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Mixed Bundling in Two-Sided Markets in the Presence of Installed Base Effects

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We analyze mixed bundling in two-sided markets where installed base effects are present and find that the pricing structure deviates from traditional bundling as well as the standard two-sided markets literature—we determine prices on both sides fall with bundling. Mixed bundling acts as a price discrimination tool segmenting the market more efficiently. Consequently, as a by-product of this price discrimination, the two sides are better coordinated, and social welfare is enhanced. We show unambiguously that platform participations increase on both sides of the market. After theoretically evaluating the impact mixed bundling has on prices and welfare, we take the model predictions to data from the portable video game console market. We find empirical support for all theoretical predictions.

Key words: mixed bundling; two-sided markets; installed base; video game industry

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1. Introduction

The practice of mixed bundling consists of selling two or more separate products together with a discount, in addition to selling them individually. Mixed bundling is commonly used in the technology and media industries where two-sided market structures are prevalent, both in bundling hardware with software and in bundling different software products. Moreover, many of these markets exhibit the characteristic where the purchase of one product leads to the potential demand for another complementary product. For instance, consider Sony, the originator of the Blu-ray player and owner of a movie production studio, or Nintendo, designer of both video game hardware and software. Each of these examples exhibits the characteristic where the purchase of hardware leads to an installed base of consumers who will purchase future software. In these scenarios, Sony and Nintendo can price the hardware (Blu-ray player or console) and the software (DVD or video game) separately in an attempt to maximize combined profit. Alternatively, they can practice mixed bundling in which they sell two or more separate products together with a discount in addition to selling them individually.¹ Firms can also sell only the

bundle, a practice known as pure bundling or tying. An additional example of mixed bundling is Apple incorporating its iLife software suite as part of its operating system with every new Mac computer as well as making it available for sale through its retail channels.

Besides an efficiency reason, two leading explanations of bundling are price discrimination and entry deterrence. For price discrimination,² it is the heterogeneity in consumer valuations that frustrates the seller in its ability to extract consumer surplus through one price. Thus, bundling helps reduce the dispersion in valuations, which increases a firm's profit. Whinston (1990) proposed another explanation for bundling—changing the market structure by exclusion, and that precommitment matters. Nalebuff (2004) advanced the literature by showing that bundling can effectively deter entry even without precommitment.

Although mixed bundling has been widely studied, as is evident from the previously mentioned literature, it has yet to be studied in the context of a two-sided (or multisided) market.³ This is because

¹ An example of a mixed bundle of a Blu-ray player and content is the Sony BDP-S300/SM with Spiderman 3; see <http://www.amazon.com/Sony-BDP-S300-SM-Blu-ray-Spiderman/dp/B000X22YTK> (accessed February 25, 2013).

² See Stigler (1963), Adams and Yellen (1976), Schmalensee (1984), McAfee et al. (1989), and Bakos and Brynjolfsson (1999).

³ A two-sided market differs from a “traditional” one-sided market because it involves two or more end users who interact via an intermediary. Moreover, the interactions result in externalities on either

two-sided market theory is quite recent and sparse.⁴ To the best of our knowledge, only three papers—Rochet and Tirole (2008), Amelio and Jullien (2012), and Choi (2010)—have analyzed an extreme form of bundling: tying. Rochet and Tirole (2008) studied the payment card industry and illustrated how tying can make the pricing structure more balanced and raise social welfare. Amelio and Jullien (2012) considered a platform that would like to set a negative price on one side of the market but worries about opportunistic risk. They determined tying can serve as an implicit subsidy without attracting undesirable customers. Choi (2010) analyzed the effect of tying on two-sided market competition with multihoming and showed that tying can be welfare enhancing.

We attempt to fill the gap in the bundling and two-sided markets literature by presenting a theoretical monopoly model of mixed bundling in the context of a two-sided (or multisided) market with an installed base. We formulate a theoretical model of mixed bundling to establish a moderator on the existing bundling theory and on the existing two-sided market literature. Specifically, our interest is in the relative price effects of mixed bundling with pure component pricing acting as the baseline measure. We then take our theoretical predictions to data on the portable video game console market, where a bundle consists of a game and console sold together for a single price. The empirical analysis is intended to lend support to the novel theoretical predictions. We select the video game industry to empirically support our theoretical model because it is a prototypical two-sided market with consumers and game developers interacting through the intermediary console. Furthermore, during a period from mid-2001 through March 2005, there existed only one portable video game console manufacturer, Nintendo. With access to a new data set that tracks sales and revenue of Nintendo's portable consoles, all available software, and bundles, we are able to determine whether our theoretical model predictions are consistent with the data.

From our theoretical model, we determine results that run counter to both the traditional mixed bundling and two-sided market literature. The classical case in traditional bundling literature is that stand-alone component prices should rise under bundling. *But in our model, the stand-alone platform price falls with the introduction of bundling.* Table 1 presents the predicted price-bundle correlations from the standard

Table 1 Predicted and Observed Correlations Between Bundling and Component Prices

	Traditional bundling/ two-sided literature	Our results
Stand-alone platform price	+	–
Stand-alone content price	+	+
Content royalty rate	?	–

case in the traditional bundling literature next to correlations we find from our model.

The intuition behind these price results is as follows. Specifically, by offering a bundle, a platform induces consumers to reveal their true types, and the bundle allows a platform to segment consumers into two distinct groups, new potential consumers and the installed base. In doing so, the platform can implement price discrimination by setting segment specific prices—the effective content price for new potential platform consumers (the difference between the bundle price and the stand-alone platform price) and the content price for the installed base. The more efficient extraction of rents from consumers with regard to the stand-alone bundled content leads to a stronger complementary price effect and therefore a reduction in the price of the component hardware.

Additionally, our theoretical results determine that the platform price levied on the other side of the market, which is the per-unit price content developers pay for the right to produce and sell content, declines too. In standard two-sided market literature, the optimal pricing usually involves a cross-subsidy from the inelastic side to the elastic side (Rochet and Tirole 2006), which is in the same spirit as Ramsey pricing. Under bundling, we show that prices on the consumer side are lower because of price discrimination, so according to the cross-subsidization rule, we should expect an inflated price on the content developer side. However, we see the opposite. The intuition behind this result is nonetheless quite simple and consistent with the very cross-subsidization intuition. With offering a bundle and being able to more efficiently extract consumer rents, the relative elasticities with respect to platform participation of consumers and content developers change. Consequently, consumers become relatively more inelastic with respect to their participation on the platform from the fact that bundling can target the consumers more accurately. Such a shift changes the relative elasticities between consumers and content developers' platform participations. With relatively more elastic content developers with respect to participation, the platform is required to shift its relative attention away from consumers to content developers. Lowering its price to content developers is done to attract content to its platform.

or both sides of end users. Examples of such markets are credit cards, media, yellow page phone directories, computer operating systems and video game consoles.

⁴ See Kaiser (2002), Caillaud and Jullien (2003), Rysman (2004), Armstrong (2006), Carrillo and Tan (2006), Hagiu (2006), Kaiser and Wright (2006), Rochet and Tirole (2006), and Weyl (2010) for general literature on two-sided platform markets.

Embedded in the results above is the role cross-group externalities play in the two-sidedness. It is important to discuss their role. As we have just discussed, a platform lowers its price to content when a bundle is present. This decrease leads to more content onboard the platform and from the cross-group externalities a greater demand in the platform from consumers, which helps offset the lowered consumer platform price. Likewise, more consumer demand for the platform leads to more content. Such two-way indirect network effects reinforce each other and give the platform more incentive to lower prices. However, profits still increase because of a rise in participation on both sides.

The driving force of bundling in our model is price discrimination resulting from the consumer heterogeneity. In other words, the platform's incentive to bundle in our model is based purely upon price discrimination. The firm wants to lock in as many consumers as possible and to perfectly price discriminate with respect to those who buy the stand-alone content only, and it does so with a lower stand-alone platform price to new consumers and a lower price to content developers. Consequently, as a by-product of this price discrimination, the two sides are better coordinated and social welfare is enhanced. We show unambiguously that platform participations increase on both sides of the market.

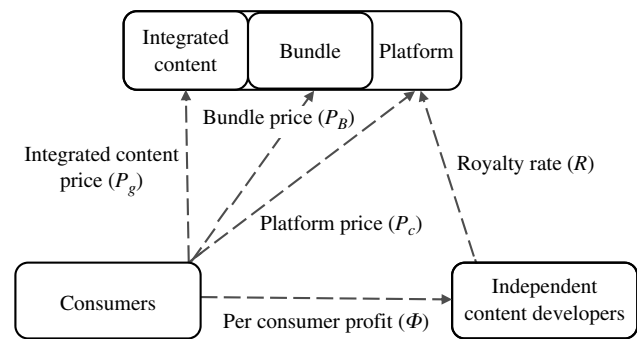
After theoretically evaluating the impact mixed bundling has on prices and welfare, we determine whether the theoretical model predictions are consistent with data from the portable console market in the early to mid-2000s. We employ a reduced form approach to do so and conclude that the proposed model is consistent with the data.

The structure of this paper is as follows. First, we set up the model and describe the game. In §3, we present two regimes in a two-sided market structure. To assist the identification of the impact mixed bundling has in a two-sided market structure, the first regime does not allow for mixed bundling, whereas the second regime does. In this section we also compare prices, profits, and welfare between the two regimes. Moreover, we perform the analyses with the price levied to the content developer side as both exogenously and endogenously determined. Section 4 discusses our data and presents industry statistics. We present the results of our reduced form regression of the theoretical model in §5. Last, we conclude in §6. All proofs are relegated to the appendix.

2. Model Setting

There are three classes of players in the model: two types of agents and a platform. The agents are consumers and content developers. We assume interactions among all three classes of players exist and are

Figure 1 Two-Sided Market Structure



illustrated by Figure 1. In this section, we use lowercase letters to denote prices, and in the later part, lowercase letters are used specifically for the independent pricing (IP) regime, whereas uppercase letters are used to denote the corresponding prices under bundling.

2.1. Platform

There is a monopoly platform that locates at the origin of a unidirectional horizontal line of unit length and produces integrated content. For simplicity, we assume the platform has only one piece of integrated content, and the marginal costs of producing its platform and content are both zero. The platform interacts with both agents by charging a price p_c to consumers for the access to its platform and a price p_g for the integrated content, and levying a per-unit royalty rate r to independent content developers for the right to produce and sell content compatible with the platform, where a unit is not a content title, but a copy of a title. More explicitly, the royalty rate is not a rate of revenue or a rate of profit but a rate of sale, or, put differently, a simple fixed dollar amount per title sold (e.g., \$8). And, in some cases, in addition to p_c and p_g , the platform can set price P_B for a bundle.

2.2. Consumer Side

We implement a modified Hotelling model to analyze the consumers' decisions. There are two groups of consumers ($i = 1, 2$) with total size normalized to one. Group 1, identified as the installed base (with fraction α) locating at the origin, is a preexisting group who already has purchased access to the platform but has yet to purchase the integrated content. There are several realistic reasons why there might be a set of consumers who have yet to purchase the integrated content but own access to the platform: (a) the integrated content was not yet available when the consumers bought their platforms, or (b) some fraction of the installed base did not have enough information about this content to decide whether they should

purchase it.⁵ Regardless of the reason why a set of consumers chooses to own a platform and not the integrated content, the mere fact there exists such a set is important.

The gross utility a consumer from Group 1 garners from purchasing the integrated content is $u_{\text{installed}} = 1$. Group 2, a continuum of new potential consumers with fraction $1 - \alpha$ population, is uniformly located on the horizontal line of unit length and has yet to purchase access to the platform. The utility a Group 2 consumer receives from purchasing access to the platform is dependent upon the quality of independent content d provided by the independent content developer and the transportation cost equal to $t \cdot x$. Here, t is the transportation cost per unit of length, x is the consumer's distance from the origin where the platform is located at, and x is uniformly distributed on the interval $[0, 1]$. The marginal utility of the independent content is β ($\beta > 0$). To be more specific, the gross utility associated with a new consumer situated at point x who elects to purchase access to platform *only* is $1 - tx + \beta \cdot d$,⁶ but is $1 - tx + v_g + \beta \cdot d$ if he purchases *both* the platform access and the integrated content, where 1 and v_g are the new consumer's intrinsic values for the platform and integrated content, respectively. For simplicity, we assume that v_g is drawn from the uniform distribution $U(\cdot)$ on $[0, 1]$, which is always weakly less than that of Group 1 users. This higher willingness to pay for the installed base group is to capture the fact that early adopters are more likely to be "locked-in" than new consumers, or they have more experience with the platform, and thus are more likely to purchase the integrated content than those who have never experienced the platform before. Note that new users are heterogeneous in two dimensions: in their location x and in their valuation for the integrated content v_g .⁷

2.3. Independent Content Developer Side

We assume the platform is essential for consumers to enjoy content. In the case of independent content developers, they must join the platform for their content to be compatible with the platform.

⁵ We thank an anonymous reviewer for suggesting this interpretation.

⁶ When $\beta = 0$, the platform itself will not provide any utility to the consumer unless purchased with the integrated content. Hence, this term will be zero in this case. Moreover, the consumers will not care about the independent contents leading to the market structure no longer being two-sided. For details about the case when $\beta = 0$, please see §3.4.

⁷ Empirically, one might construe the new users' valuations for platform and content should be positively correlated, rather than independent as assumed here. As we will discuss in the appendix, positively correlated preferences won't change our main results. So we choose the independent preference for the simplicity of illustration.

For simplicity, we consider a representative content developer. Denote the per-consumer profit for the independent content developer as ϕ . Then the quality of independent content is given by $d = (\phi - r)[\alpha + (1 - \alpha)q_{\text{new}}]$, where q_{new} is the fraction of potential new consumers who newly purchase the access to the platform, so $\alpha + (1 - \alpha)q_{\text{new}}$ is the total number of consumers who have access to the platform.⁸ We assume each consumer with access to the platform will purchase one unit of the independent content. In equilibrium, the number of interactions between two sides will be $\alpha + (1 - \alpha)q_{\text{new}}^* = d^*/(\phi - r)$, where q_{new}^* and d^* are the corresponding equilibrium terms. Rochet and Tirole (2006), Armstrong (2006), and Choi (2010) also modeled the content developer side of the two-sided market in a similar manner—the content developer gains a profit per consumer and thus its profit is proportional to the number of consumers on the other side.

Thus, the royalty revenue the platform receives is $r \cdot [\alpha + (1 - \alpha)q_{\text{new}}] = r \cdot d^*/(\phi - r)$, which says the royalty revenue is the product of per-unit royalty rate and the number of interactions between two sides. This equation therefore implies that as more consumers join the platform, higher royalty revenue will be received, which is denoted throughout the economic literature as an indirect network effect.

2.4. Timing of the Game

The timing of the game is as follows. First, the monopoly platform chooses either to bundle or not and then sets prices accordingly. Next, after observing the price offers from the platform, consumers and the independent developer make their purchase decisions and content quality supply decision, respectively. Rational expectations are assumed for the simultaneous equilibrium outcome.

3. Equilibrium Analysis

We begin by looking at a two-sided market model that omits the practice of mixed bundling, then modify the model to allow for its practice. After the introduction

⁸ Here, we could also interpret d as the number of content developers. Assume there is free entry into the market for content and that developers are heterogeneous. Each developer's type can be summarized by θ , which is its fixed cost of developing content for platform. For simplicity, we assume θ is independent and identically distributed according to a uniform distribution $U(\cdot)$ on $[0, 1]$. The total number of potential content developers is therefore normalized to one. With the assumption of free entry into the developer segment, developers do not set content prices. Instead, they decide whether to enter the market and join the platform. The profit each developer can receive per consumer if it elects to produce a piece of content is ϕ . Consequently, a type θ developer will create and produce content for platform if and only if $\theta \leq (\phi - r)[\alpha + (1 - \alpha)q_{\text{new}}]$. Then the total amount of content available on the platform is also $d = (\phi - r)[\alpha + (1 - \alpha)q_{\text{new}}]$.

and characterization of the equilibrium of both models, we compare the two regimes to determine the effects of mixed bundling on prices and welfare.

As indicated in §2, the quality of independent content is determined as $d = (\phi - r)[\alpha + (1 - \alpha)q_{new}]$. The presence of the independent content has two implications: first, integrated content is not essential to new potential consumers, because they can enjoy the platform with independent content; second, indirect network effects are present in this setting, because the royalty revenue from the content developer side depends on the number of total platform owners $\alpha + (1 - \alpha)q_{new}$, and the number of total platform owners hinges on the quality of independent content too. As a result, the market structure is two sided.

3.1. Independent Pricing Equilibrium

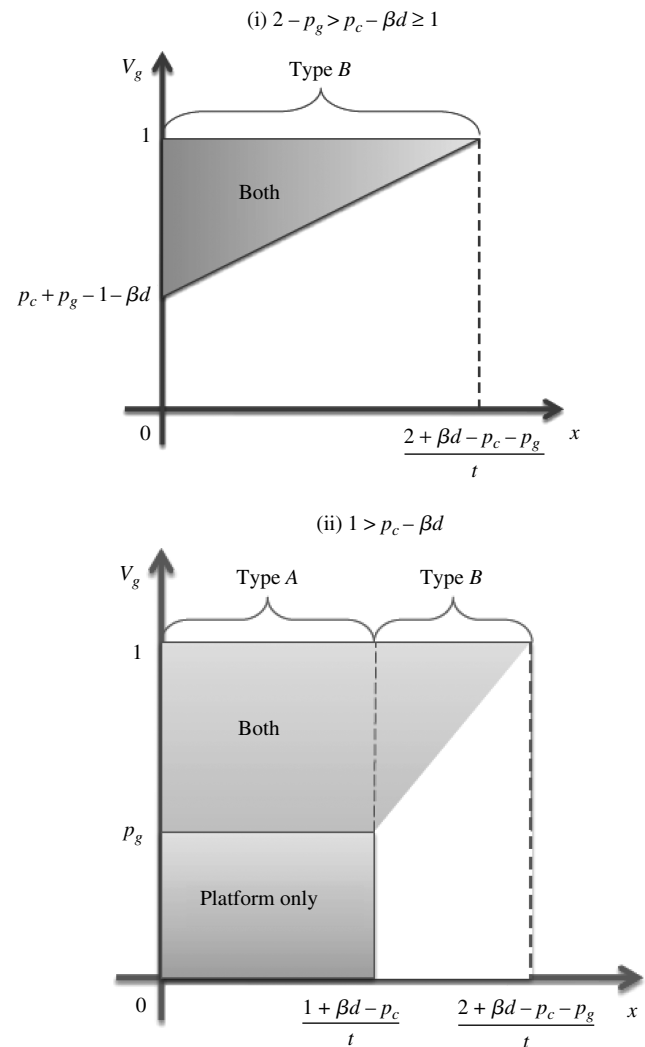
The IP equilibrium consists of the monopoly platform setting prices (p_c, p_g) . The two groups of consumers' decisions are as follows.

For the installed base, they will purchase the integrated content from the platform if and only if $u_{installed} - p_g \geq 0$. Because $u_{installed} = 1$ is the upper bound of all consumers' valuation for the integrated content, we will have $1 \geq p_g$ in equilibrium. Thus, the demand for the independent content from the installed base is α .

The equilibrium number of new platform owners is more challenging to derive given that consumers can either purchase access solely to the platform, purchase access to the platform in conjunction with integrated content, or elect to purchase neither platform nor content. We thus classify new consumers based upon their different valuations into two different types. The first, type A, values the platform high enough on its own to purchase, given the availability of independent content; that is, the consumer's utility from consumption of the platform solely is greater than zero, or $1 + \beta \cdot d - tx - p_c \geq 0$. Hence, these type A new consumers will buy both the platform and integrated content if $v_g \geq p_g$, and only the platform if $v_g < p_g$. The second, type B, consumers do not value the platform enough on its own to purchase it, given the availability of independent content; that is, $1 + \beta \cdot d - tx - p_c < 0$. Thus, these consumers purchase access to the platform with the integrated content if the integrated content is valuable enough. In this case the integrated content is a complementary product that makes the console more attractive. They, therefore, will buy both the platform and the integrated content if $(1 + \beta \cdot d - tx - p_c) + (v_g - p_g) \geq 0$ and buy nothing otherwise. There are two possibilities: (i) when $2 - p_g > p_c - \beta d \geq 1$ and (ii) when $p_c - \beta d < 1$. The new consumers' demand is in Figure 2.⁹

⁹ For type A ($x \leq \max\{0, (1 - p_c + \beta d)/t\}$), given the availability of independent content, the platform itself is attractive enough to

Figure 2 New Consumer Demand Under Independent Pricing



The aggregate demand for the platform only as well as the demand for both a platform and the integrated content are

$$q_{\text{platform-only}} = \begin{cases} 0 & \text{(i)} \\ [p_g(1 + \beta d - p_c)]/t & \text{(ii)} \end{cases} \quad \text{and}$$

$$q_{\text{both}} = \begin{cases} [(1 + \beta d - p_c + 1 - p_g)^2]/(2t) & \text{(i)} \\ [(1 - p_g)(1 + \beta d - p_c) + (1 - p_g)^2/2]/t & \text{(ii)}, \end{cases}$$

respectively. Thus, the total fraction of new consumers joining the platform is

$$q_{\text{new}} = q_{\text{platform-only}} + q_{\text{both}} = \begin{cases} [(1 + \beta d - p_c + 1 - p_g)^2]/(2t) & \text{(i)} \\ [1 + \beta d - p_c + (1 - p_g)^2/2]/t & \text{(ii)}. \end{cases}$$

justify purchase. For type B ($x > \max\{0, (1 - p_c + \beta d)/t\}$), given the availability of independent content, platform itself is not attractive enough to justify purchase.

Given the demand for each of these products, the quality of independent content can be written as

$$d = \begin{cases} (\phi - r)[\alpha + (1 - \alpha) \cdot [(1 + \beta d - p_c + 1 - p_g)^2 / (2t)]] & \text{(i)} \\ (\phi - r)[\alpha + (1 - \alpha) \cdot [1 + \beta d - p_c + (1 - p_g)^2 / 2] / t] & \text{(ii).} \end{cases}$$

LEMMA 1. Case (i) cannot be the equilibrium.

So we focus on case (ii): $1 > p_c - \beta d$. In (ii), we determine the equilibrium d^* as

$$d^* = (\phi - r) \cdot \frac{\alpha + (1 - \alpha) \cdot (1 - p_c + (1 - p_g)^2 / 2) / t}{1 - (1 - \alpha)\beta(\phi - r) / t}.$$

Hence, the total number of platform owners is $\alpha + (1 - \alpha)q_{\text{new}}^* = d^* / (\phi - r)$. To ensure d^* as positive in the equilibrium, we assume t is large enough such that $t > (1 - \alpha)\beta(\phi - r)$.

With equilibrium demand for the platform and integrated content as well as the quality of independent content determined, in terms of platform price p_c , integrated content price p_g , and royalty rate r , the platform manufacturer maximizes its profit with respect to these strategic variables. The corresponding platform profit under IP becomes a multiproduct monopoly problem with a network externality:

$$\pi^{\text{IP}}(p_c, p_g, r) = \alpha \cdot p_g + (1 - \alpha) \cdot (p_c \cdot q_{\text{new}} + p_g \cdot q_{\text{both}}) + r \cdot [\alpha + (1 - \alpha) \cdot q_{\text{new}}]. \quad (\text{IP-Profit})$$

3.2. Bundling Equilibrium

Our mixed bundling model differs slightly from the above IP model in that new consumers now possess the option of purchasing access to the platform and the integrated content bundled together, although consumers still retain the option of purchasing content and access to the platform separately. Like the above IP model, the platform interacts with both agents by charging a fixed fee, P_c , to consumers for access to the platform and levying a per-unit royalty rate, R , to the independent content developer for the right to produce and sell content compatible with the platform. Consumers and independent content developer still interact, with consumers purchasing independent content from the developer. Consumers can purchase the integrated content separately for a fixed fee, P_g . Yet, in the bundling model, the platform also sells its content and access to its platform together at price P_B . Prices are thus $\{P_c, P_g, P_B, R\}$.

To begin our equilibrium analysis, first note that for the bundle to be effective, we must have $P_c + P_g > P_B$. Hence, if the new consumers elect to purchase the integrated content, they will do so via the bundle.

And, they will never solely purchase the integrated content at P_g since the content provides zero utility without access to the platform; P_g is thus specifically targeted to the installed base of users who already have access to the platform but have not purchased the integrated content. Hence, it is easy to see that the price of the integrated content is set to $P_g = 1$, since P_g is directed to the installed base. The resulting demand for the independent content from the installed base is α .

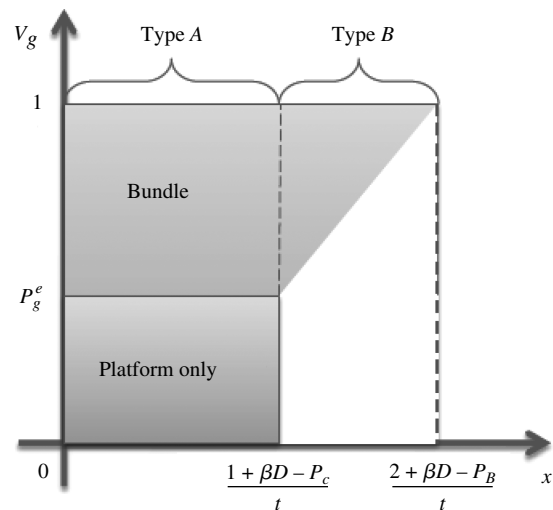
Note that if we remove the installed base from our model, then there is no need to bundle—only two prices (P_c, P_B) matter for new consumers since they either buy access to the platform only, or buy both the integrated content and access to the platform. In other words, it is the presence of installed base or heterogeneity among consumers that makes the bundle necessary.

Under bundling, new consumers determine their purchase decisions on two strategic variables: the price of the platform P_c and the effective price of the integrated content $P_g^e \equiv P_B - P_c$. Our analysis regarding new consumer demand for the platform and the purchase of both the platform and integrated content (the bundle) takes the same structure as the IP equilibrium if we replace p_g with the effective price P_g^e . Likewise, we have two possible cases: (i') $2 - P_g^e > P_c - \beta D \geq 1$ and (ii') $1 > P_c - \beta D$. Direct computation can eliminate (i') and thus we can focus on (ii'). The new consumers' demand under bundling is given in Figure 3.

The stand-alone demand for the platform and the bundled demand are

$$Q_{\text{platform-only}} = \frac{P_g^e(1 + \beta D - P_c)}{t} \quad \text{and} \\ Q_B = \frac{(1 - P_g^e)(1 + \beta D - P_c) + (1 - P_g^e)^2 / 2}{t},$$

Figure 3 New Consumer Demand Under Mixed Bundling



respectively. Thus, the total fraction of new consumers joining the platform is

$$Q_{\text{new}} = Q_{\text{platform-only}} + Q_B \\ = \frac{1 + \beta D - P_c + (1 - P_g^e)^2/2}{t}.$$

Similarly, assuming rational expectation, the quality of independent content is

$$D^* = (\phi - R) \cdot \frac{\alpha + (1 - \alpha) \cdot (1 - P_c + (1 - P_g^e)^2/2)/t}{1 - (1 - \alpha)\beta(\phi - R)/t}.$$

Given the demand for the platform-generated content from the installed base, the demand from new consumers for only the platform and the demand for the bundle, and the quality of independent content, the monopoly platform's profit under bundling is

$$\begin{aligned} \Pi^B(P_c, P_g^e, R) \\ &= \alpha \cdot 1 + (1 - \alpha) \cdot (P_c \cdot Q_{\text{new}} + P_g^e \cdot Q_B) \\ &\quad + R \cdot [\alpha + (1 - \alpha) \cdot Q_{\text{new}}]. \\ &= \alpha \cdot P_g^e + (1 - \alpha) \cdot (P_c \cdot Q_{\text{new}} + P_g^e \cdot Q_B) \\ &\quad + R \cdot [\alpha + (1 - \alpha) \cdot Q_{\text{new}}] + \alpha \cdot (1 - P_g^e) \\ &= \pi^{IP}(P_c, P_g^e, R) + \alpha \cdot (1 - P_g^e). \quad (\text{Bundling-Profit}) \end{aligned}$$

Notice that the structure of this profit function is identical to the IP model, except that p_g is replaced by P_g^e , and now the platform has one more degree of freedom by setting $P_g = 1$ for the installed base. Thus, compared with the platform's profit under IP, the only extra term is the surplus gains extracted from the installed base, that is, $\alpha \cdot (1 - P_g^e)$. Consequently, we determine that bundling is a dominant strategy for the monopoly platform because offering P_B and P_g simultaneously is equivalent to offering P_g^e and P_g to new consumers and the installed base separately while retaining $P_c = P_B - P_g^e$ as the platform price. Offering a bundle, therefore, provides the monopoly platform an additional instrument to extract consumer surplus.

LEMMA 2 (MIXED BUNDLING IS PROFITABLE). *Whenever bundling is possible, mixed bundling is a dominant strategy over no bundling or pure bundling.*

Lemma 2 is consistent with the existing literature on mixed bundling in traditional one-sided market that finds mixed bundling is the optimal strategy for the monopolist. Next, we perform the comparative statics analyses for both cases in which the royalty rate is exogenously or endogenously determined.

3.3. Prices, Profits, and Welfare Comparison

In this subsection, we compare the equilibria of the two regimes—IP versus bundling. Interestingly, we find that the bundling pricing structure, when royalty rate is exogenously given, differs from that when royalty rate is endogenously determined. Moreover, with an endogenous royalty rate, the pricing structure differs from that of traditional bundling.

3.3.1. When Royalty Rate \bar{R} Is Exogenously Determined.

PROPOSITION 1 (ONE-SIDED PRICING IN TWO-SIDED MARKETS). *In two-sided markets, when royalty rate \bar{R} is exogenously determined, under mixed bundling, the pricing structure is the same as the standard bundling pricing in the traditional one-sided market: the stand-alone prices for the access to the platform and the integrated content are higher than their corresponding prices under IP, whereas the bundle price is lower than the sum price of platform and integrated content under IP. Specifically,*

$$\begin{aligned} P_c^{*\bar{R}} &> p_c^{*\bar{R}}, \\ P_g^{*\bar{R}} &= 1 > p_g^{*\bar{R}} > P_g^{e*\bar{R}} = P_B^{*\bar{R}} - P_c^{*\bar{R}}, \\ p_c^{*\bar{R}} + p_g^{*\bar{R}} &> P_B^{*\bar{R}}. \end{aligned}$$

We determine from Proposition 1 that offering the bundling option allows the monopolist to increase the stand-alone price of the integrated content. The above price structure allows consumers to sort into distinct groups and consequently reveal their true preferences. The mixed bundling option thus acts as a price discrimination tool and allows the monopolist to raise stand-alone prices in search of more efficient and complete extraction of consumer surplus. It is true that when the platform faces a two-sided market and can set prices on both sides, it should employ two-sided pricing. The above one-sided pricing in a two-sided market serves as an intermediate step illustrating the effects of a bundle and two-sided pricing. As shown above, when pricing is one sided, the bundling pricing structure is the same as the traditional one—both component prices go up while the bundle price goes down even though the market is two sided here. By contrast, as we will see next, the pricing structure is different from the traditional structure when the platform performs two-sided pricing. Consequently, this intermediate “one-sided pricing in two-sided markets” step clearly identifies the role the two-sidedness plays in the pricing structure. In the appendix, we show that total surplus increases under mixed bundling.

3.3.2. When Royalty Rate R Is Endogenously Determined.

PROPOSITION 2 (TWO-SIDED PRICING IN TWO-SIDED MARKETS). *In two-sided markets, when royalty rate R is*

endogenously determined, under mixed bundling, all prices except the stand-alone price of the integrated content are lower than their counterparts under IP. Specifically,

$$\begin{aligned} r^* &> R^*, \\ p_c^* &> P_c^*, \\ P_g^* = 1 &> p_g^* > P_g^{e*} = P_B^* - P_c^*, \\ p_c^* + p_g^* &> P_B^*. \end{aligned}$$

This is quite a surprising result. Both the stand-alone platform price and the royalty rate are lower under the mixed bundling equilibrium than their respective counterparts in the IP equilibrium. As stated by Rochet and Tirole (2006, p. 658), “the price to side i is inversely related to that side’s elasticity of demand.” In two-sided markets, the optimal pricing scheme is to subsidize the more elastic side of the market and extract rents from the other, more inelastic side. Or more generally, the optimal price structure is to adjust prices downward by the external benefit a platform receives from attracting an additional user. When the platform maker uses mixed bundling, they are in effect offering a “subsidy” to consumers, which increases demand for its platform by attracting a greater number of marginal consumers. We might expect that by subsidizing consumers, via mixed bundling in our case, the platform maker is increasing the content developer’s willingness to participate and thus the ability to raise the royalty rate in which it levies. Yet, this is not what we encounter. We find that the royalty rate is in fact lower under the mixed bundling equilibrium. By offering the mixed bundle, the platform becomes more effective in extracting consumer surplus, compared to the IP case. Consequently, by offering the mixed bundle, the consumer side becomes less elastic to platform pricing because it can more efficiently extract consumer surplus without deterring consumer participation. This creates an incentive for the platform to lower R under mixed bundling.¹⁰

There also is an additional argument for the lowering of the royalty rate. We know that the platform

would like to increase participation on the side it can more efficiently extract surplus from, because doing so will increase profits. Given that nonlinear pricing is available only to the consumer side, the platform is able to more effectively extract rents from consumers. Given this, the platform has an incentive to increase demand for its platform. How does the platform accomplish this? It does so by reducing the content developer’s royalty rate R . A reduction in the royalty rate will lead to an increase in content development and attract more consumers through the indirect network effect, which will consequently lead to higher quality of independent content.

In addition to a decrease in royalty rate, we also find that the stand-alone platform price is less under a mixed bundling regime. This is in stark contrast with the pricing pattern in the traditional bundling literature or our one-sided pricing in the two-sided markets. When \bar{R} is exogenously given, the pricing structure is parallel to the traditional bundling pricing structure that stand-alone prices go up while the bundle price goes down, compared with the IP case. Nevertheless, in our two-sided pricing in two-sided markets case, when R is endogenously determined, the stand-alone platform price falls.

This smaller stand-alone platform price results from two factors. First, it is a consequence of the mixed bundle segmenting the market into new consumers and the installed base. Under the mixed bundle regime, the stand-alone integrated content price is specifically targeted to the installed base as opposed to a uniform price under the IP equilibrium. Because the installed base’s valuation of the integrated content is known to all, the platform is able to perfectly price discriminate and set price equal to 1, which is greater than p_g . As a result, the additional profit the platform receives from selling its integrated content and from the payment of royalty rates from the independent content is larger under a mixed bundling equilibrium, leading to a larger discount of the stand-alone platform price and hence a smaller price.¹¹ The second source is the cross-market strategic interactions related to multiproduct pricing. When \bar{R} is exogenously given, only two prices for the new consumers are set. Because the platform and the integrated content are substitutes ($\partial^2 \pi / (\partial p_c \partial p_g) < 0$), their price changes in the opposite direction. When R is endogenously determined, the problem involves one more price to be set—the royalty rate R . As can be checked from their pairwise cross-derivatives, the platform, the integrated content, and the independent content are all pairwise substitutes. However, overall,

¹⁰ To be more specific, the price elasticity of demand from the content developer side is $|\varepsilon_D| = |d'(r) \cdot r/d(r)|$, which is fixed for a given r . The demand for new consumers $q_{\text{new}} = (1 + \beta d)/t - (p_c - (1 - p_g)^2)/t$ depends on both p_c and p_g . So we can define an effective price index for new consumers as $PI \equiv (p_c - (1 - p_g)^2)/t$. Then $q_{\text{new}} = (1 + \beta d)/t - PI$. The price elasticity of demand from new consumers $|\varepsilon_N| = |(dq_{\text{new}}/dPI) \cdot (PI/q_{\text{new}})| = 1/[(1 + \beta d)/(t \cdot PI) - 1]$ is increasing in PI . For any given r , it is shown that PI under IP is larger than PI under bundling (please see the last part of the proof of Proposition 1 in appendix). Therefore, if we fix r and switch from IP to bundling, then $|\varepsilon_D|$ will not change, whereas $|\varepsilon_N|$ will become smaller. Relatively, the content developer side becomes more elastic under bundling, which leads the platform to lower the royalty rate under bundling.

¹¹ Remember that the presence of an installed base makes bundling have bite. If we eliminate the installed base from our model, then there won’t be any bundling, and hence no such price decline.

the platform and the integrated content become complements ($-(\partial^2 \pi / \partial p_c \partial p_g)(\partial^2 \pi / \partial r^2) - (\partial^2 \pi / \partial p_c \partial r) \cdot (\partial^2 \pi / \partial p_g \partial r) > 0$). The independent content market here is crucial in the overall effect because the demands are interdependent. Consequently, although the lower integrated content price gives an incentive to increase the stand-alone platform price as when \bar{R} is exogenously given, the lower royalty rate offers an offsetting power to lower the stand-alone platform price. As a result, the latter effect dominates the former.

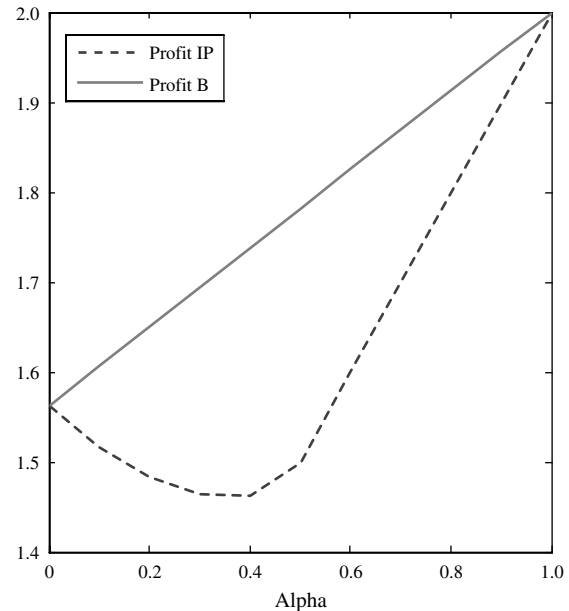
After determining that all prices are lower, with the exception of the stand-alone integrated content price, we find that new consumers are strictly better off. The installed base of consumers is strictly worse off, a consequence of the installed base being locked in to the platform and the ability of the platform to segment the market and target the installed base with a segment-specific content price that extracts full surplus from them under mixed bundling. This extraction, however, does not cause total surplus to change since it is a transfer from consumers to the platform. Moreover, from Lemma 2, we know that the platform's profits are strictly higher under mixed bundling. Thus, total surplus is larger under mixed bundling than independent pricing.

From our theoretical analyses, we show the effects of mixed bundling on prices, surplus, and demand for the platform differ substantially under two different market structures. Although the motivations behind the act of offering a bundle are consistent across structures (price discrimination), mixed bundling under a two-sided market structure leads to a unique outcome. We determine that, unlike in the single-sided case, all prices with the exception of the stand-alone platform-created content price are lower, and total surplus in a two-sided market structure is definitively larger than the welfare under an IP regime. When a platform is able to optimally set its royalty rate and offer a mixed bundle, the firm's response is not to increase the stand-alone platform price but to lower both the royalty rate and stand-alone platform price. The decreases in marginal revenues from the decline in platform price and content developer royalty rate are more than overcome by the increases in consumer demand and independent content developer's quality supply.

3.4. Discussions

We certainly recognize that our model is stylized, and any implications from our proposed model may be limited because of the assumptions it is based on. Below we provide a discussion on a few of the most disconcerting assumptions and how they may impact the results and implications of our model.

Figure 4 Platform Profit Under IP and Bundling Equilibrium for $t = 1$, $\beta = 0.5$, and $\phi = 1$



3.4.1. Role of α . We have emphasized above that all of our results hinge on the existence of the installed base group, whose valuation for the integrated content is higher than that of new consumers. It is a particular type of installed base effect where past purchases lead previous consumers to want only the platform's integrated content.¹² This is why mixed bundling can perfectly segment the installed base from new consumers. Hence, the incentive to bundle comes from the heterogeneity across the installed base and new consumer group. It is worthwhile to look at how the fraction of the installed base affects the platform's incentive to bundle. Figure 4 shows platform's profit under IP and bundling equilibrium for a set of parameter values, as α varies from 0 to 1.

In the two extreme cases when $\alpha = 0$ or $\alpha = 1$, we either have no installed base or all consumers are the installed base. In the former, only two prices, p_c and p_g , are enough to segment the new consumers, whereas in the latter only one price, p_g , is enough for the installed base. Therefore, there is no need to bundle in these two extreme cases. Yet, when $\alpha \in (0, 1)$, these two prices are not sufficient to segment the new consumers and target the installed base at the same time. Thus, bundling has some bite as it introduces an extra pricing tool to further segment the market. This confirms the key role of the existence of the installed base for bundling adoption. Note that in Figure 4, the profit gain from bundling compared with IP ($\Pi^B - \Pi^{IP}$) reaches maximum for a certain intermediate value of α . This is because the major

¹² We thank the associate editor for bringing this to our attention.

gains of switching from IP to bundling include more profit extracted from the installed base via higher integrated content price and better segmentation of consumers, which encourages more participation on both sides. Because the overall consumer market size is fixed, as α increases, fewer new consumers means less demand for access to the platform. Although the platform still gains from better price discrimination and coordination through bundling, the profit gain from bundling may shrink because of the fact that the market for the platform access becomes saturated as the fraction of new consumers falls. As a result, even with our model being static, this simple comparative statics analysis provides a dynamic guideline on how much mixed bundle profit increases over IP as the installed base evolves.

This result also aids us in our subsequent empirical analysis. The fact that a firm's decision to offer a bundle is endogenous does complicate our empirical analysis. However, to overcome this complication, we leverage the fact that bundling becomes more irrelevant as the installed base or the number of new consumers purchasing the console tends toward zero. We thus employ lagged measures of the installed base as instruments for when a platform should offer a bundle to control for the bias associated with the endogenous bundling decision in our empirical analysis.

3.4.2. Role of β . The positive β ensures that the market is two-sided. In the extreme case when $\beta = 0$, consumers do not receive any utility from independent content, and so there will not be any interactions between consumers and independent content. Hence, no royalty revenue can be collected. Consequently, the indirect network effects on both sides disappear and the market is reduced to a one-sided market. Moreover, because there is only one piece of content available on the platform, the platform and its integrated content become perfect complements with fixed proportion. Every new consumer must buy both to make the platform useful. Hence, a pure bundle would suffice for them, and what matters for them is the *sum* of the platform price and the integrated content price. As for the installed base, they buy only the integrated content because they already have access to the platform; the stand-alone content price is all they care about. Therefore, only two prices are enough to segment the installed base and the new consumers. In this one-sided market, the Chicago School's "single-monopoly-profit theorem" is restored, and mixed bundling becomes redundant in this extreme case.¹³

Once $\beta > 0$, the market structure switches to a two-sided market. Although the platform and the integrated content remain complements, they no longer are *perfect* complements with fixed proportion—new consumers could buy access to the platform without purchasing the integrated content, for independent content can be consumed with the platform. There will be interactions between two sides through the sales of independent content, and hence the platform can collect royalty revenue. Consequently, the availability of substitutes to the integrated content ($\beta > 0$) dramatically changes the market structure and invalidates the "single-monopoly-profit theorem."

Furthermore, from the proof of Proposition 2, the comparative statics results are independent of β so long as $\beta > 0$. This indicates our results in Proposition 2 are robust when the synergies across two sides vary. To be more specific, the drop in royalty rate comes from the extra royalty revenue from the expansion on the consumer side, which changes the relative elasticities of two sides. This feedback effect from consumer side exists as long as $\beta > 0$, no matter the size of β . With respect to the fall in stand-alone platform price, there are two main reasons as pointed out before: (1) the additional profits from better targeting consumers and coordination of two sides give the platform more leeway to entice new consumers through lower platform price, and (2) the additional pricing instrument, royalty rate r , transforms the relationship between p_c and p_g from substitutes to complements. Although the magnitudes of these two effects will change as β varies, their signs never change. Starting from the extreme case of $\beta = 0$, where prices do not change before or after bundling as explained above, prices will move in the direction as predicted in Proposition 2, no matter how tiny β is so long as $\beta > 0$. This interesting result is rooted in our modeling of how royalty revenue kicks in with $\beta > 0$, as we will discuss below in §3.4.6.

3.4.3. Role of Two-Sidedness. There are several features in our two-sided model—installed base effect, complementary products, and two-sidedness. What is the driving force for the contrast in our mixed bundling results? Below we will clarify this question by discussing the role of each aspect.

First, as discussed before, the presence of the installed base (e.g., $\alpha \in (0, 1)$) gives rise to the incentive to bundle. Either with or without the installed base ($\alpha = 0$ or 1), IP suffices for the platform to segment consumers, and bundling therefore becomes redundant. Thus, it is the heterogeneity across consumer groups that motivates mixed bundling.

However, for the mixed bundling to generate the contrast in prices between the two regimes as we have identified, it needs a key aspect—two-sidedness. This can be seen by looking at the crux of our

¹³ In an earlier version of this paper, we have a detailed analysis on this extreme case. It is available upon request.

result—the platform's profit function under independent pricing.¹⁴ By rearranging and relabeling, we can decompose π^{IP} as¹⁵

$$\begin{aligned}\pi^{IP}(p_c, p_g, r) \\ = A(p_c, p_g) + I_+\{\beta\} \cdot R(r) \cdot B(p_c, p_g) \\ + \beta \cdot \frac{1-\alpha}{t} \cdot C(p_c, p_g, r). \quad (\text{IP-Profit-Decomposed})\end{aligned}$$

The first term $A(p_c, p_g)$ is the regular profit in a one-sided market, whereas the remaining two terms are unique to two-sided markets. To be more specific, the second term, $I_+\{\beta\} \cdot R(r) \cdot B(p_c, p_g)$, is the royalty revenue collected by the platform, and the third term, $\beta \cdot ((1-\alpha)/t) \cdot C(p_c, p_g, r)$, is the extra value for new consumers created by the independent content. These two terms will disappear when $\beta = 0$, because consumers will not care about the independent content, and hence there will not be any interactions between the two sides, resulting in no royalty revenue. Hence, the market is reduced to one-sidedness when $\beta = 0$.

One may wonder if it is the complementarity between products that generates our main results. We can exclude this aspect by looking at the case with the same consumer demand when $\beta = 0$. When $\beta = 0$, the two-sidedness is removed as explained above, but the complementarity between the platform and the integrated content still remains, because the platform would be useless without the content. With the consumer demand from the term $A(p_c, p_g)$ as before, we can easily verify that the comparative statics for the term $A(p_c, p_g)$ is consistent with traditional bundling literature.¹⁶ This one-sided case with complemen-

¹⁴ From (Bundling-Profit), $\Pi^B(P_c, P_g^e, R) = \pi^{IP}(P_c, P_g^e, R) + \alpha \cdot (1 - P_g^e)$. So the key part is π^{IP} .

¹⁵ Here,

$$\begin{aligned}A(p_c, p_g) \equiv \alpha \cdot p_g + (1-\alpha) \cdot \left[p_c \cdot \frac{1-p_c + (1-p_g)^2/2}{t} \right. \\ \left. + p_g \cdot \frac{(1-p_g)(1-p_c) + (1-p_g)^2/2}{t} \right],\end{aligned}$$

$I_+\{\beta\}$ is the indicator function,

$$R(r) \equiv \frac{r}{1 - ((1-\alpha)\beta(\phi-r))/t},$$

$$B(p_c, p_g) \equiv \alpha + (1-\alpha) \cdot \frac{1-p_c + (1-p_g)^2/2}{t},$$

$$C(p_c, p_g, r) \equiv [p_c + p_g(1-p_g)] \cdot \frac{(\phi-r) \cdot B(p_c, p_g)}{1 - ((1-\alpha)\beta(\phi-r))/t}.$$

The derivation of such decomposition can be found in the appendix.

¹⁶ By the same argument in the proof of Proposition 1, change in p_g is determined by $A_{11} = -((1-\alpha)/t) \cdot 2 < 0$, change in $(p_c + p_g)$ is given by $A_{11} - A_{12} = -((1-\alpha)/t) \cdot 3p_g < 0$, and change in p_c is determined by $A_{12} = -((1-\alpha)/t) \cdot (2 - 3p_g) < 0$. Thus, the stand-alone prices for the access to the platform and the integrated content are higher than their counterparts under IP, as the traditional bundling literature predicts.

tary products underscores the finding in the literature: When two products complement each other, but two-sidedness is missing (e.g., there is no indirect network effect), that stand-alone prices of both components are higher than their counterparts under IP, as shown by Venkatesh and Kamakura (2003). Venkatesh and Mahajan (2009, p. 13) confirmed this as “[u]nder mixed bundling, the bundle and component prices are weakly greater than under the corresponding pure strategies” with two complements.

Consequently, it is the existence of the installed base that gives the platform an incentive to bundle. But the contrast of prices between regimes is attributed to the two-sidedness.

3.4.4. Heterogeneity of the Installed Base's Valuation on the Integrated Content. We have assumed that the installed base is homogeneous in their valuation of the integrated content. This makes our model concise since the entire installed base will purchase the integrated content with certainty as long as its price is lower than their common valuation. Introducing heterogeneity of the installed base will make their purchase decision dependent on the price level, but our main results still hold. For instance, assume the installed base's valuation for the integrated content is drawn from certain distribution $F(\cdot)$. Then the platform's profits under bundling and under IP will have a relationship as¹⁷

$$\begin{aligned}\Pi^B(P_c, P_g^e, R) \\ = \pi^{IP}(P_c, P_g^e, R) + \alpha \cdot \{P_g \cdot [1 - F(P_g)] - P_g^e \cdot [1 - F(P_g^e)]\} \\ = \pi^{IP}(P_c, P_g^e, R) - \alpha \cdot P_g^e \cdot [1 - F(P_g^e)] + \alpha \cdot P_g \cdot [1 - F(P_g)].\end{aligned}$$

It is easy to see that under bundling, the optimal P_g will be set at the optimal monopoly price for the installed base, that is, $P_g^* \equiv \arg \max_p \{p \cdot [1 - F(p)]\}$. As long as optimal P_g^e differs from P_g^* , by definition of P_g^* , we must have $P_g^* \cdot [1 - F(P_g^*)] - P_g^e \cdot [1 - F(P_g^e)] > 0$. Thus, the platform will have incentive to price discriminate.

For bundle to be effective and thus our comparative statics arguments to go through, we further need $P_g^* > P_g^e$. Note that $P_g^* = 1 > P_g^e$ automatically holds when the installed base's valuation for the integrated content is homogeneous at 1. With heterogeneity within the installed base, we do need some conditions to guarantee $P_g^* > P_g^e$. Intuitively, as long as the average willingness to pay from the installed base is sufficiently higher than that of new consumers, we can have $P_g^* > P_g^e$, and hence our main results will not change even if we introduce heterogeneity within the installed base. We certainly recognize, nonetheless,

¹⁷ We thank an anonymous reviewer for helping us identify such a relationship.

that there are some situations $P_g^* > P_g^e$ will not hold with a heterogeneous installed base and is a limitation of our model.

3.4.5. Fee-Based Secondary Product. It is important to recognize the fact that our model does not apply to all two-sided markets. Our model addresses the impact of mixed bundling in a very important and growing market consisting of, broadly speaking, hardware and software. Below we determine if our theoretical results are consistent with data from the video game industry. Yet, we could have also employed data on smartphones, where the operating system/hardware device acts as the platform with consumers purchasing applications to load and use on such devices acting as the software. Embedded in each of these examples is the key feature of consumers purchasing platform access leading to an installed base of consumers who purchase software or content. The number of consumers who purchase platform access, however, is meaningless if the platform is unable to bundle a secondary product, either because there is no such secondary product or because the platform is unable to charge a positive price for it; a feature not all two-sided markets exhibit. For instance, a dating website is a two-sided market with men and women acting as the two distinctive end users, but it lacks a secondary product to offer to leverage the installed base by charging a positive price. Last, we are aware that our model cannot address the impact of mixed bundling on prices when two platforms are bundled in addition to being offered separately, such as a newspaper and the access to its website.

3.4.6. Functional Form Specifications. Our model assumes the indirect network effects on both sides are linear in the number of users on the other side. Although this is standard in two-sided markets literature, it could be argued that these network effects are nonlinear. For example, consumers' marginal gain from the independent content's quality may not be constant because of the decreasing marginal utility. Similarly, the marginal indirect network effects on the independent content developer side may not be constant either, because new consumers (or later participants) may be less enthusiastic than the installed base (or earlier participants). Notice that our comparative statics results for the platform lowering prices are based on the indirect network effects from the two-sidedness. If these network effects become nonlinear, especially when they become sufficiently concave, our results may not generalize.

Additionally, we assumed the royalty revenue enters the profit function in a very specific way—it kicks in as long as $\beta > 0$, no matter how small β is. This is why our main results are independent of the

magnitude of β once $\beta > 0$. A different case would be when the royalty revenue is proportional to the size of β . Under this case, when the synergies across the two sides of the network are relatively weak, our main price results may not hold.¹⁸

Following some precedents in the two-sided markets literature (e.g., Schmalensee 2002, Rochet and Tirole 2003), we use a multiplicative formula to consider the number of interactions as a product of the number of users on both sides. And the “partial demand” of the independent content developer side that we use is not that elastic. Recall that in our Proposition 1, when \bar{R} is fixed, both stand-alone prices go up. This implies that if we use a very elastic demand such that optimal R is essentially fixed even when it is endogenously determined (e.g., $d = r^e \cdot [\alpha + (1 - \alpha)q_{\text{new}}]$ when $\varepsilon \rightarrow -\infty$), our result on stand-alone platform price drop may be reversed.¹⁹

Consequently, our results are based on a particular set of functional forms. Despite their analytical tractability, they limit the scope of the results of our model. More general functional forms will likely offer more insights.

4. Hypotheses and Data

Next, we provide empirical support for the above theoretical predictions with data from the portable video game console market. Our model above generates three distinct pricing results between two regimes—mixed bundling and independent pricing. They are

$$H_1: P_c^* < p_c^*, \quad H_2: P_g^* > p_g^*, \quad H_3: R^* < r^*,$$

where H_1 accordingly predicts that the stand-alone console price under a mixed bundling regime is smaller than its price under independent pricing, H_2 states that the stand-alone component price of the software bundled with the console under a mixed bundling regime is larger than its price associated with an independent pricing model, and H_3 states that the royalty rate levied on independent game developers is smaller with mixed bundling than without.

If all of the above results are present in the data, we by no means should interpret our proposed theoretical model as the only correct model. Instead, the empirical evidence should lead the reader to interpret our theoretical model of mixed bundling in two-sided markets as being consistent with the data.

The data used in this study originate from NPD Funworld, a marketing group that tracks sales and

¹⁸ A similar argument can be made to the fraction of consumers who purchase the independent content; e.g., when the fraction approaches zero, the synergies across two sides will be weak and our results may not hold. We thank an anonymous reviewer for bringing this to our attention.

¹⁹ We thank an anonymous reviewer for suggesting this insight.

pricing for the video game industry, and were collected using point-of-sale scanners linked to more than 65% of the consumer electronics retail stores in the United States. NPD extrapolates the data to project sales for the entire country. Included in the data are quantity sold and total revenue for two consoles and three bundles and all of their compatible video games, approximately 700. The data set covers 45 months starting in June 2001 and continues through February 2005, during which Nintendo was a monopolist in the portable video game market before Sony's PlayStation Portable entered the market.

During the early 2000s through February 2005, Nintendo was a monopolist in the production of portable video game consoles. Specifically, Nintendo was a multiproduct monopolist producing two versions of its very popular Game Boy Advance (GBA) console as well as a portfolio of games to be played on its console. Each version was internally identical, but the second version, dubbed the GBA SP, was redesigned such that it looked like a mini laptop computer and was close to half the width of the original GBA. Moreover, it is usually the case with the introduction of a new device that new games are released that are not backwards compatible, yet with the introduction of the GBA SP, this was not the case because the internal parts of both devices were identical. Consequently, both devices shared the same set of games. The target market of these two devices was toward younger children rather than teenagers or young adults, which were the targeted demographic for the home console. The portable console market most drastically differs from the traditional home video game console market in that it is extremely portable with the size of the device being no larger than an adult hand. It can travel easily and be played in a car or airplane, whereas a home console is restricted to a location that has a television and an electricity supply.

General statistics of the portable video game industry are provided in Tables 2 and 3, where we present statistics regarding the release date, total units sold, the number of months on the console market, average (min and max) prices, and total stand-alone units sold

Table 2 Portable Console Market Statistics

	Release date	Units	Months on console market
Nintendo			
GBA	June 2001	12,821,233	45
GBA SP	March 2003	13,070,720	24
GBA w/Mario Kart	November 2001	215,394	29
GBA w/Mario Advance 2	November 2002	199,225	17
GBA SP w/Mario Advance 4	November 2003	149,065	4

Table 3 Portable Console and Bundle Prices

	Average price (\$)	Max price (\$)	Min price (\$)	Independent games sold
Nintendo				
GBA	72.00	94.46	52.37	
GBA SP	93.73	100.30	70.60	
GBA w/Mario Kart	86.17	150.54	61.50	2,027,636
GBA w/Mario Advance 2	67.33	71.73	56.60	2,438,732
GBA SP w/Mario Advance 4	97.62	99.85	94.92	1,673,304

of the bundle games for the two stand-alone consoles and three bundles. From these tables, it is evident that Nintendo elected to release its bundles during the holiday time period but continued to sell such bundles well into the following year(s)—the first being a GBA device bundled with the hit game Mario Kart in November 2001. Additionally, all bundled games were high-quality hit video games, with each selling more than one and half million stand-alone units.

Figure 5 illustrates the sales of consoles and bundles over time. The video game industry exhibits a large degree of seasonality in console sales with significant increases in the months of November and December. Therefore, accounting for the large degree of seasonality in our empirical models is important. Figure 5 also illustrates that sales of pure hardware dominated sales of bundles in all months including holiday periods, and that bundle sales were prevalent throughout the intermediate months—the average duration of a bundle was approximately 16 months. In Figure 6 we present the prices of each console and bundle to illustrate declining prices, which is prevalent in durable goods, and to more clearly compare prices of consoles to bundles.

5. Empirical Support

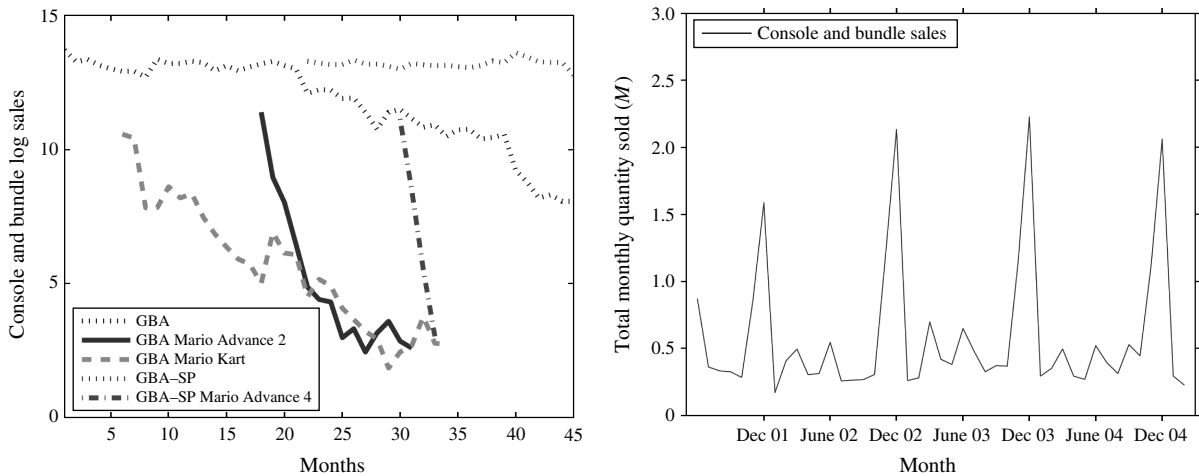
We estimate the impact of bundling on associated prices by using regressions. Denote the price of product i in period t by Y_{it} . Prices depend on a vector of observed characteristics, X_{it} , and an indicator τ_{it} which equals one if a bundle is present in period t and zero otherwise. Let ε_{it} represent the error term in the price equations, and assume that $E[\varepsilon_{it}] = 0$, $\varepsilon_{it} \perp X_{it}$, and $\tau_{it} \perp X_{it}$. We also assume that prices in levels or logs (Y_{it}) are linear in the observable covariates such that

$$Y_{it} = \alpha\tau_{it} + X'_{it}\beta + \varepsilon_{it}, \quad (1)$$

where α and β are parameters. Moreover, we assume the effect of bundling has the same impact for all i and t . We therefore do not allow the impact of bundling to increase or decrease over time.

From our theoretical model above, we know a platform will implement mixed bundling as long as profit

Figure 5 Console and Bundles Sales



from doing so is greater than when it is not implemented, i.e., $\Pi(\text{Bundling}) - \Pi(\text{No Bundling}) > 0$. Let IN_t be an index of the differential benefit for the platform in period t from implementing mixed bundling. The index is a function of observed (Z_t) and unobserved (ξ_t) variables

$$IN_t = \Pi_t(\text{Bundling}) - \Pi_t(\text{No Bundling}) = Z_t' \gamma + \xi_t. \quad (2)$$

Thus, bundling will occur in period t ($\tau = 1$) if and only if $IN_t > 0$, and no bundling takes place otherwise, resulting in a standard discrete choice model if $\xi_t \perp Z_t$. However, given that a platform makes a strategic decision as to when to offer a bundle, there will be endogeneity bias if $E[\varepsilon_{it} \tau_{it}] \neq 0$. Consequently, we control for such bias with the implementation of an instrumental variable (IV) estimator. From our theory above, our discussion on the role of α in particular, we know IN_t is a function of the installed base (α). Our model determines that bundling becomes more irrelevant as the installed base or the number of

Table 4 First-Stage Results of Excluded Instruments

$I(\text{Bundle})$	H_1	H_2	H_3
IB_{t-1}	4.16e-07** (7.21e-08)	3.37e-07** (8.92e-08)	2.46e-07** (1.23e-09)
IB_{t-1}^2	-8.11e-15** (1.02e-15)	-6.62e-15** (9.06e-16)	-6.41e-15** (4.21e-17)
Partial R^2	0.6094	0.3780	0.6248
F-stat. of excluded instruments	33.34	14.23	398.02
Number of observations	67	94	13,743

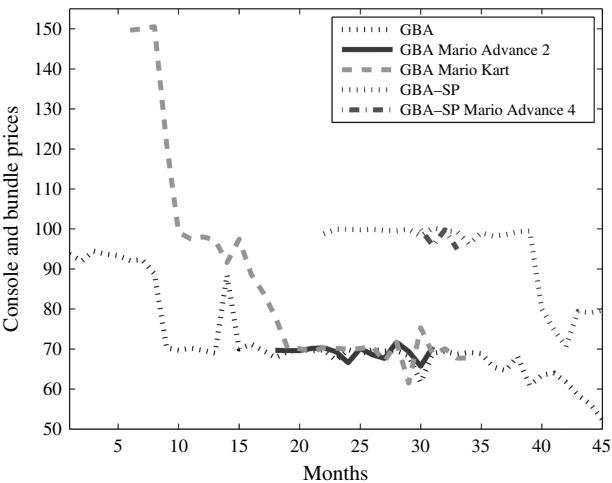
Note. Nonexcluded instruments are not reported.
**Significant at 95%.

new consumers purchasing the console tends toward zero. The exclusion restriction or instrument (Z_t) we employ to identify the bundling effect is the measure of the installed base in period $t - 1$ (IB_{t-1}) and its corresponding squared value (IB_{t-1}^2).²⁰

As our theory predicts, we see a nonlinear effect (an inverted-U shape) of the instruments on the bundle indicator in the first-stage regression of the IV estimator, which is presented in Table 4.

Before we report the IV results, there are two important empirical concerns we need to address. The first is that perhaps numerous high price sensitivity shoppers enter the market during the holiday months of November and December and cause prices to fall during these months (e.g., Chevalier et al. 2003, Sudhir et al. 2005, Meza and Sudhir 2006), thus impacting our estimate of the presence of bundling on prices. To specifically control for the impact of numerous high price sensitivity shoppers entering the market on

Figure 6 Console and Bundles Prices



²⁰ An alternative approach to correcting this bias is to implement a simultaneous equations model with a nonlinear logit equation for the probability of bundling or a control function approach. Heckman and Robb (1985) show that when faced with a similar model structure, an IV estimator consistently estimates α without additional model assumptions.

prices, one should build a structural model like those in the previously mentioned papers. With a regression approach we cannot isolate the impact from other confounding effects. However, with the inclusion of an indicator variable for the month of November or December, we can control the effect along with any other reasons that are restricted to these two months, such as an increase in demand from existing consumers because of the holidays. We separately identify such an effect (we will discuss only the ordinary least squares (OLS) regression for simplicity) from the variation between the bundle indicator and our “seasonal” indicator variable. The variable we use to capture the possible influx of consumers with different price sensitivities during November and December again only picks up these month effects for each year, whereas the bundle indicator not only incorporates these months but also includes many other months over a stretch of some years. Thus, this variation in the data allows us to separately identify both effects.

The second concern is with regard to why we do not elect to include the number of video games in any of the following regressions. It is important to note that the inclusion of the number of video games in any of the regressions may seem like a natural covariate to control either the indirect network effect associated with the platform or software competition, but if the number of games were to be included, the assumption above regarding $\tau_{it} \perp X_{it}$ would be violated. Specifically, we do not include the number of games as a control because of the fact that the number of games is affected by whether a bundle is present or not. Imbens (2004) addresses the concern of including intermediate outcomes, like that of number of games, in a treatment regression and the pitfalls associated with it. He discusses that the only suitable control

variables for a treatment regression are those that are unaffected by treatment.

Our first empirical model determines whether the presence of bundles leads to lower stand-alone console prices. We analyze the impact mixed bundles have on stand-alone console prices by restricting the data to consist only of the two stand-alone consoles, the GBA and the GBA SP. Tables 5 and 6 present the results in levels and logs, respectively. In each table, the first column reports the results from a simple regression without correcting for any endogeneity bias. The second column presents the results in which the endogeneity bias is corrected with the use of an IV estimator. We included in these regressions covariates that control for console age and the presence of an additional console (GBA or GBA SP) in period t , an indicator variable for the month of November or December, and a time trend. To determine whether console fixed effects or a pooled model should be accepted, we implement a Hausman test, which rejects the regression with fixed effects for the pooled regression. This test result should not be surprising given that the internal parts of both devices are identical. The coefficient of interest, the indicator variable for the presence of a bundle, is negative and significantly different from zero in each of the two regressions, informing us that our first theoretical prediction is consistent with the data.

Next, we analyze our second prediction, whether the component bundled software price increases when a bundle is introduced, by restricting the data set to include only software that was bundled with a console. We follow a similar methodology in the above analysis to analyze the bundle effect on price. The third columns of Tables 5 and 6 show OLS regressions that do not correct for the bundle endogeneity and do not include software fixed effects. Similar

Table 5 Empirical Results—Price Levels

Price	H_1		H_2		H_3	
	1-OLS	2-IV	1-OLS	2-IV	1-OLS	2-IV
$I(\text{Bundle})$	−4.974** (1.3602)	−3.243** (1.6971)	0.337** (0.1405)	0.562** (0.2525)	−3.744** (0.2513)	−5.370** (0.2161)
Age	−1.338** (0.0781)	−1.351** (0.0740)	0.023** (0.0075)	0.017** (0.0070)	−0.234** (0.0325)	−0.215** (0.0061)
Time trend	0.195* (0.1418)	0.248* (0.1496)	0.016** (0.0071)	0.022** (0.0097)	−0.391** (0.0318)	−0.447** (0.0100)
$I(\text{Nov Dec})$	0.363 (2.2947)	0.043 (2.1929)	−0.458** (0.1805)	−0.545** (0.1921)		
$I(\text{AdditionalConsole})$	10.968** (2.8553)	10.476** (2.7660)				
Number of observations	69	67	97	94	14,435	13,743

Notes. Month fixed effects are employed in H_3 . All models report heteroskedasticity and autocorrelation consistent standard errors.

*Significant at 90%; **significant at 95%.

Table 6 Empirical Results—Log(Price)

Log(Price)	H_1		H_2		H_3	
	1-OLS	2-IV	1-OLS	2-IV	1-OLS	2-IV
$I(\text{Bundle})$	−0.059** (0.0165)	−0.034* (0.0213)	0.011** (0.0046)	0.018** (0.0083146)	−0.097** (0.0058)	−0.167** (0.0111)
<i>Age</i>	−0.016** (0.0001)	−0.017** (0.0009)	0.001** (0.0002)	0.001** (0.0002)	−0.014** (0.0007)	−0.012** (0.0003)
<i>Time trend</i>	0.002 (0.0016)	0.003* (0.0017)	0.001** (0.0002)	0.001** (0.0003)	−0.014** (0.0007)	−0.017** (0.0004)
$I(\text{Nov Dec})$	0.002 (0.0275)	−0.002 (0.0262)	−0.015** (0.0060)	−0.018** (0.0064)		
$I(\text{Additional Console})$	0.128** (0.0349)	0.121** (0.0338)				
Number of observations	69	67	97	94	14,435	13,743

Notes. Month fixed effects are employed in H_3 . All models report heteroskedasticity and autocorrelation consistent standard errors.

*Significant at 90%; **significant at 95%.

to the above, we perform a Hausman test to determine whether fixed effects or a pooled regression is more appropriate. We determine that we cannot reject the pooled regression. The fourth columns report the results for the model, which corrects the endogeneity bias because we use the same exclusion restriction to identify the bundle effect as in the second columns. As the tables illustrate, the OLS estimates in the third columns underestimate the treatment effect due to the correlation between the error term and the bundle indicator. The result illustrates that bundling has a causal effect on price, which leads to higher component prices for the bundled software and is consistent with our theoretical prediction. It is important to discuss that this result is not being identified from the fact that in high demand periods (or in low demand periods for that matter) software is subsidized when in a bundle, causing our empirical model to interpret a higher price for stand-alone products. Because again the data used to investigate this prediction are *only* individual sales data from the three bundled games (e.g., data of software when sold individually), our dependent variable is the stand-alone price of the software and not a mixture of effective game price and stand-alone price. Crudely, identification originates from variation in stand-alone bundle game prices and the presence of bundles over time after controlling for selection. Last, we control for the concern that numerous high price sensitivity shoppers enter the market during the holiday months leading to lower prices with a November or December indicator variable. Like the first prediction, we also include additional covariates, game age and a market time trend.

Our third prediction determines whether the royalty rate levied by Nintendo decreases when mixed bundles are offered. It is important to point out that royalty rates are not exogenous and fixed; they do

fall in the video game industry, as is evident by a 2003 Reuters story that announced a Nintendo royalty adjustment (Paul 2003). Additionally, the game maker THQ (2011, p. 5) reported in its 10-K evidence that platforms do change their fee structure: “[T]he amounts charged by the platform manufacturers for both console discs and handheld cartridges include a manufacturing, printing and packaging fee as well as a royalty for the use of the platform manufacturer’s name, proprietary information and technology, and are subject to adjustment by the platform manufacturers at their discretion.” Likewise, Electronic Arts (2010, p. 19) also reported in its 10-K the ability of platforms to change its royalty fee: “these companies have retained the flexibility to change their fee structures... for their consoles.” Unfortunately, royalty rates are unobserved, and we are unable to directly regress the royalty rates on a set of covariates. We, nonetheless, are able to determine whether the royalty rates decrease indirectly with a simple assumption regarding the marginal cost of independent games. We assume the marginal cost of an independent piece of software in a given period t takes the form $mc_{jt} = mc_j + r_t$, where mc_j is a constant plus the time varying royalty rate, r_t . With this assumption, we can infer that the royalty rate declines if independent software prices decrease under the existence of bundles. We are aware that such an assumption is quite strong, but one can think of the following analysis as a first approximation of the causal effect. We analyze the last theoretical prediction with data that are restricted to include all available third party software (over 14,000 observations). If our theoretical model is consistent with the data, we expect the sign of the bundle measure to be negative, indicating the royalty rate declines as bundles enter.

There are, however, several alternative explanations that also would lead to a decline in software prices

in the data and, thus, if not accounted for, will confound the bundle indicator estimate. The first explanation is the entrance of lower-quality independent software products. As lower-quality games enter over time, these games will be priced lower, leading to a negative parameter estimate for the bundle indicator. We test, like the above two predictions, whether a fixed effect model is more appropriate than a pooled model. We determine with the inclusion of a market time trend that a Hausman test cannot reject the pooled model, eliminating the first concern. The second explanation is one we touched upon above: dynamic evolution of consumer price sensitivity over time (e.g., more price sensitive consumers enter during the holiday period). We address this concern by deviating from the above analysis and including month of year indicator variables given the larger data set and thus more power to estimate a larger set of parameters.

The results are again in Tables 5 and 6. There is clear evidence to support our theoretical prediction in levels and logs. In each of the models we empirically observe the predicted relationship between the presence of a bundle and price.

5.1. Robustness

Employing an IV estimator is not the only method to address the endogeneity concern surrounding the bundle indicator variable. An alternative approach is to employ a difference-in-differences (DinDs) estimator and gather data from a suitable comparison group that does not experience the introduction of bundles (a control group) and compare the outcomes from these two groups. Data from the home video game console market would be an ideal control given the video games available for the portable consoles and for Nintendo's home console substantially overlap. These data will not suffice because they too include bundles. Another such alternative is to employ data from the computer video game market as the control, given this market of software never receives or experiences the presence of a bundle. Nonetheless, such a control is only available for the software markets. We therefore implement a DinD estimator as a robustness check for our second and third predictions above.

With the availability of computer video game data from July 2002 through February 2005, we implement a DinDs estimator to recover the bundle effect on prices.²¹ We are certainly aware that the implementation of a DinDs estimator does not require means to match, only that the trends in the absence of the intervention are the same for both groups. Consequently,

we test whether such trends are equivalent by restricting the data to only the nontreatment period and allowing month fixed effects to be control and treatment specific. If we cannot reject the null hypothesis that the month effects are equivalent, then the computer video game data can be used as a proper control. We determine we cannot reject the null.

Additionally, we adapt the parametric forms above to account for state dependence in pricing by including one period of lagged outcomes as an additional robustness check:

$$Y_{it}(\tau) = \rho Y_{it-1} + \alpha \tau_{it} + X'_{it}\beta + \gamma_i + \varepsilon_{it} \quad (3)$$

We run each model using the Arellano and Bond (1991) generalized method of moments estimator. We employ this model for each of the three predictions. This model addresses not only the possible concern of state dependence in pricing but also the issue of endogeneity of bundles. This estimator uses an unbalanced set of instruments to correct for the correlation between prices in t and $t - 1$ as well as the endogenous bundle indicator variable. For instance, for data of three periods long, $t = 3$, one can use y_{i1} , for $t = 4$, one can use y_{i1} and y_{i2} , and so on, as instruments. Furthermore, we can reject the second-order autocorrelation in the residuals (test statistic presented in Tables 7 and 8); otherwise, the Arellano and Bond (1991) estimator would be inconsistent. The results of these models are presented in Tables 7 and 8.

In summary, we implement IV estimators to determine whether the above theoretical model is consistent with the data from the portable video game industry. In addition to the IV methodology, we implement DinD and dynamic panel data methodologies as robustness checks, when applicable. Specifically, when employing a DinD estimator, we use the computer video game market as the control group given the inability of this market to offer hardware and software bundles. Determining whether our estimates are unbiased in our DinD estimator depends on the identifying assumption that the time effects in the two markets are identical, whereas the IV methodology hinges on determining a proper exclusion restriction.

With each of the three theoretical predictions being present in the data, and with the implementation of three different methodologies, we conclude that our theoretical monopoly model of mixed bundling in the two-sided market setting is consistent with the portable video game market. Nonetheless, we by no means conclude that the above theoretical model is the only correct model that generates these results. There may be alternative theoretical models that produce predictions consistent with the empirical data.

²¹ Given the computer game data do not originate until July 2002, we restrict the treated group date to also originate in July 2002 in the each of the two DinD estimates.

Table 7 Empirical Robustness Results—Price Levels

	H_1	H_2		H_3	
Price	Dynamic	DinDs	Dynamic	DinDs	Dynamic
$I(Bundle)$	−1.880* (1.2264)	0.9133* (0.5426)	0.238** (0.0918)	−3.158** (0.2217)	−0.200** (0.0908)
Age	−5.932 (6.5890)	−0.0981* (0.0560)	−1.949** (0.7718)	−0.086** (0.0137)	−0.004 (0.0515)
$Time\ trend$	5.415 (6.5124)	—	1.968** (0.7650)	—	−0.063 (0.0517)
$I(Nov Dec)$	0.799** (0.2982)	—	−0.338* (0.1778)	—	—
$Price_{t-1}$	0.589** (0.1081)	—	0.420** (0.0765)	—	0.802** (0.0102)
$Competition$	5.900** (0.0750)	—	—	—	—
Console/game FEs	—	Yes	—	Yes	—
Number of observations	65	6,685	91	107,330	13,098
Test statistic (prob. > T)	1.41 (0.1589)	1.27 (0.1919)	0.23 (0.23565)	1.21 (0.2322)	1.58 (0.1134)

Notes. The first and second columns include an unreported constant. Month fixed effects (FEs) are not reported for the H_3 dynamic model. Test statistic for DinDs: Month FE of control = month FE of treated. Test statistic for dynamic: Arellano and Bond test for zero autocorrelation in first differences of error.

*Significant at 90%; **significant at 95%.

Table 8 Empirical Robustness Results—Log(Price)

	H_1	H_2		H_3	
Log(Price)	Dynamic	DinDs	Dynamic	DinDs	Dynamic
$I(Bundle)$	−0.024* (0.0129)	0.026* (0.016)	0.007** (0.0030)	−1.250** (0.0176)	−0.102* (0.0056)
Age	−0.291 (0.3342)	−0.003* (0.0017)	−0.226** (0.8888)	−0.011** (0.0011)	−0.0004 (0.0043)
$Time\ trend$	0.284 (0.3329)	—	0.227** (0.8886)	—	−0.008* (0.0043)
$I(Nov Dec)$	0.008** (0.0040)	—	−0.011* (0.0059)	—	—
$Price_{t-1}$	0.551** (0.1083)	—	0.414** (0.0766)	—	0.678** (0.0158)
$Competition$	0.074** (0.005)	—	—	—	—
Console/game FEs	—	Yes	—	Yes	—
Number of observation	65	6,685	91	107,330	13,098
Test statistic (prob. > T)	1.41 (0.1589)	1.31 (0.1619)	0.29 (0.7681)	1.21 (0.2322)	1.38 (0.1688)

Notes. The first and second columns include an unreported constant. Month fixed effects (FEs) are not reported for the H_3 dynamic model. Test statistic for DinDs: Month FE of control = month FE of treated. Test statistic for dynamic: Arellano and Bond test for zero autocorrelation in first differences of error.

*Significant at 90%; **Significant at 95%.

6. Conclusion

This paper establishes a moderator between the existing bundling theory and two-sided markets literature. In addition to filling the theoretical gap, it provides a possible explanation for a few peculiar data trends that run contrary to the pricing structure of bundling in the one-sided market—some stand-alone component prices fall with the introduction of bundling. We further extend the traditional literature on bundling and the burgeoning literature on two-sided markets

by presenting a theoretical monopoly model of mixed bundling in the context of the portable video game console market, a prototypical two-sided market.

Deviating from both the traditional bundling literature and standard two-sided markets literature, we find that under mixed bundling, both the stand-alone platform price on the consumer side and the royalty rate on the content developer side are lower than their counterparts under independent pricing equilibrium. In our setting, mixed bundling acts as a price

discrimination tool segmenting the market more efficiently as well as functions as a coordination device helping solve “the chicken or the egg” problem in two-sided markets. We further provide clear empirical evidence for the model predictions with new data from the portable video game console market.

Despite the model being somewhat stylized, there are several general insights we can draw from for business and public policy.

First, our model confirms that consumer heterogeneity is the primary reason for the firm to adopt a bundling strategy. More importantly, in the context of two-sided markets and network effect, bundling as a price discrimination tool can further help in restructuring the platform’s pricing structure and increase its profit. Because of the cross-side network effect, business managers can set prices at low levels without suffering any loss. Therefore, failing to take this indirect network effect into consideration may severely underestimate the impact of promotion and penetration, especially in two-sided markets where the demand is more elastic, thanks to the network effect.

Turning to public policy, bundling has been a heated antitrust issue. When lower prices are associated with bundling, concerns regarding predatory pricing and exclusion may arise. Although we cannot draw a general policy conclusion in favor of bundling in our analysis, our model does point to a possibility of welfare-enhancing bundling in two-sided markets. Through bundling, the platform can internalize the cross-market externality by better segmenting consumers and coordinating two sides, leading to consumers gaining, too, when the platform’s profit increases.

With this paper being the first to link mixed bundling and two-sided markets, there are some important limitations to our study that may serve as potential directions for further research. First, we adopt a static model as almost all previous bundling or two-sided markets studies have done; however, the market is inherently dynamic. Theoretically, introducing dynamics into bundling decisions in the two-sided market context will considerably complicate the model and will likely force a loss of tractability for analytical solutions. Empirically, Derdenger and Kumar (2013) present a dynamic structural model to examine how bundling affects sales of video game consoles and games.

Second, we do not model the independent content developer side in detail. This is because modeling developer’s dynamic pricing and entry decisions would significantly complicate our model without providing too much insight into the main topic—the platform’s incentive to bundle. It would be interesting to extend our model to look into some other topics, such as how bundling affects independent content providers’ decisions on when to enter, when

to release their games, how to price, and how to compete against other content.

Third, probably the most fruitful area of research moving forward is to introduce competition into the platform market so that one may understand how that affects pricing decisions. Nonetheless, our monopoly model does provide important insight into the optimal pricing of mixed bundles in two-sided markets, which is quite useful for marketing managers given the existence of such monopoly markets and the prevalence of asymmetric structure of most of two-sided markets.

Acknowledgments

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Appendix

Table A.1 provides the glossary of notations.

Theoretical Proofs²²

PROOF OF LEMMA 1. We first show that the quality of independent content d under (i) is lower than that under (ii), for any given p_g . Then we find that π^{lp} under (i) must be lower than that under (ii).²³

For any given p_c and p_g , let $E_{(i)}(d) \equiv [1 - (p_c - \beta d) + 1 - p_g]^2 / (2t)$, and let $E_{(ii)}(d) \equiv [1 - (p_c - \beta d) + (1 - p_g)^2 / 2] / t$. Thus, d is determined by

- (i) $d = (\phi - r) \cdot [\alpha + (1 - \alpha) \cdot E_{(2i)}(d)]$,
- (ii) $d = (\phi - r) \cdot [\alpha + (1 - \alpha) \cdot E_{(2ii)}(d)]$.

CLAIM 1. $E_{(i)}(d) < E_{(ii)}(d)$, $\forall p_g, d$.

PROOF OF CLAIM 1. $E_{(i)}(d) = [1 - (p_c - \beta d) + 1 - p_g]^2 / (2t) \leq (1 - p_g)^2 / (2t) < E_{(ii)}(d)$, where the first inequality follows from $p_c - \beta d \geq 1$ and the second inequality follows from $1 > p_c - \beta d$.

CLAIM 2. $0 < \partial E_{(i)} / \partial d < \beta / t = \partial E_{(ii)} / \partial d$, $\forall d$.

PROOF OF CLAIM 2. $\partial E_{(i)} / \partial d = [1 - (p_c - \beta d) + 1 - p_g] / t \cdot \beta \leq (1 - p_g) / t \cdot \beta < \beta / t = \partial E_{(ii)} / \partial d$, where the first inequality results from $p_c - \beta d \geq 1$, and the second follows from $p_g > 0$.

It is easy to see $E_{(i)}(0) > 0$ and $E_{(ii)}(0) > 0$. So our assumption in §3.1 that $t > (1 - \alpha)\beta(\phi - r)$ ensures d has a unique positive solution, as shown in Figure A.1.

From Figure A.1 and the two claims above, we can infer that $d_{(i)}^* < d_{(ii)}^*$, $\forall p_g$.

²² The Mathematica codes for computation are available on authors’ websites.

²³ The proof for Π^b is parallel, with the only modification being replacing p_g here by P_g^c .

Table A.1 Glossary of Notations

p_c, P_c	Prices for accessing the platform under independent pricing and under bundling, respectively
p_g, P_g	Integrated content prices under independent pricing and under bundling, respectively
P_B	Bundle price under bundling
P_g^e	Effective price of the integrated content under bundling
r, R	Royalty rates under independent pricing and under bundling, respectively
t	Transportation cost per unit of length
α	Fraction of installed base
β	Marginal utility of the content
d, D	Quality of independent content under independent pricing and under bundling, respectively
x	Consumer's distance from the origin
$u_{\text{installed}}$	Installed base consumer's gross utility from the integrated content
v_g	New consumer's intrinsic value for the integrated content
$q_{\text{new}}, Q_{\text{new}}$	Fraction of potential new consumers who purchase the access to the platform under independent pricing and under bundling, respectively
$q_{\text{platform-only}}, Q_{\text{platform-only}}$	Fraction of potential new consumers who purchase only the access to the platform under independent pricing and under bundling, respectively
$q_{\text{both}}, Q_{\text{both}}$	Fraction of potential new consumers who purchase both the access to the platform and the integrated content under independent pricing and under bundling, respectively
π^{IP}, π^B	Platform's profits under independent pricing and under bundling, respectively

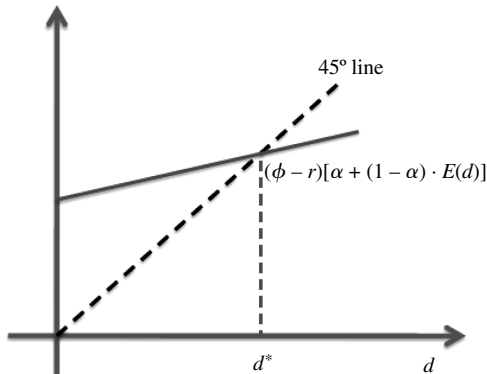
CLAIM 3. $\partial d_{(i)}^*/\partial p_c < 0$.

PROOF OF CLAIM 3. $\partial E_{(i)}(d)/\partial p_c = -(1 - (p_c - \beta d) + 1 - p_g)/t < 0$. The claim follows from the diagram in Figure A.1.

PROOF OF PROPOSITION 1. When \bar{R} is exogenously given, the following applies:

$(p_c^{*\bar{R}}, p_g^{*\bar{R}})$ for IP are given by	$(P_c^{*\bar{R}}, P_g^{e*\bar{R}})$ for bundling are given by
$\partial \pi^{IP}(p_c, p_g, \bar{R})/\partial p_c = 0$	$\partial \pi^{IP}(P_c, P_g^e, \bar{R})/\partial P_c = 0$,
$\partial \pi^{IP}(p_c, p_g, \bar{R})/\partial p_g = 0$,	$\partial \pi^{IP}(P_c, P_g^e, \bar{R})/\partial P_g^e = s$.
where $s = \alpha > 0$.	

Figure A.1 Determination of the Number of Game Developers



Consequently, we can focus on the properties of $\pi^{IP}(x, y, \bar{z})$ for comparative statics on s . Denote its Hessian matrix as $H \equiv D_i D_j [\pi^{IP}(x, y, \bar{z})] = [h_{ij}]$.

Standard comparative statics gives the following:

- (Change in p_g):

$$\frac{\partial y}{\partial s} = \frac{h_{11}}{|H|}$$

because

$$h_{11} = -\frac{2}{t - (1 - \alpha)\beta(\phi - z)} < 0,$$

and therefore

$$\frac{\partial y}{\partial s} < 0.$$

- (Change in $(p_c + p_g)$):

$$\frac{\partial x}{\partial s} + \frac{\partial y}{\partial s} = \frac{h_{11} - h_{12}}{|H|}$$

because

$$h_{11} - h_{12} = -\frac{3y}{t - (1 - \alpha)\beta(\phi - z)} < 0,$$

and therefore

$$\frac{\partial x}{\partial s} + \frac{\partial y}{\partial s} < 0.$$

- (Change in p_c):

$$\frac{\partial x}{\partial s} = \frac{-h_{12}}{|H|}.$$

It will depend on the sign of

$$-h_{12} = \frac{2 - 3y}{t - (1 - \alpha)\beta(\phi - z)}.$$

Thus, if $2/3 > P_g^{e*\bar{R}}$, then

$$\frac{\partial x}{\partial s} > 0$$

because

$$\left. \frac{\partial B}{\partial y} \right|_{y=1/2} = -\frac{1 + 4x + 4\bar{z}}{4[t - (1 - \alpha)\beta(\phi - z)]} < 0,$$

and therefore

$$P_g^{e*\bar{R}} < \frac{1}{2} < \frac{2}{3}.$$

Hence, $\partial x/\partial s > 0$.

PROOF OF PROPOSITION 2. When R is endogenously determined, the following applies:

(p_c^*, p_g^*, r^*) for IP are given by	(P_c^*, P_g^{e*}, R^*) for bundling are given by
$\partial \pi^{IP}(p_c, p_g, r)/\partial p_c = 0$,	$\partial \pi^{IP}(P_c, P_g^e, R)/\partial P_c = 0$,
$\partial \pi^{IP}(p_c, p_g, r)/\partial p_g = 0$,	$\partial \pi^{IP}(P_c, P_g^e, R)/\partial P_g^e = s$,
$\partial \pi^{IP}(p_c, p_g, r)/\partial r = 0$,	$\partial \pi^{IP}(P_c, P_g^e, R)/\partial R = 0$.
where $s = \alpha > 0$.	

Similarly, we can focus on the properties of $\pi^{IP}(x, y, z)$ for comparative statics on s . Denote its Hessian matrix as $K \equiv D_i D_j [\pi^{IP}(x, y, z)] = [k_{ij}]$.

Standard comparative statics gives the following:

- (Change in p_g):

$$\frac{\partial y}{\partial s} = \frac{\begin{vmatrix} k_{11} & k_{13} \\ k_{31} & k_{33} \end{vmatrix}}{|K|}$$

because

$$\begin{vmatrix} k_{11} & k_{13} \\ k_{31} & k_{33} \end{vmatrix} > 0, |K| < 0$$

from negative definiteness of K , and therefore $\partial y/\partial s < 0$.

- (Change in r):

$$\frac{\partial z}{\partial s} = -\frac{\begin{vmatrix} k_{11} & k_{12} \\ k_{31} & k_{32} \end{vmatrix}}{|K|}$$

because

$$\begin{vmatrix} k_{11} & k_{12} \\ k_{31} & k_{32} \end{vmatrix} < 0,$$

and therefore

$$\frac{\partial z}{\partial s} < 0.$$

- (Change in p_c):

$$\frac{\partial x}{\partial s} = -\frac{\begin{vmatrix} k_{12} & k_{13} \\ k_{32} & k_{33} \end{vmatrix}}{|K|}$$

because

$$\begin{vmatrix} k_{12} & k_{13} \\ k_{32} & k_{33} \end{vmatrix} < 0,$$

and therefore

$$\frac{\partial x}{\partial s} < 0.$$

- (Change in $(p_c + p_g)$):

$$\frac{\partial x}{\partial s} + \frac{\partial y}{\partial s} < 0.$$

Below is the proof showing that total surplus under bundling is higher than that under IP, when royalty rate \bar{R} is exogenously determined.

First, the change in stand-alone price of the integrated content for the installed base is a direct transfer to the platform resulting in total surplus remaining unchanged. Consequently, total surplus is dependent upon the change in surplus of new consumers and game developers.

First, we show that mixed bundling increases participations on both sides. Note that the fraction of potential new consumers who newly purchase is

$$q_{\text{new}} = \frac{\alpha\beta(\phi - \bar{R}) + [1 - p_c + (1 - p_g)^2/2]}{t - (1 - \alpha)\beta(\phi - \bar{R})},$$

and the quality of independent content is

$$d = \frac{\phi - \bar{R}}{t - (1 - \alpha)\beta(\phi - \bar{R})} \cdot \left\{ \alpha t + (1 - \alpha) \left[1 - p_c + \frac{(1 - p_g)^2}{2} \right] \right\}.$$

So the determinant is the change in $\Gamma \equiv 1 - p_c + (1 - p_g)^2/2$ under two regimes:

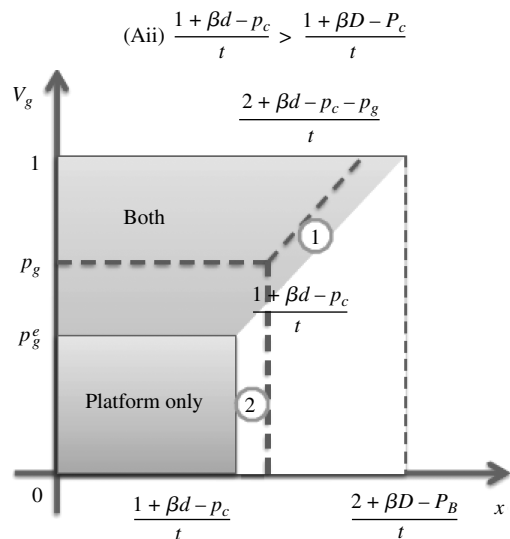
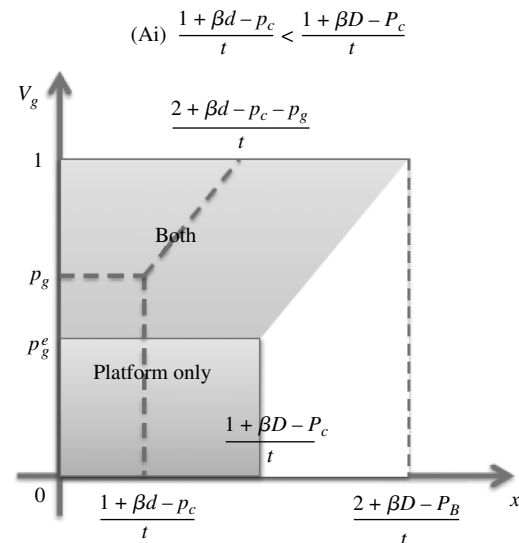
$$\begin{aligned} \frac{\partial \Gamma}{\partial s} &= - \left[\frac{\partial p_c}{\partial s} + (1 - p_g) \cdot \frac{\partial p_g}{\partial s} \right] = - \left[\frac{-h_{12}}{|H|} + (1 - y) \cdot \frac{h_{11}}{|H|} \right] \\ &= \frac{y}{t - (1 - \alpha)\beta(\phi - \bar{z}) \cdot |H|} > 0 \\ &\quad \left(\text{because } h_{11} = -\frac{2}{\Omega(\bar{z})}, h_{12} = -\frac{2 - 3y}{\Omega(\bar{z})} \right). \end{aligned}$$

So both q_{new} and D are higher under mixed bundling.

From Proposition 1, we know that when \bar{R} is exogenously given, $P_B < p_c + p_g$, $P_g^e < p_g$, $P_c > p_c$. Therefore, there are two possible distribution changes in new consumers as shown in Figure A.2.

In panel (Ai), it is easy to see both participation and distribution are increased under mixed bundling. So total surplus must increase in this case. In panel (Aii), although the

Figure A.2 The Change of New Consumers' Participation After Mixed Bundling



total participation from the new consumers q_{new} increases as shown above, there is a caveat in the distribution change—area 2 is lost, whereas area 1 is gained. Note the total surplus gains (area 1) are all above P_B , whereas the total surplus losses (area 2) are all below P_B . Combined with the fact that the overall participation from new consumers are higher, we can conclude that the gains dominate losses in panel (Aii).

Profitability of Bundling When Preferences Are Positively Correlated

One may wonder about the correlation of preferences between goods and its role on the profitability of bundling. We assume new consumers' valuations for the platform and the integrated content are independent, which may appear peculiar for some empirical applications when one considers positively correlated preferences. However, as shown in our analysis below, the main results of this paper still hold when new consumers' valuations for the platform and the integrated content are positively correlated.

Let us consider a setup exactly as the one in §2, with the exception that new consumers' valuations for the platform and the integrated content are perfectly correlated. To be more specific, the gross utility associated with a new consumer situated at point x who elects to purchase access to only platform is $v - tx + \beta d$, whereas it is $2v - tx + \beta d$ if he purchases both the platform access and the integrated content. Here, we assume consumers' valuations for the platform and for the integrated content are perfectly correlated, that is, $v_c = v_g = v$. This is an extreme case for the positively correlated case, but serves analytically sufficient to illustrate our point. Similarly, we assume that v is drawn from the uniform distribution $U(\cdot)$ on $[0, 1]$.

Parallel analysis gives the new consumers' demand as shown in Figure A.3:

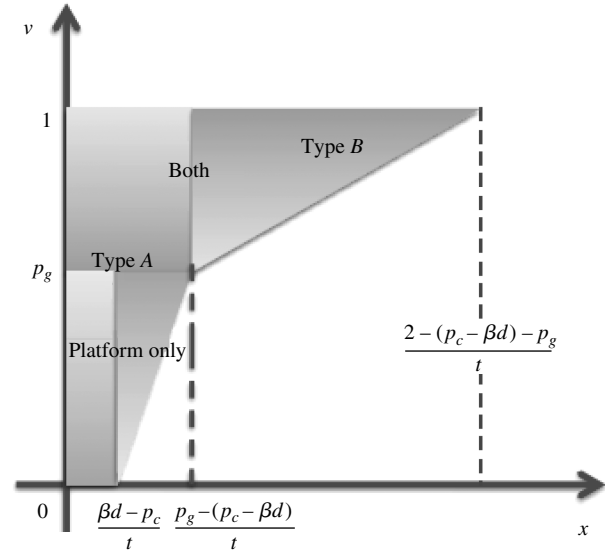
$$q_{\text{platform}} = \frac{p_g(p_g/2 + \beta d - p_c)}{t}, \quad q_{\text{both}} = \frac{(1 - p_g)(1 + \beta d - p_c)}{t}.$$

$$q_{\text{new}}^{(b2)} = q_{\text{platform}} + q_{\text{both}} = \frac{1/2 + \beta d - p_c + (1 - p_g)^2/2}{t}.$$

Comparing with the independent preferences case, the two demand systems look similar. This is because, for new consumers, access to the platform is essential. Thus, if new consumers decide to purchase, there are only two options for them: (1) buy both the access to platform and the integrated content from the platform or (2) buy only the access to the platform. Moreover, the borderline case for these two options is if $v - p_g \geq 0$, which is exactly the same as when consumer preferences are independent. This result is true not only for the perfectly correlated case, but also for any positively correlated case. Furthermore, if we write down the profit functions of two regimes for any positively correlated case, they will be in the same pattern as those for the independent case—the structure of Π^B will be identical to π^{IP} except for an extra term representing the surplus gain from the installed base. All of these similar functional forms tell us that the main results will hold when preferences are positively correlated.

Moreover, they also confirm that the key reason for bundling adoption in our paper is the heterogeneity of

Figure A.3 New Consumer Demand with Perfectly Correlated Preferences



valuations on the integrated content between installed base and new consumers. And the heterogeneity of valuations on the integrated content within new consumers is not critical. Consequently, positively correlated preferences within new consumers will not change our main results. We choose the independent preferences, because our objective is to use a simple model to illustrate the interesting and surprising pricing pattern shown in the paper.

Derivation of (IP-Profit-Decomposed)

Recall that in §3.1,

$$q_{\text{new}} = \frac{1 - p_c + (1 - p_g)^2/2}{t} + \frac{\beta}{t} \cdot d^*,$$

$$q_{\text{both}} = \frac{(1 - p_g)(1 - p_c) + (1 - p_g)^2/2}{t} + (1 - p_g) \cdot \frac{\beta}{t} \cdot d^*.$$

So (IP-Profit) becomes

$$\begin{aligned} \pi^{IP} &= \alpha \cdot p_g + (1 - \alpha) \cdot (p_c \cdot q_{\text{new}} + p_g \cdot q_{\text{both}}) + r \cdot [\alpha + (1 - \alpha) \cdot q_{\text{new}}] \\ &= \alpha \cdot p_g + (1 - \alpha) \cdot \left\{ p_c \cdot \left[\frac{1 - p_c + (1 - p_g)^2/2}{t} + \frac{\beta}{t} \cdot d^* \right] \right. \\ &\quad \left. + p_g \cdot \left[\frac{(1 - p_g)(1 - p_c) + (1 - p_g)^2/2}{t} + (1 - p_g) \cdot \frac{\beta}{t} \cdot d^* \right] \right\} \\ &\quad + r \cdot \left\{ \alpha + (1 - \alpha) \cdot \left[\frac{1 - p_c + (1 - p_g)^2/2}{t} + \frac{\beta}{t} \cdot d^* \right] \right\} \\ &= \underbrace{\alpha \cdot p_g + (1 - \alpha) \cdot \left[p_c \cdot \frac{1 - p_c + (1 - p_g)^2/2}{t} + p_g \cdot \frac{(1 - p_g)(1 - p_c) + (1 - p_g)^2/2}{t} \right]}_{A(p_c, p_g)} \\ &\quad + \underbrace{(1 - \alpha) \cdot [p_c + p_g(1 - p_g)] \cdot \frac{\beta}{t} \cdot d^*}_{(1)} \\ &\quad + r \cdot \underbrace{\left\{ \alpha + (1 - \alpha) \cdot \left[\frac{1 - p_c + (1 - p_g)^2/2}{t} + \frac{\beta}{t} \cdot d^* \right] \right\}}_{(2)}. \end{aligned}$$

The definition of $A(p_c, p_g)$ is given in Footnote 15.

Note the equilibrium

$$d^* = (\phi - r) \cdot \frac{\alpha + (1 - \alpha) \cdot ((1 - p_c + (1 - p_g)^2)/2)/t}{1 - ((1 - \alpha)\beta(\phi - r))/t}$$

$$= \frac{(\phi - r) \cdot B(p_c, p_g)}{1 - ((1 - \alpha)\beta(\phi - r))/t}$$

$$\langle 1 \rangle = (1 - \alpha) \cdot [p_c + p_g(1 - p_g)] \cdot \frac{\beta}{t} \cdot d^*$$

$$= \beta \cdot \frac{1 - \alpha}{t} \cdot [p_c + p_g(1 - p_g)] \cdot \frac{(\phi - r) \cdot B(p_c, p_g)}{1 - ((1 - \alpha)\beta(\phi - r))/t}$$

$$= \beta \cdot \frac{1 - \alpha}{t} \cdot [p_c + p_g(1 - p_g)] \cdot C(p_c, p_g, r).$$

$$\langle 2 \rangle = r \cdot \left\{ \alpha + (1 - \alpha) \cdot \left[\frac{1 - p_c + (1 - p_g)^2/2}{t} + \frac{\beta}{t} \cdot d^* \right] \right\}$$

$$= r \cdot \left[\alpha + (1 - \alpha) \cdot \frac{1 - p_c + ((1 - p_g)^2)/2}{t} + (1 - \alpha) \cdot \frac{\beta}{t} \cdot d^* \right]$$

$$= r \cdot \left[B(p_c, p_g) + (1 - \alpha) \cdot \frac{\beta}{t} \cdot \frac{(\phi - r) \cdot B(p_c, p_g)}{1 - ((1 - \alpha)\beta(\phi - r))/t} \right]$$

$$= r \cdot B(p_c, p_g) \cdot \frac{t}{t - (1 - \alpha)\beta(\phi - r)}$$

$$= R(r) \cdot B(p_c, p_g).$$

The definitions of $B(p_c, p_g)$ and $R(r)$ can be found in Footnote 15.

It is worth noting that both $\langle 1 \rangle$ and $\langle 2 \rangle$ will disappear when $\beta = 0$, i.e., when consumers don't care about the independent content, and hence there will not be any interactions between the two sides resulting in no royalty revenue. So we have to include an indicator function $I_+\{\beta\}$ in front of $\langle 2 \rangle$. Thus, (IP-Profit-Decomposed) follows.

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