for the UF platform cannot be such that $u(0,x_{uf}) = p_{uf}$. If this were the case, the optimality of p_{uf} given x_{uf} would require $u(M,x_{uf}) \leq 2u(0,x_{uf})$ and $u(M,x_{uf}) - M\pi(x_{uf}) \geq 2u(0,x_{uf})$, which cannot be satisfied simultaneously. Thus, the buyer benefit from first-party content without seller participation, $u(0,x_{uf})$, is either strictly lower or strictly greater than the buyer price, p_{uf}. This implies that there are only two *possible* solutions to the platform's optimization problem. Depending on parameter values, only one or both of these solutions are feasible. If both are feasible, the platform chooses the one yielding higher profits.

The first possible solution is the *seller subsidy strategy*. This solution, (p_{uf1}, x_{uf1}), is defined by the two first-order conditions:

$$p = \frac{u(M,x)}{2} \quad \text{and} \quad \frac{u_x(M,x)u(M,x)}{2} = C'(x), \quad (4)$$

and must satisfy $p_{uf1} > u(0,x_{uf1})$ to be viable. This implies that the seller price fully subsidizes the sellers' fixed costs, i.e., $w_{uf1} = -\phi$. The platform therefore generates all of its profits from the buyer side of the market. In Figure 1 the seller subsidy strategy eliminates the low-participation equilibrium by moving the seller participation curve, $m = MH[\pi(x)n - w - \phi]$, to the *left*.

The second possible solution is the *buyer attraction strategy*. This solution, (p_{uf2}, x_{uf2}), is defined by

$$p = \frac{u(M,x)-M\pi(x)}{2}$$
$$\frac{[u_x(M,x)-M\pi_x(x)][u(M,x)-M\pi(x)]}{2} + M\pi(x)u_x(0,x) + M\pi_x(x)u(0,x) = C'(x), \quad (5)$$

and must satisfy $p_{uf2} < u(0,x_{uf2})$ to be viable, implying that $w_{uf2} = \pi(x_{uf2})[u(0,x_{uf2}) - p_{uf2}] - \phi$, which is greater than $-\phi$. In other words, the price to buyers is relatively low to ensure that even when each individual seller expects no sellers to join, there is sufficient buyer demand to make it profitable for that seller to join. In Figure 1 this strategy eliminates the low participation equilibrium by moving the buyer participation curve, $n = u(m,x) - p$, to the *right*.

These two solutions correspond to different pricing and content strategies for solving the coordination problem by the UF platform. Both strategies ultimately rely on convincing sellers to join despite unfavorable expectations. With the first strategy, the UF platform subsidizes sellers' fixed costs through a negative w and then charges a high price p to buyers, With the second strategy, it charges a low price p to buyers[7] and a higher price w to sellers.

The existence of these two possible pricing strategies for the UF platform contributes to the ongoing debate regarding the source of highly skewed pricing strategies in two-sided markets. In our model, price skewness is fundamentally driven by unfavorable expectations, in contrast to other models in which

[7] This price need not be a strict subsidy, i.e., it can be positive.

it is driven by the structure of preferences or the nonconcavity of the objective function. Unfavorable expectations create a discontinuity in the UF platform's marginal revenue function with respect to p (at given x), which implies a discontinuous choice between either high p/low w or low p/high w.[8]

3.3. Equilibrium Characterization

We start with an important lemma (proven in the appendix) that characterizes the UF platform's optimal choice of pricing strategies as a function of first-party content.

Lemma 1. *With simultaneous entry of buyers and sellers, the UF platform's optimization problem is equivalent to solving* $\max_x \Pi^{\mathrm{UF}}(x)$, *where*

$$\Pi^{\mathrm{UF}}(x) = \begin{cases} \dfrac{u(M,x)^2}{4} - C(x) - M\phi \\ \qquad \text{if } u(M,x) \geq 2u(0,x) + \dfrac{M\pi(x)}{2}, \\ \dfrac{[u(M,x) - M\pi(x)]^2}{4} + M\pi(x)u(0,x) - C(x) - M\phi \\ \qquad \text{if } u(M,x) \leq 2u(0,x) + \dfrac{M\pi(x)}{2}. \end{cases} \quad (6)$$

The resulting solution is either the seller subsidy strategy, x_{uf1} *(defined in* (4)) *or the buyer attraction strategy,* x_{uf2} *(defined in* (5)).

If first-party content x is such that seller surplus per buyer, $\pi(x)$, is low relative to the surplus derived by buyers from sellers' participation, $u(M,x)$, then the UF platform should choose the seller subsidy strategy (and vice versa). This feature is consistent with the classic two-sided pricing strategy insight that platforms should charge relatively lower prices to (or even subsidize) the side that cares less about the other (see Armstrong 2006, Rochet and Tirole 2006, Hagiu 2009, Weyl 2010). The novelty here is that the choice between the two pricing strategies emerges endogenously through the choice of x.

We are now ready to derive our first main result, which compares platforms' levels of investment in first-party content.

Proposition 1. *If first-party content x and seller participation m are strong complements or independent, then the UF platform invests less in first-party content relative to the F platform regardless of the pricing strategy chosen* ($x_{uf1} < x_f$ *and* $x_{uf2} \leq x_f$). *If x and m are strong substitutes, then* (i) *when the UF platform chooses the buyer attraction strategy, it invests more in x relative to the F platform* ($x_{uf2} > x_f$); *and* (ii) *when the UF platform chooses the seller subsidy strategy, it invests less in x relative to the F platform* ($x_{uf1} \leq x_f$) *if seller profits per buyer are constant or only moderately decreasing in x, otherwise it invests more.*

[8] We are grateful to an anonymous referee for pointing out this aspect of our model.

Table 1 **UF Platform Strategies—Simultaneous Participation**

UF platform strategy	x and m are strong complements	x and m are strong substitutes
Buyer attraction	Lower investment	Greater investment
Seller subsidy	Lower investment	Lower investment/ greater investment

Table 1 summarizes the results in Proposition 1 by taking the perspective of the UF platform relative to the F platform.

The F platform *always* extracts more total surplus from buyers and sellers relative to the UF platform. But what determines investment incentives is the *responsiveness* of total surplus extracted to an additional dollar of investment x, which may be higher with either type of platform. To better understand the underlying mechanism, it is useful to compare platform profits as a function of x. For the UF platform, they are given by expression (6) in Lemma 1. For the F platform, they are derived from expression (1):

$$\Pi^{\mathrm{F}}(x) = \max_x \left\{ \frac{[u(M,x) + M\pi(x)]^2}{4} - C(x) - M\phi \right\}.$$

Let $\Delta(x) \equiv \Pi^{\mathrm{F}}(x) - \Pi^{\mathrm{UF}}(x) > 0$ denote the loss in profitability due to unfavorable expectations. The UF platform chooses a greater (lower) investment in x whenever $\Delta(x)$ is decreasing (increasing).

If the UF platform chooses the buyer attraction strategy, then both the F and UF platforms charge buyers the same price $p(x) = [u(M,x) - M\pi(x)]/2$ and therefore extract the same surplus from buyers. The difference comes from the seller side: The UF platform is constrained by the need to eliminate the "bad" equilibrium. The maximum price it can charge sellers ($w = \pi(x)[u(0,x) - p(x)] - \phi$) reflects unfavorable expectations regarding seller participation and therefore buyer demand. In contrast, the F platform can charge a higher price ($w = \pi(x)[u(M,x) - p(x)] - \phi$), corresponding to the expectation that all sellers participate. The resulting loss in profitability due to unfavorable expectations, $\Delta(x) = M\pi(x)[u(M,x) - u(0,x)]$, is increasing (decreasing) in x when m and x are strict complements (substitutes). In particular, the UF platform invests more in x than the F platform if buyer demand is *more* responsive to first-party content when sellers are *absent* than when they are *present* (and vice versa).

If, on the other hand, the UF platform chooses the seller subsidy strategy, then it completely forfeits any rents from sellers (it subsidizes their fixed cost ϕ) to overcome unfavorable expectations. Instead, it extracts maximum rents from buyers by charging $p^{\mathrm{UF}}(x) = u(M, x)/2$, which is larger than $p^{\mathrm{F}}(x) = [u(M, x) - M\pi(x)]/2$ charged by the F platform. The resulting gap in profits due to unfavorable expectations, $\Delta(x) = M\pi(x)[2u(M, x) + M\pi(x)]/4$, is increasing in x if m and x are strict complements but can be either increasing or decreasing if m and x are strict substitutes. The reason is that the UF platform completely ignores the effect of first-party content on seller surplus (it extracts no surplus from them). Ignoring the *positive* effect of x on buyer demand for sellers ($u(M, x) - p$) tends to lead the UF platform to choose a *lower investment* in first-party content, whereas ignoring the *negative* effect of x on seller profits per buyer $\pi(x)$ tends to lead UF to choose a *greater investment* in x. If substitutability is sufficiently strong, i.e., if $\pi(x)$ is strongly decreasing in x, the latter effect may dominate the former.

Note that, regardless of the pricing strategy chosen by the UF platform, $\pi_x < 0$ (> 0) tends to lead to greater (lower) investment by the UF platform relative to the F platform. This is simply because in all cases the F platform extracts a higher share of seller surplus per buyer $\pi(x)$ relative to the UF platform. The latter is therefore always less responsive to the effect of first-party content on sellers' profits: it chooses a greater investment when first-party content crowds out seller participation and chooses a lower investment when the two are complementary.

4. Monopoly Platform with Sequential Participation Decisions

In many two-sided markets, the platform firm must secure participation of one side of the market before the other. In some markets, the platform firm must secure the participation of sellers for exogenous technological reasons (e.g., video game console manufacturers have to approach independent game publishers one to two years before the planned launch of their systems to allow enough time for game development). In other markets, the platform firm first secures the participation of buyers for strategic reasons (e.g., search firms attract users before obtaining seller advertising). The question is whether inducing sequential participation affects the platform firm's strategic use of first-party content. The discussion of sequential participation in this section provides a set of robustness checks on the basic model with simultaneous participation decisions. We also examine how the platform's commitment ability affects its pricing and content strategies.

Table 2 **Timing with Sequential Participation Decisions**

With commitment	Without commitment
1(a) The platform sets w, p, and x	1(a) The platform sets w and x
1(b) Sellers decide whether or not to participate	1(b) Sellers decide whether or not to participate
2(a) Buyers observe everything and decide whether or not to participate	2(a) Platform observes sellers' decisions and sets p
	2(b) Buyers observe everything and decide whether or not to participate

To address this question, suppose that sellers make their participation decisions before buyers and that buyers can observe the sellers' participation decisions before making their decisions. Because buyers arrive after sellers, the platform has two options: it can either choose to commit (if commitment is feasible) to the price it will charge buyers at the time it announces its price for sellers or it can wait until after sellers have made their adoption decisions and announce its price to buyers afterward (which is, of course, factored in the sellers' decisions). We thus have two possible timings (see Table 2).

For example, video game console makers oftentimes announce their console prices roughly a year before launch at very public events, such as the annual Consumer Electronics Show and the Electronic Entertainment Expo (see Hagiu 2006, Evans et al. 2006). Online search and social network platforms have thus far committed to free services for buyers (e.g., Google, Bing, Facebook). And Amazon announced the Kindle Fire tablet and its \$199 price on September 28, 2011, a month and a half before the device was made available to buyers on November 15, 2011. Developing tablet applications tends to be faster and less costly than creating video games for new consoles. A month and a half provided ample time for third-party content providers to make their Kindle Fire apps ready for launch.

Suppose that the platform is able to make credible commitments. When the platform chooses to commit, let p^c denote the buyer price in stage 1. If the platform does not commit, then in stage 2 it chooses a buyer price $p(m)$ that depends on the number m of sellers who adopt in stage 1:

$$p(m) = \arg\max_{p}\{p[u(m, x) - p]\} = \frac{u(m, x)}{2}.$$

In the commitment scenario, the net profits derived by individual sellers when they adopt are

$$\pi(x)\max[u(m, x) - p^c, 0] - \phi - w.$$

In the no-commitment scenario, individual sellers' net profits when they adopt are

$$\pi(x)[u(m, x) - p(m)] - \phi - w = \pi(x)\frac{u(m, x)}{2} - \phi - w.$$

In both cases, seller profits are directly increasing in the total number m of sellers who participate because that in turn determines total buyer participation on the platform in the second stage. Going from simultaneous to sequential adoption by the two sides has transformed a *two-sided* coordination problem with *indirect* network effects into a *one-sided* coordination problem with *direct* network effects (among sellers). The platform can nevertheless still face favorable or unfavorable expectations.

4.1. Monopoly Problem with Sequential Participation

Consider first the platform facing favorable expectations. In the first stage, all M sellers coordinate on the equilibrium with highest adoption for the platform. In this case, if the F platform commits to p^c, then all M sellers adopt if and only if $w \leq \pi(x)[u(M,x) - p^c] - \phi$. Then the F platform's profits are

$$\max_{p^c,x}\{[\pi(x)M + p^c][u(M,x) - p^c] - C(x) - M\phi\}, \quad (7)$$

which is the same as in the case with simultaneous entry (see (1)).

If, on the other hand, the F platform does not commit to p^c, then sellers anticipate it will charge $p = u(m,x)/2$ in the second period and therefore adopt if and only if $w \leq \pi(x)u(M,x)/2 - \phi$. Thus, the F platform's profits are

$$\max_{x}\left\{\left[\pi(x)M + \frac{u(M,x)}{2}\right]\frac{u(M,x)}{2} - C(x) - M\phi\right\}. \quad (8)$$

It is clear that (7) is larger than (8), i.e., the F platform always prefers to commit. It then obtains the same profits and chooses the same level of investment in first-party content x_f (see (2)) as in the case with simultaneous entry.

Consider now the UF platform. In the first stage, all M sellers coordinate on the equilibrium with lowest adoption for the UF platform. In this case, if the UF platform commits to p^c, then sellers adopt if $w \leq \pi(x)\max[u(0,x) - p^c, 0] - \phi$. Otherwise, no seller adopts. The platform sets w such that this constraint binds, so that its resulting optimization problem is

$$\max_{p^c,x}\{M\pi(x)\max[u(0,x) - p^c, 0] + p^c[u(M,x) - p^c] - C(x) - M\phi\},$$

which is identical to the UF platform optimization in the case with simultaneous entry (see (3)). Just like for the F platform, commitment to the price charged to buyers in the case with sequential entry replicates the outcome of the case with simultaneous entry.

If, on the other hand, the UF platform does not commit to p, then sellers adopt if and only if $w \leq \pi(x)u(0,x)/2 - \phi$, so that the UF platform's optimization problem becomes

$$\max_{x}\left\{M\pi(x)\frac{u(0,x)}{2} + \frac{u(M,x)^2}{4} - C(x) - M\phi\right\}, \quad (9)$$

yielding x_{uf3}, which is the solution to

$$\frac{u_x(M,x)u(M,x)}{2} + \frac{M\pi_x(x)u(0,x) + M\pi(x)u_x(0,x)}{2} = C'(x). \quad (10)$$

Recall that with commitment (just like in the simultaneous entry case), there are only two possible solutions, corresponding to two distinct pricing strategies: one with $p_{uf} > u(0, x_{uf})$ and $w_{uf} = -\phi$ and the other with $p_{uf} < u(0, x_{uf})$ and $w_{uf} = \pi(x)[u(0, x_{uf}) - p_{uf}] - \phi$. But now note that no commitment *always* dominates the first of these strategies. Indeed, when feasible, the latter yields profits equal to $\max_x\{u(M,x)^2/4 - C(x) - M\phi\}$, which is strictly lower than (9). This is understood in the following way: if the platform is to subsidize sellers, it is better not to commit to maintain the flexibility to charge a higher price to buyers, which in turn allows the platform to also charge a higher price to sellers ($w = \pi(x)u(0,x)/2 - \phi$ instead of $w = -\phi$).

Consequently, the only relevant strategy with commitment has $p_c = [u(M,x) - M\pi(x)]/2 < u(0,x)$, yielding profits equal to

$$\max_{x}\left\{M\pi(x)u(0,x) + \frac{[u(M,x) - M\pi(x)]^2}{4} - C(x) - M\phi\right\}. \quad (11)$$

4.2. Equilibrium Characterization

We start with a lemma that summarizes the analysis above regarding optimal commitment strategies for both platforms as a function of first-party content:[9]

LEMMA 2. *Given x and sequential entry, a platform facing favorable expectations always follows a commitment strategy. A platform facing unfavorable expectations follows a commitment strategy if and only if* $u(M,x) - u(0,x) \leq M\pi(x)/2$.

The second part of the lemma results from comparing (11) with (9).

The fact that commitment is always the dominant strategy for the F platform should not be surprising in a monopoly setting. If the platform does not commit, it suffers from a time inconsistency problem: sellers

[9] A version of this result was first proven by Hagiu (2006) in a simpler model. Here, however, our focus is ultimately on the levels of investment in first-party content made by platforms.

correctly anticipate that in the second stage the platform will choose $p = u(M, x)/2$ to maximize its own second stage profits, whereas the optimal buyer price from the first stage perspective is the one that maximizes joint profits, i.e., $p^c = [u(M, x) - \pi(x)M]/2$.

Things are different for the UF platform. Commitment involves giving up the ability to extract higher rents from the buyer side to extract higher rents from the seller side because the platform must commit to a low buyer price to convince sellers to join. This can only be profitable if the surplus that can be extracted from the seller side ($\pi(x)$) is sufficiently large relative to the surplus that can be extracted on the buyer side ($u(M, x) - u(0, x)$).

The UF platform's optimization problem is now equivalent to solving $\max_x \Pi^{\mathrm{UF}}(x)$, where

$$\Pi^{\mathrm{UF}}(x) = \begin{cases} M\pi(x)\dfrac{u(0,x)}{2} + \dfrac{u(M,x)^2}{4} - C(x) - M\phi \\ \qquad \text{if } u(M,x) \geq u(0,x) + \dfrac{M\pi(x)}{2}, \\ M\pi(x)u(0,x) + \dfrac{[u(M,x) - M\pi(x)]^2}{4} - C(x) - M\phi \\ \qquad \text{if } u(M,x) \leq u(0,x) + \dfrac{M\pi(x)}{2}. \end{cases} \tag{12}$$

The resulting solution is either x_{uf3} defined by (9) or x_{uf2} defined in (5). This is similar to the program defined in Lemma 1; but, overall, the UF platform derives higher profits when the two sides arrive sequentially. The reason is that sequential arrival allows the UF platform to extract significant surplus from the side arriving later (buyers) *after* it has secured the participation of sellers. In contrast, when the two sides arrive simultaneously, the UF platform can never afford to charge prices to one side that *assume* the other side will participate.

We are now ready to derive the main result of this section, regarding platforms' investments in first-party content. We assume that second-order conditions hold.

Proposition 2. *With sequential entry, if first-party content and seller participation are strong complements (substitutes), then the UF platform always invests less (more) in first-party content relative to the F platform, i.e.,* $x_{uf2} < x_f$ *and* $x_{uf3} < x_f$ *(respectively,* $x_{uf2} > x_f$ *and* $x_{uf3} > x_f$*).*

The result contained in Proposition 2 is similar to—but cleaner than—the one in Proposition 1 (see Table 3).

The profits extracted by the F platform and those extracted by the UF platform when it chooses the

Table 3 UF Platform Strategies—Sequential Participation

UF platform strategy	x and m are strong complements	x and m are strong substitutes
Buyer attraction (commitment)	Lower investment	Greater investment
Seller subsidy (no commitment)	Lower investment	Greater investment

buyer attraction strategy (which implies commitment) are exactly the same as in the scenario with simultaneous entry, which is why the first rows in Tables 1 and 3 are the same. The key difference arises when the UF platform chooses the "new" seller subsidy strategy (no commitment). It now extracts a larger surplus from sellers ($M\pi(x)u(0, x)/2$) relative to what the seller subsidy strategy yielded under simultaneous entry (0), whereas the surplus extracted from buyers is the same ($u(M, x)^2/4$). As a result, when x and M are substitutes, the incentives to invest in first-party content for the UF platform that chooses to subsidize sellers are now stronger relative to the simultaneous entry case.

5. Examples and Further Interpretation

We now use the specific examples of buyer and seller preferences introduced in §2 to provide further interpretations of the formal results obtained in §§3 and 4, and we relate them to stylized two-sided market facts.

5.1. Examples

Example 1 (Further Interpretation). Let $u(m, x) = ms + x$, $\pi(x) = \pi$ and $C(x) = c(x^2/2)$, where[10] $s > 0$ and $2c > 1$:

- The F platform always chooses $x_f = (M(s + \pi))/(2c - 1)$.
- With simultaneous entry, the UF platform chooses the seller subsidy strategy with $x_{uf1} = (Ms)/(2c - 1) < x_f$ if $c(1 - \pi/(2s)) \geq 1$ and the buyer attraction strategy with $x_{uf2} = (M(s + \pi))/(2c - 1) = x_f$ if $c(1 - \pi/(2s)) \leq 1$.
- With sequential entry, the UF platform chooses the no-commitment (seller subsidy) strategy if $\pi \leq 2s$; it chooses the commitment (buyer attraction) strategy if $\pi \geq 2s$. In both cases, the UF platform sets $x_{uf2} = x_{uf3} = M(s + \pi)/(2c - 1) = x_f$.

Example 2 (Further Interpretation). Let $u(m, x) = u_0 + msx$, $\pi(x) = \pi$ and $C(x) = c(x^2/2)$, where $2u_0 > M\pi$ and $2c > M^2s^2$:

- The F platform always chooses $x_f = Ms(u_0 + M\pi)/(2c - M^2s^2)$.

[10] These conditions ensure concavity of all profit expressions in (p, x), as well as existence and uniqueness of all solutions derived here.

• With simultaneous entry, the UF platform chooses the seller subsidy strategy with $x_{uf1} = Msu_0/(2c - M^2s^2) < x_f$ if $c \leq Ms^2(2u_0M/(2u_0 + M\pi))$ and the buyer attraction strategy with

$$x_{uf2} = \frac{Ms(u_0 - M\pi)}{2c - M^2s^2} < x_f \quad \text{if} \quad c \geq Ms^2\frac{2u_0M}{2u_0 + M\pi}.$$

• With sequential entry, the UF platform chooses the no-commitment (seller subsidy) strategy with $x_{uf3} = (Msu_0/(2c - M^2s^2)) < x_f$ if $c \leq Ms^2(u_0/\pi)$; it chooses the commitment (buyer attraction) strategy with $x_{uf2} = Ms(u_0 - M\pi)/(2c - M^2s^2) < x_f$ if $c \geq Ms^2(u_0/\pi)$.

Example 3 (Further· Interpretation). Let $u(m, x) = ms(1-x) + M_0sx$, $\pi(x) = \pi$ and $C(x) = c(x^2/2)$, where $M_0 > M$ and $2c > (M_0 - M)^2s^2$:

• The F platform chooses $x_f = (M_0 - M)Ms(s + \pi)/(2c - (M_0 - M)^2s^2)$.

• With simultaneous entry, the UF platform chooses the seller subsidy strategy with $x_{uf1} = (M_0 - M)Ms^2/(2c - (M_0 - M)^2s^2) < x_f$ if $c(2s - \pi)/(M_0s^2) \geq 2(M_0 - M)s + 2M\pi$ and the buyer attraction strategy with $x_{uf2} = [(M_0 - M)s + (M_0 + M)\pi] \cdot Ms/(2c - (M_0 - M)^2s^2) > x_f$ if $c(2s - \pi)/(M_0s^2) \leq 2(M_0 - M)s + 2M\pi$.

• With sequential entry, the UF platform chooses the no-commitment (seller subsidy) strategy with $x_{uf3} = [(M_0 - M)s + M_0\pi]Ms/(2c - (M_0 - M)^2s^2) > x_f$ if $c(2s - \pi)/(M_0s^2) \geq (M_0 - M)s + (2M - (M_0/2))\pi$; it chooses the commitment (buyer attraction) strategy with $x_{uf2} = [(M_0 - M)s + (M_0 + M)\pi]Ms/(2c - (M_0 - M)^2s^2) > x_f$ if $c(2s - \pi)/(M_0s^2) \leq (M_0 - M)s + (2M - (M_0/2))\pi$.

First, note that these examples clearly illustrate the results from Propositions 1 and 2. The only cases in which the UF platform invests more in first-party content relative to the F platform is Example 3 (first-party content and third-party products are strict substitutes), either when buyers and sellers enter sequentially or when they enter simultaneously and the UF platform chooses the buyer attraction strategy ($x_{uf1} < x_f < x_{uf3} < x_{uf2}$).

5.1.1. Impact of Content Cost. An important aspect of our analysis is how the content cost parameter, c, impacts the choice of pricing strategy for the UF platform. Content costs can be viewed as the costs of obtaining necessary resources and organizational capabilities (see Farrell and Katz 2000, Gawer and Henderson 2007). In Example 2, the UF platform chooses the seller subsidy strategy or no-commitment strategy when c is *low*. By contrast, in Examples 1 and 3, the UF platform chooses the seller subsidy strategy or no-commitment strategy when c is *high* (assuming $\pi < 2s$ so that both strategies are profitable on nonempty sets of c values).

Consider Example 2. A lower c increases the platform's incentives to invest in first-party content x. Because first-party content and seller participation are strict complements, increasing x also raises buyer benefits from the presence of a seller on the platform (they are equal to sx). On the other hand, a seller's benefits from the presence of a buyer remain unchanged (equal to π). Thus, the *net* effect of an increase in x is to make the buyer side easier to attract *relative to* the seller side. Standard two-sided market logic (see Armstrong 2006, Caillaud and Jullien 2003, Hagiu 2009) implies then that the platform is more likely to focus its subsidization efforts on sellers and extract more profits from buyers; i.e., the platform will choose the seller subsidy strategy or no-commitment strategy. This intuition can be confirmed by plugging $u(m, x) = u_0 + msx$ in expression (6): in this case, the condition for the UF platform to choose the seller subsidy or no-commitment strategy holds for *high* x.

Example 3 is interpreted in a similar way. Because first-party content and third-party products are strict substitutes, a higher x decreases the net benefit obtained by a buyer from the presence of a seller on the platform (it is equal to $s(1 - x)$). Consequently, the *net* effect of a lower c is to make the buyer side *harder* to attract relative to the seller side, which in turn makes the UF platform more likely to choose the buyer attraction or commitment strategy.

5.1.2. Impact of Seller Profits (π). Finally, note that in all three examples, the UF platform is more likely to choose the buyer attraction strategy or commitment strategy over the seller subsidy or no-commitment strategy when π is larger (and vice versa). This is a general result with a standard intepretation in the two-sided market literature: the buyer attraction strategy or commitment strategy involves offering a lower price to the buyer side and extracting more profits from the seller side; therefore, it is naturally more attractive when the benefits that sellers obtain from the presence of buyers are larger.

5.1.3. Impact of Buyer Stand-Alone Utility (s, u_0 or M_0). Conversely, the seller subsidy strategy or no-commitment strategy should be more attractive when buyers' stand-alone utilities, or the benefits they derive from the presence of sellers, are larger. This is indeed the case in Examples 1 and 2: the seller subsidy strategy or no-commitment strategy is more likely to be chosen when s (Example 1) and u_0 (Example 2) are larger. In Example 3, however, the seller subsidy strategy or no-commitment strategy is more likely to be chosen for *lower* M_0. This is somewhat surprising given that M_0 can be interpreted as a measure of stand-alone utility offered to buyers: one would expect that higher M_0 should make buyers easier to attract and therefore make the platform more likely to subsidize sellers. The reason this intuition breaks down is the presence of first-party content x, which changes the platform's optimal strategy in subtle ways. An increase in M_0 raises the effectiveness of investments in x, which means the platform has stronger incentives to invest in first-party content. But given the substitutability with third-party products, higher x decreases the *net* benefits obtained by buyers from the presence of sellers (they are equal to $(1-x)s$) on the platform. Because seller benefits from the presence of buyers remain unchanged (equal to π), this means that the *net* effect of an increase in M_0 is to make the buyer side harder to attract *relative to* the seller side. Standard two-sided market logic implies then that the platform is more likely to focus its subsidization efforts on the buyer side, i.e., to choose the buyer attraction strategy or commitment strategy.

5.2. Interpretation

The results summarized in Tables 1 and 3 have implications for the evolution of two-sided platforms over time. Our discussion here applies to contexts in which a platform's technology and corresponding market expectations can be viewed as evolving exogenously over several generations. This implies that the platform can be modeled as making a series of static strategy decisions. Additional struture would be needed to fully characterize a dynamic strategy. Our analysis is meant to explain why a platform firm might change its investment in first-party content in different generations of the technology. In practice, generations of technology are observed for e-commerce, communications, hardware, and software platforms.

According to our results, in markets with sequential entry, when expectations change from unfavorable to favorable in later generations, a platform should increase (decrease) its investments in first-party content from the earlier to the later generation if first-party content and seller participation are strong complements (strong substitutes).

A good illustration is provided by the video game industry, where console manufacturers (Microsoft, Nintendo, and Sony) sell their consoles at or below cost and derive most of their profits from royalties charged to game developers. Throughout the history of video games, every new entrant in the industry has made significant investments in first-party games just before the launch of their first console: Nintendo in the United States in 1985, Sega in 1988, Sony in 1994, Microsoft in 2001. These investments took the form of either in-house development (Nintendo and Sega) or acquisition of independent development studios (Microsoft and Sony). The evolution of Microsoft's in-house game development studios is particularly interesting. The company made two big acquisitions around the launch of the first Xbox, when it arguably suffered from strongly unfavorable expectations from market participants: It bought Bungie (developer of the highly popular *Halo* franchise) in 2000 and then Rare, another strong development studio, in 2002. Interestingly enough, Rare was 49% owned by Nintendo at the time of the Microsoft acquisition. This illustrates the fact that Nintendo—an established platform player at the time—had less value for Rare as a first-party content provider than Microsoft, the new platform entrant. Microsoft did not make any such high-profile acquisitions for the launch of the Xbox 360 in 2005, partly because its ownership of Bungie and Rare already guaranteed the availability of strong first-party content and partly because by 2005 the Xbox platform was clearly established as a major contender. In fact, Microsoft started disbanding or divesting some of its in-house development studios after 2005. Most remarkably, it divested Bungie in 2007 and, although Microsoft maintained a close relationship with the studio, the latter would reportedly gain the ability to publish games for competing platforms (Romano 2007).[11] At the same time, however, Microsoft ramped up its investments in complements to the Xbox: It acquired an in-game advertising company in 2006, then formed in-house software development studios for its online gaming portal Xbox Live in 2008 and for its motion-sensing controller Kinnect in 2009 (Microsoft News Center 2006, *Edge* 2008, *Gamers Daily News* 2009). In fact, Xbox Live and Kinnect can also be viewed (to some extent) as two-sided platforms on their own. They are highly complementary to the Xbox console, but each had to solve its own two-sided adoption problem: users must be convinced to subscribe to the Xbox Live service and to buy the Kinnect controllers, and developers must be convinced to write games compatible with Xbox Live and Kinnect.

Another illustration is Apple's successive iPhone generations. The first iPhone, launched in 2007, relied exclusively on Apple's first-party applications. Apple opened the iPhone to third-party developers in 2008, when it also launched its App Store, which made it easy for developers to distribute their applications to users. In subsequent product generations, as the iPhone became established as a leading smartphone platform, Apple shifted its focus from first-party applications toward investments that help third-party developers. A significant event occurred in November 2011, when Apple discontinued its popular Texas Hold'em iPhone game. As pointed out by Lane (2011),

[11] Part of the reason for this divestiture was increasing friction due to organizational culture differences between Bungie and its much larger (and bureaucratic) parent company. Presumably these frictions had existed from the beginning, but they had been outweighed in importance by Microsoft's need for strong first-party content. By 2007, the cost-benefit balance of keeping Bungie in-house had changed.

> [I]nstead of developing its own games, Apple has chosen to concentrate on its iOS ecosystem and the App Store where third-party developers can make their own blockbuster titles, like "Angry Birds," "Plants vs. Zombies," and "Flight Control." Apple has supported its developers with Game Center, a social networking service that lets users track their friends' progress in titles and even play games against each other head-to-head online.

These stylized facts lend some support to the formal results derived from our model. Still, the interpretation remains subject to the caveat mentioned in our modeling setup: our model does not allow platforms to choose the nature of first-party content—substitute or complement, therefore it cannot predict the optimal mix of the two types of content (statically or dynamically).

Our formal analysis also helps provide an answer to the question posed by Carlton et al. (2010) regarding why a platform would bundle content that no one uses, in particular Microsoft's *Windows Media Player*. Microsoft first introduced its *Media Player* application as part of Windows 3.0 in 1990, but then reduced its support as competing products such as *Adobe Flash Player* became widely adopted. This evolution is consistent with the prediction of our analysis that the initial introduction of *Media Player* was a first-party investment designed to increase customer and developer adoption of the Windows platform. Indeed, as pointed out by Ward (2008),

> The various versions of Windows 3.x (including 3.11) released in the early 1990s, were the first of Microsoft's graphical user interfaces to win huge worldwide success. They helped Microsoft establish itself and set the trend for how it makes its revenues, and what drives the company until the present day.

Having established Windows and earned favorable expectations for later generations, Microsoft could afford to reduce its investment in supporting applications such as *Media Player*, leaving them to specialized third-party firms.

6. Competition Among Homogeneous Platforms

In this section, we examine platform competition between an incumbent (I) and an entrant (E). Each platform chooses (p_k, w_k, x_k), where $k = \{I, E\}$. If both platforms faced the same kind of user expectations, they would engage in Bertrand competition, which would lead to zero profits. We therefore focus on the more interesting case in which the incumbent faces favorable expectations and the entrant faces unfavorable expectations. Suppose that buyers and sellers make simultaneous participation decisions. Market participants always coordinate on the equilibrium that maximizes adoption on both sides for I and minimizes adoption for E (see Caillaud and Jullien 2003, Hagiu 2006). We analyze two alternative scenarios: in the first one, sellers join at most one platform (single-home) and buyers can join both platforms (multi-home); in the second one, buyers single-home and sellers multi-home. The outcome when both sides single-home does not add any further insights. The detailed treatment is available upon request from the authors.

6.1. Sellers Single-Home and Buyers Multi-Home

Suppose first that sellers can only join one platform at most, whereas buyers may join both. Buyer i joins platform $k \in \{I, E\}$ if and only if $u(m_k^e, x_k) - p_k - i \geq 0$, where m_k^e is the expected number of sellers who join k and, as in the monopoly section, i is uniformly distributed over $[0, 1]$. A seller who joins platform $k \in \{I, E\}$ obtains a payoff $\pi(x_k)n_k^e - w_k - \phi$, where $n_k^e = u(m_k^e, x_k) - p_k$ is the expected number of buyers who join k. All M sellers are identical, therefore they all make the same platform adoption decision: they join the platform $k \in \{I, E\}$ which offers the higher payoff (we assume they join I if indifferent). The following proposition (proven in the appendix) characterizes the competitive outcome for this scenario:

Proposition 3. *When sellers single-home and buyers multi-home, the incumbent keeps the entrant out of the market and makes the same investment in first-party content as if it were a monopolist facing favorable expectations.*

Note that unlike the monopoly analysis, this result does not depend on complementarity or substitutability between first-party content and seller participation. It is because here competition between the entrant and the incumbent focuses on attracting sellers (buyers multi-home). Indeed, the incumbent can simply discount w_I by a fixed amount to prevent sellers from joining E. A good example of this situation is the competition in search between the incumbent, Google, and the entrant, Microsoft's Bing. Google benefits from favorable expectations regarding its significant market share and Bing, correspondingly may face unfavorable expectations. Google invests in improving the content of its search results as a way to retain search users (e.g., buyers) as a means of attracting advertisers (e.g., sellers) who might otherwise switch to Bing. Although large advertisers tend to multi-home, smaller specialized advertisers may single-home to take advantage of the market share of larger search providers for specialized keywords.

This has interesting policy implications (for a discussion of antitrust in Internet search markets, see Spulber 2009, Alexandrov et al. 2011). Suppose that the incumbent firm were to merge with or acquire the prospective entrant, making the incumbent a monopolist. In evaluating such a merger or acquisition, the proper comparison would be between the market outcome with competing firms and with a monopolist that faces favorable expectations. The merger or acquisition would have no effect on the incumbent's investment in first-party content or the buyer price. So, when sellers single-home and buyers multi-home, such a merger or acquisition need not raise antitrust concerns. The outcome differs when competition focuses on buyers as the next section shows.

6.2. Buyers Single-Home and Sellers Multi-Home

Suppose now that buyers single-home whereas sellers multi-home. Buyers of video games may tend to single-home because of the costs of purchasing a game console, whereas sellers of video games may multi-home by making games for multiple formats. Buyers also are likely to single-home with music players, mobile phones, and tablet computers.

Buyer i's utility from joining platform k is $u(m_k^e, x_k) - p_k - i$. A seller who joins platform $k \in \{I, E\}$ obtains payoffs $\pi(x_k)n_k^e - w_k - \phi$, whereas a seller who multi-homes obtains payoffs $[\pi(x_E)n_E^e + \pi(x_I)n_I^e] - w_E - w_I - 2\phi$. The following proposition (proven in the appendix) characterizes the competitive outcome for this scenario:

PROPOSITION 4. *When buyers single-home and sellers multi-home, the incumbent firm facing entry invests more in first-party content than when it faces no competition.*

Thus, in contrast to the previous scenario, competitive pressure from the entrant induces higher investments in first-party content by the incumbent. This is because competition is for buyers (sellers multi-home), which means the incumbent has to offer higher net utility to buyers than it would if it were a monopolist. Because buyer net utility is increasing in x, the result follows. Once again, note that the result does not depend on whether first-party content and seller participation are complements or substitutes.

7. Conclusion and Managerial Implications

Our study of two-sided platforms' incentives to invest in first-party content has yielded several important insights that should be of managerial interest. First, the strategic use of first-party content is determined by its relationship with sellers' products and the type of expectations faced by the platform. Two-sided platforms facing unfavorable expectations use first-party content not only as a third strategic variable to maximize profits (in addition to prices), but also as a way to satisfy the additional constraint they face relative to platforms facing favorable expectations: eliminate low participation equilibria. As a result, platforms facing unfavorable expectations may end up investing more or less in first-party content, depending on whether it is substitutable or complementary to seller participation and on the pricing strategy chosen.

Second, by distinguishing between complementary and substitutable first-party content, managers should be better able to adjust both content and pricing strategies. If first-party content and seller participation are substitutes (complements), then larger investments in first-party content decrease (increase) the benefits derived by buyers from the presence of sellers, so the platform should charge less to buyers (sellers) and make more profits from sellers (buyers).

Our results hold for monopoly platforms, both under simultaneous and under sequential entry of the two sides, i.e., when sellers arrive before buyers. In the latter scenario, our analysis yields an additional, important implication for practitioners. Two-sided platforms facing favorable expectations should *always* commit to the price charged to the side arriving later (buyers) at the time they are courting the side arriving earlier (sellers). In contrast, platforms facing unfavorable expectations should commit only if the surplus derived by sellers from trading on the platform is sufficiently large relative to the surplus derived by buyers.

Comparing the competitive outcome with the monopoly platform that faces favorable expectations has implications both for platform strategy and for antitrust policies toward mergers and acquisitions among platform firms. From a strategy perspective, incumbent platforms need not invest more in first-party content when they face more competition: they can keep entrants out and maintain positive profits simply by adjusting their pricing structure. This is true when sellers single-home and buyers multi-home. The competition policy implication is that, in this case, a merger between the incumbent and the entrant need not raise antitrust concerns because it would have no effect on the incumbent's investment in first-party content or the buyer price. If, on the other hand, buyers single-home and sellers multi-home, the incumbent platform always invests more when it faces competition than it does when it is an unconstrained monopolist. Then, the merger considered earlier could raise antitrust concerns because the incumbent firm would reduce investments in first-party content and raise buyer prices.

Acknowledgments

The authors are grateful to Ramon Casadesus-Masanell, three anonymous referees, and participants at the Second Annual Conference on Internet Search and Innovation (Northwestern Law School) for very helpful comments and feedback.

Appendix. Proofs

Proof of Lemma 1. Fix x. For $p \geq u(0,x)$, the expression of platform profits is

$$\Pi_1(p,x) = p[u(M,x)-p] - M\phi - C(x),$$

which attains its maximum in p at $p_1(x) = u(M,x)/2$.

For $p \leq u(0,x)$, the expression of platform profits is

$$\Pi_2(p,x) = p[u(M,x)-p] + M\pi(x)[u(0,x)-p] - M\phi - C(x),$$

which attains its maximum in p at $p_2(x) = [u(M,x) - M\pi(x)]/2 < p_1(x)$.

There are thus three possibilities:

- If $u(M,x) < 2u(0,x)$, then the platform's optimal choice of p is $p_2(x)$.
- If $u(M,x) > 2u(0,x) + M\pi(x)$, then the platform's optimal choice of p is $p_1(x)$.
- If $2u(0,x) \leq u(M,x) \leq 2u(0,x) + M\pi(x)$, then the platform's optimal choice of p is $p_1(x)$ if $\Pi_1(p_1(x),x) \geq \Pi_2(p_2(x),x)$ and $p_2(x)$ otherwise.

But $\Pi_1(p_1(x),x) \geq \Pi_2(p_2(x),x)$ is equivalent to $u(M,x) \geq 2u(0,x) + M\pi(x)/2$. Thus,

$$\Pi(x) = \begin{cases} \dfrac{u(M,x)^2}{4} - C(x) - M\phi \\ \quad \text{if } u(M,x) \geq 2u(0,x) + \dfrac{M\pi(x)}{2}, \\ \dfrac{[u(M,x) - M\pi(x)]^2}{4} + M\pi(x)u(0,x) - C(x) - M\phi \\ \quad \text{if } u(M,x) \leq 2u(0,x) + \dfrac{M\pi(x)}{2}. \end{cases}$$

The only thing left to verify is that the corner solution x_0 defined by $u(M,x_0) = 2u(0,x_0) + M\pi(x_0)/2$ cannot maximize $\Pi(x)$ unless x_0 is a maximizer of $\Pi_1(p_1(x),x)$ or $\Pi_2(p_2(x),x)$; i.e., $x_0 = x_{uf1}$ (defined in 4) or $x_0 = x_{uf2}$ (defined in 5). Suppose by contradiction that x_0 maximizes $\Pi(x)$ but $x_0 \neq x_{uf1}$ and $x_0 \neq x_{uf2}$. Then the first derivatives of $\Pi_1(p_1(x),x)$ and $\Pi_2(p_2(x),x)$ in x evaluated at x_0 must have opposite signs. There are two possibilities:

1. Either

$$\frac{[u_x(M,x_0) - M\pi_x(x_0)][u(M,x_0) - M\pi(x_0)]}{2} + M\pi(x_0)u_x(0,x_0) + M\pi_x(x_0)u(0,x_0) - C'(x_0) > 0 \quad \text{and}$$

$$\frac{u_x(M,x_0)u(M,x_0)}{2} - C'(x_0) < 0.$$

Subtracting the first from the second inequality and rearranging, we obtain

$$\frac{\pi(x_0)}{2}\left[u_x(M,x_0) - 2u_x(0,x_0) - \frac{M\pi_x(x_0)}{2}\right] + \frac{\pi_x(x_0)}{2}\left[u(M,x_0) - 2u(0,x_0) - \frac{M\pi(x_0)}{2}\right] < 0.$$

But note that the left-hand side is the derivative in x of $(\pi(x)/2)[u(M,x) - 2u(0,x) - M\pi(x)/2]$ evaluated at x_0. This means that $(\pi(x)/2)[u(M,x) - 2u(0,x) - M\pi(x)/2]$ is decreasing in x for all x smaller than but sufficiently close to x_0. In turn, this implies that $u(M,x) - 2u(0,x) - M\pi(x)/2 > 0$ for all such x, so that $\Pi(x) = \Pi_1(p_1(x),x)$. But then, because x_0 is a maximizer of $\Pi(x)$, the derivative of $\Pi_1(p_1(x),x)$ in x evaluated at x_0 must be nonnegative, i.e., $(u_x(M,x_0)u(M,x_0))/2 - C'(x_0) \geq 0$, which is a contradiction.

2. Or

$$\frac{[u_x(M,x_0) - M\pi_x(x_0)][u(M,x_0) - M\pi(x_0)]}{2} + M\pi(x_0)u_x(0,x_0) + M\pi_x(x_0)u(0,x_0) - C'(x_0) < 0 \quad \text{and}$$

$$\frac{u_x(M,x_0)u(M,x_0)}{2} - C'(x_0) > 0.$$

Using the exact same reasoning as for the previous case and focusing on x larger than but sufficiently close to x_0, we obtain once again a contradiction. □

Proof of Proposition 1. Assume that x_f, x_{uf1}, and x_{uf2} are uniquely defined. Compare then the first-order condition determining x_f (Equation (2)) with the one determining x_{uf2} (Equation (5)), the investment in first-party content by the UF platform when it chooses the buyer attraction strategy. Specifically, let us plug x_{uf2} instead of x_f in (2) taking (5) into account

$$\frac{[u_x(M,x_{uf2}) + M\pi_x(x_{uf2})][u(M,x_{uf2}) + M\pi(x_{uf2})]}{2} - C'(x_{uf2})$$
$$= M\{\pi(x_{uf2})[u_x(M,x_{uf2}) - u_x(0,x_{uf2})] + \pi_x(x_{uf2})[u(M,x_{uf2}) - u(0,x_{uf2})]\}.$$

If x and m are strong complements (strong substitutes), then the last expression is positive (negative) because $u_x(M,x) - u_x(0,x) > 0$ (< 0) and $\pi_x \geq 0$ (≤ 0). Therefore, if x and m are strong complements (strong substitutes), then $x_{uf2} < x_f$ ($x_{uf2} > x_f$). If they are independent, then $x_{uf2} = x_f$.

Similarly, compare (2) with (4), and let us plug x_{uf1} instead of x_f in (2) taking (4) into account

$$\frac{[u_x(M,x_{uf1}) + M\pi_x(x_{uf1})][u(M,x_{uf1}) + M\pi(x_{uf1})]}{2} - C'(x_{uf1})$$
$$= \frac{M}{2}\{\pi(x_{uf1})u_x(M,x_{uf1}) + \pi_x(x_{uf1})[u(M,x_{uf1}) + M\pi(x_{uf1})]\}.$$

If x and m are strong complements or independent, then the last expression is positive, so that $x_{uf1} < x_f$. If, on the other hand, x and m are strong substitutes, then the sign of the last expression is ambiguous. Clearly, if $\pi_x(x)$ is equal to 0 or sufficiently small for all x, then the last expression remains positive, so $x_{uf1} \leq x_f$. Otherwise, it is possible that the expression is negative, so that $x_{uf1} > x_f$. □

Proof of Lemma 2. If x is such that $u(M,x) \geq 2u(0,x) + M\pi(x)/2$, then we know from Lemma 1 and expression (9) that the platform's profits with commitment are strictly lower than the profits without commitment. Suppose then that x is such that $u(M,x) \leq 2u(0,x) + M\pi(x)/2$. Then the profits obtained by the platform when it commits are higher than when it does not commit if and only if

$$\frac{[u(M,x) - M\pi(x)]^2}{4} + M\pi(x)u(0,x) \geq M\pi(x)\frac{u(0,x)}{2} + \frac{u(M,x)^2}{4},$$

which is equivalent to

$$\frac{M\pi(x)}{2} \geq u(M,x) - u(0,x).$$

Note that this last inequality holds only if $u(M,x) \leq 2u(0,x) + M\pi(x)/2$ holds, which leads to expression (12) in the text of the lemma.

As in Lemma 1, we need to verify that the corner solution x_0 defined by $u(M,x_0) = u(0,x_0) + M\pi(x_0)/2$ cannot maximize $\Pi(x)$ unless x_0 is a maximizer of $[u(M,x) - M\pi(x)]^2/4 + M\pi(x)u(0,x) - C(x)$ or of $M\pi(x)(u(0,x)/2) + u(M,x)^2/4 - C(x)$, i.e., $x_0 = x_{uf2}$ (defined in (5)) or $x_0 = x_{uf3}$ (defined in (10)). This part of the proof is identical to Lemma 1 (reasoning by contradiction); therefore, we omit it here. □

Proof of Proposition 2. The comparison of x_{uf2} with x_f is unchanged from the case with simultaneous entry (Proposition 1).

Here, $x_{uf3} < x_f$ if and only if the first-order condition determining x_f (2) evaluated at x_{uf3} is positive, i.e., if and only if

$$\frac{[u_x(M,x_{uf3}) + M\pi_x(x_{uf3})][u(M,x_{uf3}) + M\pi(x_{uf3})]}{2} - C'(x_{uf3}) > 0,$$

which is equivalent to

$$\pi_x(x_{uf3})[M\pi(x_{uf3}) + u(M,x_{uf3}) - u(0,x_{uf3})] + \pi(x_{uf3})[u_x(M,x_{uf3}) - u_x(0,x_{uf3})] > 0.$$

If x and m are strong complements, the last inequality holds strictly ($\pi_x \geq 0$ and $u_x(M,x) - u_x(0,x) > 0$), so $x_{uf3} < x_f$. If, on the other hand, x and m are strong substitutes, the opposite inequality holds strictly, so $x_{uf3} > x_f$. Finally, when x and m are independent ($\pi_x = 0$ and $u_x(M,x) - u_x(0,x) = 0$), the inequality becomes an equality so $x_{uf3} = x_f$. □

Proof of Proposition 3. At a minimum, even if no sellers join E, it still attracts $\max[u(0,x_E) - p_E, 0]$ buyers (because they multi-home), in which case E can make $\Pi_0^E \equiv \max_{x_E}\{u(0,x_E)^2/4 - C(x_E)\}$. The only way in which E might do better is by attracting the M sellers, which requires

$$\pi(x_E)\max[u(0,x_E) - p_E, 0] - w_E - \phi \geq \pi(x_I)[u(M,x_I) - p_I] - w_I - \phi \equiv \pi_I.$$

By setting its prices and investment in first-party content to just satisfy this constraint, E can obtain

$$\max_{p,x}\{p[u(M,x) - p] + M\pi(x)\max[u(0,x) - p, 0] - C(x) - M\phi - M\pi_I\} \equiv \Pi^E - M\pi_I,$$

which is almost identical to expression (3) of monopoly platform profits under unfavorable expectations. The only difference is the constant factor ($-M\pi_I$), which has no impact on E's choices of (p,x). To render this stratey by E unprofitable, I must set (p_I, x_I, w_I) such that $M\pi_I \geq \Pi^E - \Pi_0^E$, which ensures that E prefers to attract buyers only or to stay out of the market. The incumbent I's profits are then

$$\max_{p_I,x_I}\{[p_I + M\pi(x_I)][u(M,x_I) - p_I] - C(x_I) - (\Pi^E - \Pi_0^E)\},$$

which is identical to the optimization problem (1) for a monopoly platform facing favorable expectations. The difference is a constant factor that has no impact on I's optimal choices of (p,x). □

Proof of Proposition 4. The entrant E sees zero adoption by buyers and sellers whenever $w_E > -\phi$ and $u(0,x_E) - p_E < \max\{0, u_I\}$, where we denote $u_I \equiv u(M,x_I) - p_I$ the net utility offered to buyers by I. Thus, the only ways in which E can break into the market are to set $w_E \leq -\phi$ or $p_E \leq u(0,x_E) - u_I$.

If E charges $w_E = -\phi$, then all sellers join E regardless of whether they join I or not. The entrant E obtains

$$\Pi_1^E = \max_{p_E,x_E}\{p_E[u(M,x_E) - p_E] - M\phi - C(x_E)\}$$
$$\text{subject to } u(M,x_E) - p_E \geq u_I.$$

If E charges $p_E \leq u(0,x_E) - u_I$, then all buyers who enter choose E even if all sellers join I only. The entrant E obtains

$$\Pi_2^E = \max_{p_E,x_E}\{[p_E + \pi(x_E)M][u(M,x_E) - p_E] - M\phi - C(x_E)\}$$
$$\text{subject to } u(0,x_E) - p_E \geq u_I.$$

The entrant E chooses the best of the two options, so that its profits are $\Pi^E = \max(\Pi_1^E, \Pi_2^E)$. Note that Π^E is nonincreasing in u_I because both Π_1^E and Π_2^E are nonincreasing in u_I (the two constraints above must be binding, otherwise E would be able to profitably enter). And, because $C(\cdot)$ is increasing and $u(\cdot,\cdot)$ is increasing in both of its arguments, there exists $\bar{u} \geq 0$ such that $\Pi^E \leq 0$ if and only if $u_I \geq \bar{u}$. Therefore, platform I solves

$$\max_{u_I,x_I}\{[u(M,x_I) - u_I + M\pi(x_I)]u_I - C(x_I) - M\phi\} \quad \text{subject to } u_I \geq \bar{u}. \tag{13}$$

Denote by $x_I(u)$ the incumbent's optimal choice of x_I given its choice of u_I, so that $x_I(u_I)$ solves

$$u_I[u_x(M,x) + M\pi_x(x)] - C'(x) = 0.$$

Assuming the optimization problem is concave, $x_I(u)$ is increasing in u. If I were an unconstrained monopolist, it would choose

$$u_I^* = \arg\max_u\{[u(M,x_I(u)) - u + M\pi(x_I(u))]u - C(x_I(u))\}.$$

By contrast, when I is constrained by E's presence, its choice u_I^C is the solution in u_I to (13), which implies $u_I^C \geq u_I^*$ and therefore $x_I(u_I^C) \geq x_I(u_I^*)$. □

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