Upstream Bundling and Leverage of Market Power*

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Abstract

We present a novel rationale for bundling in vertical relations. In many markets, upstream firms compete to be in the best downstream slots (e.g., the best shelf in a retail store or the default application on a platform). Bundling by a multiproduct upstream firm can soften competition for slots by reducing rivals' value for them. This strategy does not rely on entry deterrence and can be achieved through contractual or even virtual tying. We also study the effects of upstream bundling on the downstream market; by intensifying competition there, bundling can leave consumers better-off even when there is foreclosure upstream.

Keywords: bundling, exclusion, vertical relations.

JEL Classification: L1, L4.

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1 Introduction

Consider manufacturers bidding to have their product stocked in the best shelf position in a retail store. One manufacturer is the sole supplier of a popular product (A), and one of several suppliers of another product (B). That manufacturer tells the retailer "you may only stock product A if you put my version of product B on the best shelf". Imagine what this might do to rivals' willingness to pay to be on the best shelf. They will realise that if they are placed on such a shelf then it must be in a store that does not offer the popular product A. But if some consumers value one-stop shopping they will shun such a store, making its shelf slots less valuable. Thus, through a kind of bundling, the manufacturer of the monopolised good can reduce rivals' slotting fee bids and thereby capture more of the surplus when contracting with the retailer.

This idea has three important ingredients. Firstly, upstream firms would be willing to pay a slotting fee only if they expect to earn a *positive mark-up* from sales. As we will show, this implies that there must be some kind of friction in contracting between upstream and downstream firms. Secondly, for there to be effective competition for slots, the downstream firm must face a *capacity constraint* (in the example, there is a single 'best' shelf). Thirdly, the number of consumers who visit the downstream firm must increase when it adds a new kind of product to its range—there must be *retail complementarity* (or, put differently, demand externalities between the different classes of product). The first contribution of this paper is to provide a new theory of bundling by formalising this reasoning and showing that an upstream firm can indeed profitably leverage market power by bundling the supply of inputs.

This idea is not specific to the retail setting. Indeed, the most important motivation for this project came from one of the largest antitrust cases in history: the European Commission's investigation into Google's bundling practices in the Android ecosystem.[1] Smartphone manufacturers (the downstream firms) wishing to pre-install the Google Play application marketplace have been required by Google to also install and make default

[1]The Commission imposed a €4.3bn fine upon Google in 2018. See `http://europa.eu/rapid/press-release_IP-18-4581_en.htm`, accessed 24 July 2019.

the Google Search application.[2] This is an environment with upstream mark-ups (application developers earn significant profits through advertising and in-app purchases). Moreover, since each phone can have only one default search engine, the downstream firm faces a capacity constraint. Lastly, because Google Play is by far the largest mobile application store and cannot easily be installed by end users, the European Commission argued that consumer demand for a phone is likely to be low if Google Play is not pre-installed. Thus, this is an environment that exhibits retail complementarity. The conditions are therefore in place for profitable leverage through bundling to reduce the slotting fees that must be paid to hardware manufacturers. The potential slotting fees are significant: in perhaps the best available counterfactual, Google pays a reported $12bn per-year to be the default search engine on iPhone (where Google's application store is not available).[3]

On a similar note, upstream TV networks offer bundles of channels to downstream distribution companies and earn advertising revenue when their channel is viewed. Thus, our work speaks to ongoing policy concerns around wholesale bundling in the pay-TV market (see Crawford, 2015, for a discussion, and Cablevision–Viacom for a recent case).

To be more precise, suppose a final product (e.g., a smartphone), sold by a downstream firm D, is made of various *components* (e.g., applications) provided by upstream firms. There are two categories of components, A (e.g., an app store) and B (e.g., a search engine). A is solely produced by upstream firm U_1, whereas two versions of B exist, one produced by U_1 and the other by U_2. Upstream firms offer contracts to the downstream firm, who chooses which component(s) to use and then sells to consumers. We assume: (i) sellers of the B component compete to be chosen by the downstream firm; (ii) the demand for the final product is higher if component A is installed than if it is not; and (iii) contractual frictions leave upstream firms with a

[2]One example of Google's so-called Mobile Application Distribution Agreement stipulated "Devices may only be distributed if all Google Applications [listed elsewhere in the agreement] ... are pre-installed [and] Google Phone-top Search must be set as the default search provider for all Web search access points on the Device." (See sections 2.1 and 3.4 of the agreement visible at `http://www.benedelman.org/docs/htc-mada.pdf`, accessed 24 July 2019).

[3]See, e.g., `https://fortune.com/2018/09/29/google-apple-safari-search-engine/`, accessed 24 July 2019.

positive mark-up.

In keeping with the logic outlined above, we show in Section 3 that U_1 can reduce the slotting fee offered by U_2 by bundling A and B_1. Indeed, under bundling U_2 expects that a final product that has component B_2 will not have A and will therefore be bought by fewer consumers. Facing a less aggressive rival, U_1 can reduce the slotting fee it offers to D and thereby increase its profit. When B_2 is more efficient than B_1, but not too much, and when the presence of A has a large effect on the demand for the final good, this bundling strategy allows U_1 to leverage its market power and is anticompetitive. Interestingly, when B_1 is more efficient than B_2, bundling is always profitable as its only effect is to relax competition from U_2. In such a case total welfare is unaffected, but the practice harms the downstream firm.

The result that inefficient foreclosure of firm U_2 may happen in equilibrium critically depends on the presence of a contractual friction, which, in the baseline model, takes the reduced-form of exogenous unit mark-ups. Without contractual frictions, efficient contracting emerges and upstream firms earn no mark-up. However, in Section 4 we again find that inefficient foreclosure arises when upstream firms can offer two-part tariffs but cannot perfectly align the downstream incentives and have to keep a positive mark-up (for instance, because of upstream moral hazard or downstream risk aversion).

In Section 5 we introduce downstream competition to our setup and show that a similar logic as in the monopoly case can make bundling profitable. Moreover, we can study how bundling by the upstream firm affects competition at the downstream level—the second main contribution of this paper. We assume that both the B components and the downstream firms themselves are horizontally differentiated. In our setup, bundling prevents downstream firms from differentiating along the dimension of the B component. We show that whether or not this results in an intensification of downstream competition depends on the distribution of tastes in the population. For instance, if the distribution of the relative preferences between downstream firms is symmetric and single-peaked, upstream bundling leads to more intense downstream competition and can increase consumer surplus. If, on the other hand, the relative preferences over downstream firms are polarized enough, bundling can hurt consumers and reduce welfare (the price reduction being insufficient to compensate for the lower product variety).

2 Literature

In this paper, bundling by an upstream firm can be profitable in the presence of contractual frictions because it lowers the willingness of upstream rivals to offer high slotting fees to the downstream firm. In order to highlight our contribution and the differences with the many established theories of bundling, we structure our discussion according to the various themes of the bundling literature.[4]

Efficient bundling A first stream of papers (e.g Adams and Yellen, 1976; Schmalensee, 1984; Bakos and Brynjolfsson, 1999) noted that bundling, by reducing consumers' heterogeneity, is a powerful instrument to extract consumer surplus and can improve social welfare. This force is absent from our baseline model, with a single buyer (the downstream firm) and no private information.

Bundling and foreclosure Another potential role for bundling is to extend (or leverage) a multiproduct firm's market power from one market to another. First dealt a blow by the Chicago School's Single Monopoly Profit Theory (e.g., Director and Levi, 1956; Stigler, 1963), the leverage theory of bundling was reinvigorated by various scholars who showed bundling could be profitably used to deter entry (e.g., Whinston, 1990; Choi and Stefanadis, 2001; Carlton and Waldman, 2002; Nalebuff, 2004). In these papers, bundling is profitable only to the extent that it deters entry.[5] This is in contrast to our paper, where bundling remains profitable in the presence of a rival on the B market. Our theory thus requires a lower level of

[4] Fumagalli, Motta, and Calcagno (2018) provides an up-to-date review of the various theories of bundling, and their applications.

[5] In Nalebuff (2004) bundling can also mitigate the adverse effects of entry. In that paper bundling reduces the range of marginal consumer types that an entrant can capture with a price cut, softening competition. We have only a single buyer with no heterogeneity so this effect is absent from our model.

commitment, compatible with contractual bundling.[6] Other papers show that foreclosure may happen even absent commitment power, simply because bundling is optimal in the presence of rivals (Peitz, 2008; Greenlee, Reitman, and Sibley, 2008). Buyers' heterogeneity (or imperfect rent extraction) play an important role in these theories. Our paper also features imperfect rent extraction, albeit in a different setup. Choi (2003) is another paper in which entry deterrence is not necessary: bundling lowers rivals' incentives to invest in cost reduction through a logic of scale effects absent from our paper.

Upstream bundling An important feature of our model is the vertical dimension of the market: bundling occurs at the upstream level. Previous papers have looked at this practice (also known as full-line forcing) from different angles (see, e.g., Burstein, 1960; Shaffer, 1991a; O'Brien and Shaffer, 2005; Ho, Ho, and Mortimer, 2012). Closest to us are Ide and Montero (2016) and Chambolle and Molina (2018), who show how bundling by an upstream multiproduct firm can be profitably used to exclude an upstream rival. The differences between this paper and Ide and Montero (2016) can be illustrated by the different implications: in Ide and Montero (2016) bundling is necessary to achieve leverage (unlike here, see Section 4) and, more importantly, downstream competition is necessary for bundling to be profitable whereas our theory applies both under downstream monopoly and competition. Chambolle and Molina (2018) share with us the feature that slotting fees play an important role (more on this below), but their analysis focuses on substitute products, so that our main effect (reduction of the rival's willingness to offer slotting fees) does not appear.

Bundling in multi-sided markets In our model, contracting frictions introduce cross-group externalities between upstream firms and consumers: upstream firms benefit when downstream demand is greater. The paper therefore also relates to the literature on bundling in two-sided markets (Choi, 2010; Amelio and Jullien, 2012; Choi and Jeon, 2016). In particular, Choi and Jeon (2016) is also motivated in part by the Google Android case.

[6]Of course we require a commitment not to undo bundling if the buyer picks the rival's offer. But absent such commitment, bundling would have little meaning as a concept.

The modelling setup is quite different, however, since they do not model the vertical chain, and rely on a different kind of friction (the impossibility of charging negative prices to consumers) to show the possibility of leverage through tying, whereas our theory relies on the possibility of negative payments, i.e., slotting fees. Motivated by the Android case, Etro and Caffarra (2017) rely on a logic related to Choi and Jeon (2016), that is based on a zero-pricing constraint.[7]

Competitive bundling and compatibility Some papers study the effects of bundling (or incompatibility) on competition among multiproduct firms (e.g. Matutes and Regibeau, 1988; Gans and King, 2006; Armstrong and Vickers, 2010; Kim and Choi, 2015; Zhou, 2017; Hurkens, Jeon, and Menicucci, 2019), or among a multi-product firm and an asymmetric one (Carbajo, De Meza, and Seidmann, 1990; Chen, 1997; Chen and Rey, 2018). In the former setup, Zhou (2017) for instance shows that bundling is more likely to intensify competition when there are few firms, and to soften it otherwise. When a multiproduct firm competes with single product firms, bundling tends to soften price-competition by introducing differentiation. In these papers, bundling happens at the retail level (the vertical channel is not modelled), so that retailer i forces consumers to buy products A_i and B_i simultaneously. When we study the effects of upstream bundling on downstream competition (Section 5), bundling forces all the retailers who want to offer product A to also offer product B_1, thus shutting down a possible dimension of differentiation (offering B_2 might generate more downstream profits absent bundling). In this way upstream bundling can increase downstream competition.

Slotting fees Earlier literature has emphasized the role of slotting allowances as signalling/screening mechanisms (Chu, 1992), as well as their potential anticompetitive effects (Shaffer, 1991b; Shaffer, 2005; Foros and Kind, 2008; Caprice and Schlippenbach, 2013). In our paper slotting fees result both from the positive wholesale markup induced by the contractual friction (a mechanism discussed by Farrell, 2001) and from the constraint preventing

[7] See also Lee (2013) and Pouyet and Trégouët (2016) for papers on vertical integration in multi-sided markets, the latter with a particular focus on the smartphone industry.

the downstream firm from procuring both B components (see, e.g., Marx and Shaffer, 2010, for a discussion of this point). The purpose of bundling is then to reduce U_2's willingness to offer high slotting fees, thereby softening the competition for access to final consumers.

Exclusive contracts Because of the constraint preventing the downstream firm from using two different B components, a bundled offer is a sort of exclusive contract whereby the downstream firm agrees to buy both components from the same supplier. In particular, our result that anticompetitive bundling can be profitable in the presence of contracting frictions echoes the one by Calzolari, Denicolò, and Zanchettin (2016), who show that such frictions may make exclusive contracts profitable (unlike in the frictionless environment of Bernheim and Whinston, 1998). Their mechanism differs from ours in several respects: exclusive dealing makes the rival behave more aggressively and a boost in demand is required to make it profitable. Here, in contrast, bundling makes the rival softer and can be profitable even if it does not increase the number of units sold (e.g. when B_1 is more efficient than B_2).

3 Baseline model

Basic institutional environment A downstream firm, D, sells a final good to consumers at price p. The finished good is made of components, obtained from upstream suppliers. There are two categories of components, A and B. Upstream firm U_1 is the sole producer of the A component, but firms U_1 and U_2 each compete to sell their own version of B: B_1 and B_2 respectively. D can only install one version of component B.[8]

Our main motivating example is the market for smartphones (where

[8]The debate around bundling of smartphone applications has mostly focused on the manufacturer's choice of a default application (or on which applications make it onto the phone's home screen dock). Capacity is constrained because there can be only one default for each task and space on the dock is limited. Jeon and Menicucci (2012) also study bundling in a setup where the buyer has a limited capacity. The difference between their model and ours is that the capacity constraint is over the whole set of products, whereas we impose a constraint on the B-applications only. More specifically, we don't allow the manufacturer to install B_1 and B_2 only, i.e., A never competes against the B applications.

components are pre-installed applications). In keeping with this motivation, we assume that component B_i generates a direct revenue nr_i for U_i when it is used by n consumers. This revenue may come from advertising, sale of consumer data to third parties, or "in-app purchases".[9]

Demand for the final product is $Q(p, S)$, where p is the price and $S \in \{\{B_i\}, \{A, B_i\}\}$ is the set of components installed by D.[10] We assume that, for any S, D's revenue function $pQ(p, S)$ is quasi-concave in p and maximized at p_S. We also assume $Q(p, \{A, B_1\}) = Q(p, \{A, B_2\})$ and $Q(p, \{B_1\}) = Q(p, \{B_2\})$—the two B components are equally attractive to consumers (this assumption is not essential but makes the exposition cleaner, and we relax it when we introduce downstream competition in Section 5).

We write $\Pi \equiv p_{\{A,B_i\}} Q(p_{\{A,B_i\}}, \{A, B_i\})$ and $\pi \equiv p_{\{B_i\}} Q(p_{\{B_i\}}, \{B_i\})$ respectively for the downstream profit gross of payments to upstream firms when A is and is not installed alongside B.

The two key ingredients of our theory are retail complementarity and a contractual friction.

Retail complementarity We assume demand is such that

$$Q \equiv Q(p_{\{A,B_i\}}, \{A, B_i\}) > Q(p_{\{B_i\}}, \{B_i\}) \equiv q \quad \text{and} \quad \Pi > \pi.$$

In words: when component A is installed, (i) more consumers buy the finished good (ii) downstream sales revenue is larger.

Contractual friction Our final ingredient is a contractual friction that leaves upstream firms with a positive per-unit income from each consumer. In the baseline model, we assume that the unit mark-up is exogenously fixed and that the upstream firms' only available instrument is their slotting fee. To make things even simpler, we normalize the exogenous unit fee to zero, so that the unit mark-up for U_i is r_i.[11] We write F_X for the lump-sum

[9]For brevity, we normalize component A's revenue to zero. But our analysis easily extends to positive revenues for A.

[10]For notational brevity we assume that component B is essential, but this plays no role in our analysis.

[11]With positive unit payments w_i to the downstream firms, our reasoning would apply to the mark-up $\tilde{r}_i \equiv r_i - w_i$.

that the upstream producer of component X demands from D ($F_X < 0$ corresponds to a payment to D, i.e. a slotting fee). We relax the assumption of exogenous unit fees and allow richer contracts in Section 4.

Payoffs Given D's optimal choice of price conditional on S, firms' payoffs are as follows. If the downstream firm installs A and B_i, its profit is $V_D = \Pi - F_A - F_{B_i}$. If it only installs B_i, $V_D = \pi - F_{B_i}$. Firm U_1's profit if both A and B_1 are installed is $V_1 = F_A + F_{B_1} + r_1 Q$. If only B_1 is installed, $V_1 = F_{B_1} + r_1 q$. Firm U_2's profits is $V_2 = F_{B_2} + r_2 Q$ if B_2 is installed alongside A, and $V_2 = F_{B_2} + r_2 q$ if B_2 is installed without A.

Timing and equilibrium The game proceeds as follows: At $t = 0$, U_1 announces whether it bundles A and B_1. At $t = 1$, upstream firms make simultaneous offers to the downstream firm. At $t = 2$ the downstream firm decides which component(s) to install, and chooses a final price. Payoffs are realized at $t = 3$. We restrict attention to subgame-perfect equilibria in undominated strategies. We study the two subgames without bundling and with bundling in turn.

3.1 Separate marketing

Let us start with the case where components A and B_1 are sold separately.

Lemma 1. *Suppose that $r_i \geq r_j$. Under separate marketing:*

i The downstream firm chooses components A and B_i in equilibrium.[12]

ii B_j's (rejected) offer is $F_{B_j} = -(Qr_j - \epsilon)$.[13]

iii The accepted offers are $F_A = \Pi - \pi$ and $F_{B_i} = -Qr_j$.

iv If $r_1 \geq r_2$, firm U_1's profit is $V_1 = \Pi - \pi + Q(r_1 - r_2)$. If $r_1 < r_2$, it is $V_1 = \Pi - \pi$. Firm U_2's profit is then $V_2 = Q(r_2 - r_1)$. In both cases the downstream firm's profit is $V_D = \pi + \min\{r_1, r_2\}Q$.

[12] If $r_i = r_j$ then there is also the mirror allocation.

[13] Here we assume that ϵ, small, is the minimal size of a price change. In the remainder of the paper we simplify notations by removing the ϵ. Without the minimal size assumption the equilibrium in undominated strategies would be such that firm j mixes over $(-Qr_j, -Qr_j + \epsilon)$ for ϵ small enough, leading to equivalent outcomes. See Kartik (2011).

Proof. (i) Suppose $S = \{A, B_j\}$. B_j cannot offer a slotting fee above Qr_j as this would generate negative profits. But then there exists an F'_{B_i} that B_i can offer to D representing a Pareto improvement for the pair (e.g., $F'_{B_i} = -Qr_j - \epsilon$). A similar reasoning holds for A. (ii) Given $A \in S$, each U_k is willing to offer up to Qr_k. The standard logic of asymmetric Bertrand competition implies that the least efficient firm makes the best offer it could afford, in this case $F_{B_j} = -r_j Q$. (iii) Given $F_{B_j} = -r_j Q$, the downstream firm prefers to install A and B_i rather than B_i alone (denoted $\{A, B_i\} \succsim \{B_i\}$) iff $\Pi - F_A - F_{B_i} \geq \pi - F_{B_i}$. Similarly, $\{A, B_i\} \succsim \{B_j\}$ implies $F_A + F_{B_i} \leq \Pi - \pi - r_j Q$. Lastly, $\{A, B_i\} \succsim \{A, B_j\}$ requires $F_{B_i} \leq F_{B_j}$. Together, these constraints imply $F_A = \Pi - \pi$ and $F_{B_i} = -r_j Q$. (iv) Component A generates profit F_A for U_1; B_i generates profit $Qr_i + F_{B_i}$ for U_i; $V_D = \Pi - F_A - F_{B_i}$. ■

Under separate marketing, competition on the B market forces firms to offer slotting fees $F_{B_i} < 0$, and therefore to transfer part of the rent to the downstream firm.

On the A market, firm U_1 can capture the *direct* value it brings to the downstream firm, $\Pi - \pi$. Component A also brings some *indirect* value to the downstream firm, through B firms' increased willingness to pay slotting fees (from qr_i to Qr_i). However, U_1 cannot capture this indirect value.

As we now show, bundling the two components allows firm 1 to capture more of A's marginal value.

3.2 Bundling

Now let firm 1 bundle A and B_1 with a single transfer offer $\hat{F}_1 = \hat{F}_A + \hat{F}_{B_1}$. Thus, D is constrained to choose $S \in \{\{B_2\}, \{A, B_1\}\}$. Firm 1 would only bundle if it expects to be chosen by D; we thus restrict attention to this case. We have:

Lemma 2. *Under bundling:*

i U_2 *offers* $\hat{F}_{B_2} = -qr_2$*;*

ii Firm 1 offers $\hat{F}_1 = \Pi - \pi - qr_2$*;*

iii Firm 1's profit is $\hat{V}_1 = \Pi - \pi + Qr_1 - qr_2$. *The downstream firm's profit is* $\hat{V}_D = \pi + qr_2$.

Proof. (i) $F_{B_2} < -r_2 q$ is dominated: if it were accepted U_2's profit would be $r_2 q + F_{B_2} < 0$. Suppose $\hat{F}_{B_2} > -qr_2$ and firms do not expect B_2 to be installed. D must be indifferent between installing B_2 and the bundle (otherwise, U_1 could increase $\hat{F}_1$ a little). But that means that U_2 could reduce $\hat{F}_{B_2}$ and be installed for positive profit. (ii) Given $\hat{F}_{B_2} = -r_2 q$, D chooses the bundle if $\Pi - \hat{F}_1 \geq \pi + r_2 q$, yielding $\hat{F}_1$. (iii) U_1's profit is $\hat{V}_1 = \hat{F}_1 + r_1 Q$. D's profit is $\hat{V}_D = \Pi - \hat{F}_1$. ■

Bundling allows firm U_1 to extract the whole joint marginal value of components A and B_1 by keeping the downstream firm at its outside option, $\pi + qr_2$. The key to understand this is that bundling reduces firm U_2's willingness to pay a slotting fee. Indeed, U_2 anticipates that, should B_2 be chosen, component A would not be installed. It is therefore only willing to offer up to $r_2 q$ to be installed.

Proposition 1. *If* $r_1 < r_2$ *then firm 1 is better-off under bundling (i.e.* $\hat{V}_1 > V_1$*) if* $r_1 Q > r_2 q$. *If* $r_1 \geq r_2$ *then firm 1 is always better-off under bundling than under separate marketing.*

The proof follows immediately as a corollary of Lemmas 1 and 2. The gain for U_1 stems from the weaker competition from U_2, who now only bids $r_2 q$ instead of $r_2 Q$. When $r_1 < r_2$, bundling creates an inefficiency. Bundling is more likely to be profitable if (i) the inefficiency, r_2/r_1, is small; and (ii) component A is important to attract consumers (Q/q is large), meaning that the effect of bundling on U_2's bid is large.

When $r_1 \geq r_2$, there is no inefficiency associated with bundling. But because firm 2 is still less aggressive than under separate pricing, firm 1 can demand a larger fixed fee, and bundling is always profitable.

3.3 Discussion

Having exposed the mechanism in this simple model, we now discuss in more details how it differs from "standard" models of bundling, and the sensitivity of our results to some of the assumptions.

Cost-complementarity We have already emphasized that our model does not rely on entry-deterrence unlike, for instance, Whinston (1990). To further understand the novelty of our mechanism, one useful way to think about our model consists in framing it as a model of bundling with cost-complementarity, and to compare it to a model of bundling with consumption-complementarity in the style of the Chicago School.

Suppose that the buyer's utility from consuming A alone, B alone, and A and B together are respectively v_A, v_B, and $v_A + v_B + \Delta_v$, with a consumption of at most one unit of each product. The cost of producing A is normalized to zero, but the cost of producing B is smaller if the buyer also consumes A, going from c_{B_i} to $c_{B_i} - \Delta_c$.[14] We assume that product B_2 is cheaper to produce.

In the more common model with consumption complementarity we would have $\Delta_v > 0$ and $\Delta_c = 0$. In such a model, two forces make the bundling of A and B_1 unprofitable. First, U_1 could extract the complementarity value Δ_v through a higher stand alone price, $p_A = v_A + \Delta_v$. Second, bundling makes U_2 more aggressive, offering $p_{B_2} = c_{B_2}$ under bundling, instead of $p_{B_2} = c_{B_1}$ under independent pricing.

In our model where complementarity is at the cost level (i.e., $\Delta_v = 0$, $\Delta_c > 0$), the first force is removed, while the second is reversed. Indeed, first U_1 cannot charge the buyer for the cost saving Δ_c of the other supplier, as the buyer would prefer not to buy A if $p_A > v_A$. Second, bundling makes U_2 less aggressive, offering $p_{B2} = c_{B2}$ instead of $p_{B2} = c_{B1} - \Delta_c$ (the condition for bundling to be profitable being that $c_{B2} > c_{B1} - \Delta_c$).

Such complementarities at the cost level may seem artificial when the buyer is a final consumer, but they emerge naturally when the buyer is a downstream firm who enjoys a larger demand when it offers product A, provided that the B supplier receives a positive mark-up for each unit (see below for a more thorough discussion of more general contracts).

Exclusion and profit shifting Another difference with the main theories of bundling is that bundling does not have to cause exclusion to be profitable. Whenever $r_1 > r_2$, the downstream firm would choose B_1

[14] In our model such costs are $-r_i q$ and $-r_i Q$, so that Δ_c is in fact firm specific, $\Delta_{c_i} = r_i(Q - q)$. This distinction is not important.

with or without bundling. Bundling in this case is not inefficient, but it harms the downstream firm who no longer exploits upstream competition to the fullest.

Moreover, although bundling excludes U_2 from being chosen when $r_2 \geq r_1$, the profitability of bundling does not require B_2 to exit the market. Indeed, U_1 still faces a competing offer made by U_2 in equilibrium. This is in contrast to classic models, such as Whinston (1990), where bundling is only profitable if it completely forecloses competing offers from the market (and otherwise makes competition tougher). Thus, the continued presence of rival firms in the market does not suffice to nullify competitive concerns when bundling is at the upstream level.

Timing and commitment Regarding the timing, two assumptions stand-out, namely that bundling is announced prior to offers being made, and that offers are simultaneous. Let us discuss these points in turn.

If U_1 could not commit to bundling in stage 1, but could choose to bundle A and B_1 at the same time as it makes its offer, there would be a multiplicity of equilibria. One equilibrium would be for U_1 not to bundle its products, with the same offers as in Lemma 1. But, when $r_1 Q \geq r_2 q$ (i.e., when bundling is profitable), there is another equilibrium where U_1 bundles its products and firms play as in Lemma 2.[15] Therefore, the assumption's function is that of equilibrium selection, and is not necessary for bundling to be profitable. This point distinguishes us from several papers in the literature, in particular where the profitability of bundling results from a commitment to bundling before rivals' entry decision (Whinston, 1990; Carlton and Waldman, 2002). We discuss further the equilibrium selection role of bundling in Section 4.

The simultaneity of the offers at $t = 1$ plays a more critical role in making bundling profitable. To see this, suppose that $r_2 > r_1$. If negotiation over component A occurred before B, bundling would no longer be optimal: U_1 would offer a payment $F_A = \Pi - \pi + r_1(Q - q)$. In the second stage, both firms would offer $F_{B_i} = r_1 Q$ if the first period offer had been accepted, $F_{B_i} = r_1 q$ otherwise. U_1's profit would be $\Pi - \pi + r_1(Q - q)$, greater than

[15] Notice however that in this equilibrium, there is no strict incentive to bundle given U_2's behavior.

the profit under bundling, $\hat{V}_1$.

U_1 would therefore have incentives to push the negotiations over A early. Two points are worth mentioning here. First, the downstream firm would have the opposite incentives, and would do its best to accelerate the negotiations over B. Second, a strong degree of commitment is required for such a strategy to work: U_1 must commit not to make a subsequent offer at the start of the second period of negotiations if D has rejected the first offer. Given that details of the negotiations are secretly held most of the time, it would be hard for outsiders to observe a deviation from the commitment not to make a second offer, and therefore reputation *vis-à-vis* third parties is unlikely to help sustain this commitment.

Of course, our model also requires a certain degree of commitment power by U_1, as do all models where pure bundling occurs in equilibrium: U_1 must be able to commit not to offer A on a stand-alone basis if D accepts B_2's offer. Unlike the type of commitment discussed above, reputation *vis-à-vis* third parties is more likely to help here: it would be fairly easy to observe that D has installed B_2 alongside A, and therefore that U_1 has reneged its commitment to bundle.

Side payments Would bundling still be profitable if upstream firms could contract with one another? This question is particularly relevant when B_2 is more efficient than B_1. Suppose accordingly that $r_2 > r_1$.

A first possibility is a contract whereby firm U_1 agrees not to offer B_1 to the downstream firm. For U_1 to accept such a contract, U_2 must offer a payment at least equal to $Qr_1 - qr_2$—the extra profit generated by bundling. If firm U_1 accepts, firm U_2 no longer needs to offer any positive payment to the manufacturer, and its profit is at least Qr_2, which is larger than $Qr_1 - qr_2$. Even though such a contract dominates bundling, it would likely be deemed anti-competitive.

A second possibility would be for U_2 to pay U_1 not to bundle A and B_1, without requiring it not to offer B_1. As before, firm U_1 must receive a payment at least equal to $Qr_1 - qr_2$ to accept. This time, though, firm U_2 still faces competition on the B market, and its profit is $V_2 = Q(r_2 - r_1)$ (see Lemma 1). Therefore, when $2Qr_1 > (Q + q)r_2$, U_2 cannot profitably induce firm U_1 to unbundle A and B_1.

Bargaining While we assume that upstream firms make the offers, it would be straightforward to extend the model to give more bargaining power to the downstream firm, for instance by having it make the offers with some probability. The results would essentially be the same, as long as D does not have all the bargaining power.

Only one B component For simplicity we make the assumption that consumers can only access one B product through the final good. There are two implications: that the downstream firm cannot offer two varieties of the B product, and, particularly relevant for the smartphone applications market, that consumers cannot install another B product themselves. In the model these assumptions are consistent with the perfect substitutability assumption, so that neither the downstream firm nor consumers would have a strict incentive to do so. In a model with either horizontal or vertical differentiation, our insights would continue to hold provided we interpret the choice by D as the choice of a "default" or prominent component and at least some consumers exhibit a form of status quo or saliency bias. Such bias is well documented in a variety of market contexts (see Samuelson and Zeckhauser (1988) for experimental evidence and Fletcher (2019) for a discussion in the context of smartphone applications).

Downstream unbundling While we study a framework where the downstream firms themselves offer a bundle to final consumers (irrespective of whether there is upstream bundling), our insights would carry over to situations where downstream firms sell each product separately, as is the case for example in the retail sector. Cross-product externalities could then come from the presence of shopping costs, as in Caprice and Schlippenbach (2013) (see also Rhodes, 2014; Thomassen et al., 2017). For instance, suppose that each consumer has a downward sloping demand $\widehat{Q}_A$ for product A, $\widehat{Q}_B$ for product B, as well as an idiosyncratic shopping cost s. Consumers obtain more surplus, and are therefore more likely to visit the retailer if it offers both products than if it only offers B. For brevity, we do not replicate our analysis in such a setup.

4 More general contracts

We now allow upstream firms to offer more general contracts in the form of two-part tariffs. Under a tariff $T_i = (w_i, F_i)$, D pays $nw_i + F_i$ to the producer of component i if it chooses to install it and if the final demand is n.

4.1 Frictionless contracting

The timing is as follows: at $t = 0$, U_1 publicly announces whether it bundles A and B_1 or not. At $t = 1$, U_1 and U_2 offer two-part tariffs to D. A $t = 2$, D selects the set of components it installs, and chooses a final price p. At $t = 3$ payoffs are realized.

Unlike fixed fees, the level of the unit fees w affects the optimal price chosen by D. If D installs components A and B_i, the joint profit of the involved firms would be maximized by setting $w_A = 0$ and $w_{B_i} = -r_i$, so that D's price reflects the true marginal cost of the vertical structure.[16] We denote this maximal joint profit by Π_i, and Q_i is the corresponding quantity sold given that the price is chosen optimally.[17] If D installs only B_i, the optimal unit fee is again $w_{B_i} = -r_i$, and the corresponding joint profit and quantity are denoted π_i and q_i.

Notice that in any equilibrium where D installs A and B_i the joint profit must equal Π_i. Moreover, if $r_i \geq r_j$, we have $\Pi_i \geq \Pi_j$, $Q_i \geq Q_j$, $\pi_i \geq \pi_j$ and $q_i \geq q_j$.[18]

We also make the following set of assumptions:

Assumption 1. *If $r_i \geq r_j$, we have:*

(a) $\Pi_i - \pi_i \geq \Pi_j - \pi_j$

(b) $\Pi_j \geq \pi_i$ *and* $Q_j \geq q_i$

Part (a) means that adding A to the product is more valuable if the chosen B component is the most efficient one. Part (b) implies that the

[16]If $r_i > 0$ the marginal cost of B_i is negative.

[17]I.e., $\Pi_i = (p_i^* + r_i)Q(p_i^*, \{A, B_i\})$ and $Q_i = Q(p_i^*, \{A, B_i\})$, where $p_i^* \equiv \arg\max_p\{(p + r_i)Q(p, \{A, B_i\})\}$.

[18]That $\Pi_i \geq \Pi_j$ follows from a revealed preferences argument. $Q_i \geq Q_j$ because the optimal price is a decreasing function of r.

asymmetry between B_1 and B_2 is not too large compared to the value of installing A.

By allowing firms to set two-part tariffs we have removed a contractual friction from the model. We can now see the important role such frictions play in leverage:

Proposition 2. *Bundling A and B_1 is not profitable if upstream firms can offer two-part tariffs.*

The proofs of this section appear in the appendix. Intuitively, competition in two-part tariffs leads firms to offer the efficient level of the unit fee, $w_{B_i} = -r_i$ and $w_A = 0$. Upstream firms' profits are therefore independent of quantity sold downstream and competition only takes place with respect to the fixed fees. But this set-up is equivalent to one in which the "single monopoly profit theory" applies: when B_2 is more efficient than B_1, U_1 can charge a higher price for product A if it does not bundle it with B_1.

4.2 Upstream moral hazard

We now discuss the profitability of bundling when some contracting friction prevents firms from designing contracts that achieve the joint first-best. In particular, we are interested in frictions that lead the upstream firms to offer contracts with a positive unit margin. Such a situation is not unrealistic, at least if one gives any credence to the idea that double-marginalization is a widespread problem in vertical relations. For our purpose, any friction leading to a positive upstream mark-up ($w_{B_i} > -r_i$) would work; we focus on moral hazard.

Suppose that, after D has chosen which B component to install, the selected upstream firm can exert a non-contractible effort that increases the final demand.[19] Such effort could consist of advertising or product improvement. A two-part tariff such that $w_i = -r_i$ would leave U_i with no incentives to exert effort because its profit would be independent of the number of units sold. Equilibrium contracts should therefore involve positive upstream markups so as to induce effort.

[19]Only the supplier of the B-component can exert such effort. Later we discuss the possibility of investment by the A supplier.

To keep notations simple, we focus on the following technology: effort is binary $e \in \{0,1\}$, with cost ke, $k > 0$. A positive effort increases demand by Δ. We assume that a positive level of effort is always efficient.

The timing is the following: at $t = 0$, U_1 publicly announces whether it bundles A and B_1 or not. At $t = 1$, U_1 and U_2 offer two-part tariffs to D. A $t = 2$, D selects the set of components it installs. At $t = 3$ the supplier of the selected B component chooses whether to exert effort. At $t = 4$, D observes the level of effort and chooses a final price p.

Optimal fee and notations If D has opted for component B_i, U_i finds it optimal to exert effort if and only if $(w_{B_i} + r_i)\Delta \geq k$. Therefore, assuming that it is optimal to induce effort by U_i, the unit fee that maximizes the joint profit of D and its suppliers is $w_{B_i} = -r_i + k/\Delta$. Any smaller value leads to no effort; larger values exacerbate the double-marginalization problem. After payment of the unit fees, the B supplier is therefore left with a revenue of nk/Δ if n units are sold.

We define Π_i and π_i as D's profit gross of lump-sum transfers with and without A, when $w_{B_i} = -r_i + k/\Delta$ and U_i exerts effort. Analogously, define Q_i and q_i as the corresponding quantities with and without A. To be more precise, let

$$p_S^* \equiv \arg\max_p \left\{ \left(p + r_i - \frac{k}{\Delta}\right) [Q(p,S) + \Delta] \right\}.$$

Then we define $Q_i \equiv Q\left(p^*_{\{A,B_i\}}, \{A, B_i\}\right) + \Delta$ and Π_i as

$$\Pi_i \equiv \left(p^*_{\{A,B_i\}} + r_i - \frac{k}{\Delta}\right) Q_i.$$

Likewise, $q_i \equiv Q\left(p^*_{\{B_i\}}, \{B_i\}\right) + \Delta$ and

$$\pi_i \equiv \left(p^*_{\{B_i\}} + r_i - \frac{k}{\Delta}\right) q_i.$$

Let $\widetilde{\Pi}_i$ and $\widetilde{\pi}_i$ be the corresponding objects when $w_{B_i} = -r_i$ and U_i does not exert effort.[20] We maintain Assumption 1, and assume that the value of component A is not reduced when the B supplier exerts effort:

Assumption 2. *For $i = 1, 2$, $\Pi_i - \pi_i \geq \tilde{\Pi}_i - \tilde{\pi}_i$.*

For the sake of brevity we only present results for the case where $r_2 > r_1$, implying bundling is inefficient.

4.2.1 Bundling

Because $w_{B_i} > -r_i$, upstream profits depend on the number of consumers served. Thus, as in Section 3, bundling limits the slotting fees offered by U_2 by decreasing demand when B_2 is installed.

Lemma 3. *There is a unique equilibrium under bundling in which U_2 is foreclosed and U_1's profit is $\Pi_1 - \pi_2 (Q_1 - q_2)k/\Delta - k$.*

In equilibrium both upstream firms offer the efficient unit fee that induces effort, $w_i = -r_i + k/\Delta$. U_2's losing bid offers all the joint profit (without A), $\pi_2 + q_2 k/\Delta$, to D. U_1's offer makes D indifferent between $\Pi_1 - F_1$ and $\pi_2 + q_2 k/\Delta$, and U_1 gets the mark-up k/Δ for the Q_1 units sold.

4.2.2 No bundling: possibility of virtual tie

When U_1 does not impose bundling through a contractual or technical requirement, the ensuing subgame has a multiplicity of equilibria, some of which deliver outcomes that are similar to the equilibrium under bundling.[21]

Lemma 4. *Suppose that $r_2 > r_1$. In the model with upstream moral hazard and two-part tariffs, there are two types of equilibria.*

1. ***Efficient equilibria**, such that D installs $\{A, B_2\}$, always exist. Firm U_1's profit ranges from $\frac{1}{2}(\Pi_1 - \pi_1 + \Pi_2 - \pi_2)$ to $\Pi_2 - \pi_2$.*

2. *There also exist **inefficient equilibria**, i.e. such that D installs $\{A, B_1\}$, whenever $(Q_1 - q_2)k/\Delta - k \geq \Pi_2 - \Pi_1$. U_1's profit ranges from $\Pi_2 - \pi_2$ to $\Pi_1 - \pi_2 + (Q_1 - q_2)k/\Delta - k$.*

[20] I.e., $\widetilde{\Pi}_i = \max_p \{(p + r_i)\, Q(p, \{A, B_i\})\}$, and $\widetilde{\pi}_i = \max_p \{(p + r_i)\, Q(p, \{B_i\})\}$.

[21] The multiplicity of equilibrium payoffs comes from the fact that the binding constraint on the fixed fees paid to D only pins down $F_A + F_{B_i}$.

In an efficient equilibrium, unit fees are $w_A = 0$ and $w_{B_i} = -r_i + \frac{k}{\Delta}$. The logic is then similar to Lemma 1: U_2 anticipates that D will also install A and is therefore willing to offer a large slotting fee (up to $Q_2 k/\Delta$). More specifically, the best equilibrium for U_1 has $F_A = \Pi_2 - \pi_2$, $F_{B_2} = \pi_2 - \pi_1 - \frac{Q_1 k}{\Delta}$ and U_1's rejected offer for B_1 is $F_{B_1} = -\frac{Q_1 k}{\Delta}$.

Inefficient equilibria correspond to what Carlton and Waldman (2002) call a "virtual tie": U_1 adjusts the unit fees so as to make it unprofitable for D to install B_2 alongside A, while keeping $w_A + w_{B_1}$ at the efficient level. In effect, firm 1 creates a virtual bundle through its choice of contracts. Anticipating this, U_2 is no longer willing to offer a large slotting fee. One strategy profile that sustains U_1's preferred equilibrium is: $w_A = r_2 - r_1$, $w_{B_1} = -r_2 + \frac{k}{\Delta}$, $F_A = \Pi_1 - \pi_2$ and $F_{B_1} = -\frac{q_2 k}{\Delta}$. U_2's rejected offers are $w_{B_2} = -r_2 + \frac{k}{\Delta}$ and $F_{B_2} = -\frac{q_2 k}{\Delta}$.[22]

The next Proposition is obtained as a corollary from Lemmas 3 and 4.

Proposition 3. *When $(Q_1 - q_2)k/\Delta - k > \Pi_2 - \Pi_1$, the unique equilibrium under bundling delivers the same profit to U_1 as the best equilibrium under no bundling.*

When $(Q_1 - q_2)k/\Delta - k < \Pi_2 - \Pi_1$, bundling is not profitable for U_1.

With two-part tariffs and upstream moral hazard, U_1 can again profitably leverage its market power. This can be achieved either by explicitly bundling A and B_1 ("real tie"), or through an appropriate choice of fees ("virtual tie"). The value of (explicit) bundling comes from the first-mover advantage it gives to U_1, allowing it to select its preferred equilibrium.

Discussion of moral hazard with A Our assumption that the effort only concerns producers of the B component is less innocuous than our assumption that A does not generate any revenue. Indeed, with moral hazard on both markets there would be an efficiency argument for having B_1 instead of B_2: a mark-up on A (necessary to induce effort on the A component) would reduce the need for a further markup on B_1, but not on B_2, to induce effort. This logic is similar to the logic of double

[22]Off the equilibrium path, if U_2 offers $F_{B_2} < -\frac{q_2 k}{\Delta}$, D installs B_2 alone even though it is indifferent with installing B_2 and A. In the proof we construct an equilibrium that does not rely on this tie-breaking assumption.

marginalization in the pricing of complements. While it would make the analysis of the game much more intricate, it would not affect the key insight that bundling reduces B_2's willingness to offer slotting fees. In terms of welfare, bundling would be less likely to be inefficient, given that, provided r_2 is not too large compared to r_1, the efficiency gains from having a single upstream provider (outlined just above) would offset the fact that $r_2 > r_1$.

5 Downstream competition

We now turn to the analysis of the case where there is downstream competition. We show that the mechanisms that can make bundling profitable with a downstream monopoly continue to operate. Competition also introduces new considerations: components become a potential source of differentiation between downstream firms, and bundling can therefore affect final goods prices and consumer surplus.

We maintain the same setup as in Section 3, in particular with exogenous unit mark-ups r_i. For the sake of conciseness we assume that A is essential throughout this section, i.e. that a downstream firm cannot make any sales if its final product does not include component A (results would go through even if A was not essential.). In the preceding analysis, this corresponds to the particular case where $q = 0$. We also assume that B firms are symmetric and have the same revenue, $r_1 = r_2 = r$, which allows us to focus more cleanly on the effects brought by downstream competition.

We introduce an additional downstream firm to the market, and denote the two downstream competitors by L and R. The timing of the game is as follows: at $t = 0$, U_1 publicly announces whether it bundles A and B_1 or not. At $t = 1$, upstream firms make secret offers to the downstream firms. At $t = 2$, L and R choose which components to install. At $t = 3$, L and R choose the price of their product. Sales and payments are realized.

We look for perfect-bayesian equilibria in undominated strategies. We assume passive beliefs: when a downstream firm receives an out-of-equilibrium offer at $t = 1$, it does not change its belief regarding the offers received by its competitor.

A downstream firm's profit (excluding fixed fees) depends on which B components are installed. Let Π_S be the value of this gross profit when they both choose the same B component, and Π_D when they choose different ones. We assume that in both cases the number of consumers served is Q.[23]

The following Lemma characterizes situations in which firm U_1 offers A and B_1 separately.

Lemma 5. *Under separate marketing of A and B_1: (i) both downstream firms install A; (ii) They install different B components if $\Pi_D > \Pi_S$, and the same B component if $\Pi_D < \Pi_S$.*

Similarly to the case with one downstream firm, the equilibrium under separate marketing maximizes the profits of the industry.

Under separate marketing, there is a multiplicity of offers that are compatible with the equilibrium allocation described by Lemma 5. Because our point is to show that firm U_1 can leverage its market power through bundling, we henceforth focus on the best equilibrium for firm U_1 under separate marketing. We now distinguish two cases, according to whether $\Pi_D > \Pi_S$ or not.

5.1 Efficient differentiation: $\Pi_D > \Pi_S$

Consider first the case in which $\Pi_D > \Pi_S$. The most natural setup would be one where B components are an important means by which downstream firms differentiate themselves, so that choosing different B components would soften competition (see below for a discrete choice model that makes this point more clearly). In that case, differentiation is efficient at the industry level.

Proposition 4. *When $\Pi_D > \Pi_S$, bundling is profitable if $rQ \geq \Pi_D - \Pi_S$.*

By a logic similar to the case with a downstream monopolist, bundling allows U_1 to capture more of the profit from the B market. However it cannot extract as much of downstream firms' profit because the lack of differentiation intensifies competition. Bundling is profitable when the latter effect is relatively small.

[23] Relaxing this assumption is straightforward but does not bring much insight.

5.2 Inefficient differentiation: $\Pi_S > \Pi_D$

We now turn to the case where $\Pi_S > \Pi_D$, as might be the case when the B components exhibit large network effects or, as the discrete choice model below makes clear, when the intrinsic differentiation among downstream firms is stronger than the differentiation between the B components.

Proposition 5. *Suppose that $\Pi_S > \Pi_D$. Then bundling is strictly profitable for firm U_1.*

Bundling brings two kinds of benefits to U_1 here. The first, obvious one, occurs in the case where, absent bundling, the downstream firms would coordinate and choose B_2. Bundling A and B_1 eliminates this possibility. The intuition for the second benefit is related to the case with one downstream firm when $r_1 > r_2$. Given that it is efficient from the perspective of the industry for both downstream firms to choose the same B provider, bundling does not create any inefficiency. Its only effect is to lower the price that U_1 has to pay the downstream firms, given that U_2 becomes less aggressive.

5.3 Upstream bundling with downstream competition: a discrete choice model

To investigate the effects of bundling on downstream competition and consumer surplus, we must specify some more structure for demand. Suppose that the unit mass of consumers have types $\{x, y\}$, with x and y independently distributed. Variable x measures the extent of the consumer's preference for downstream firm L over R (with x negative if the consumer prefers R). Similarly, y measures the preference for B_1 over B_2. Let them be independently distributed, $x \sim F(\cdot)$ and $y \sim G(\cdot)$, both symmetric around zero and with continuous densities f and g. We assume the market is covered: consumers choose whichever downstream firm yields the highest utility, accounting for its choice of B component and its price. We focus on symmetric equilibria in pure strategies.

B component differentiation Suppose that L installs component B_1 and R installs B_2.[24] Then a consumer prefers L if $p_L - x - y \leq p_R$, where p_i is the price charged by $i \in \{L, R\}$. This implies a demand for firm L equal to

$$D_L(p_L, p_R) = \Pr(p_L - x - y \leq p_R) = \int_{\mathbb{R}} 1 - G(p_L - p_R - x) dF(x).$$

Firm R's demand is $D_R(p_R, p_L) = 1 - D_L(p_L, p_R)$.

The firms choose prices to maximize $p_i D(p_i, p_j)$. Computing the first-order condition and imposing symmetry yields

$$p^* = \frac{1}{2 \int_{\mathbb{R}} g(-x) f(x)\, dx}$$

as the symmetric equilibrium price.[25].

No B component differentiation If L and R install the same B component then a consumer prefers L if $p_L - x \leq p_R$. Demand is $D_i(p_i, p_j) = 1 - F(p_i - p_j)$. Maximizing downstream profit $(p_i D(p_i, p_j))$, and imposing symmetry yields the equilibrium price

$$p^{**} = \frac{1}{2f(0)}.$$

Comparison and profitability of bundling Both with an without differentiation, each downstream firm serves half the market so profit is simply $p/2$. Thus, downstream firms prefer the configuration that yields the highest price: we have $\Pi_D > \Pi_S$ if and only if

$$f(0) > \int_{\mathbb{R}} g(-x) f(x)\, dx. \quad (1)$$

This expression has a clear economic interpretation. Without B component differentiation, the marginal consumers are those who like both L and R equally and $f(0)$ measures the density of such consumers. When the firms differentiate, the marginal (i.e., indifferent) consumers are those for whom

[24] By symmetry, this is equivalent to L choosing B_2 and R choosing B_1.

[25] Here, we use symmetry to imply $D(p^*, p^*) = 1/2$, simplifying the expression for p^*

their preference *for* L is exactly offset by a preference *against* B_1—i.e., for whom $y = -x$. Thus, $\int_{\mathbb{R}} g(-x)f(x)\,dx$ is the density of marginal consumers under differentiation. Firms choose whichever configuration minimizes the density of marginal consumers and thus the intensity of competition.

Bundling prevents downstream firms from differentiating their B components. Using Propositions 4 and 5, we obtain the following result:

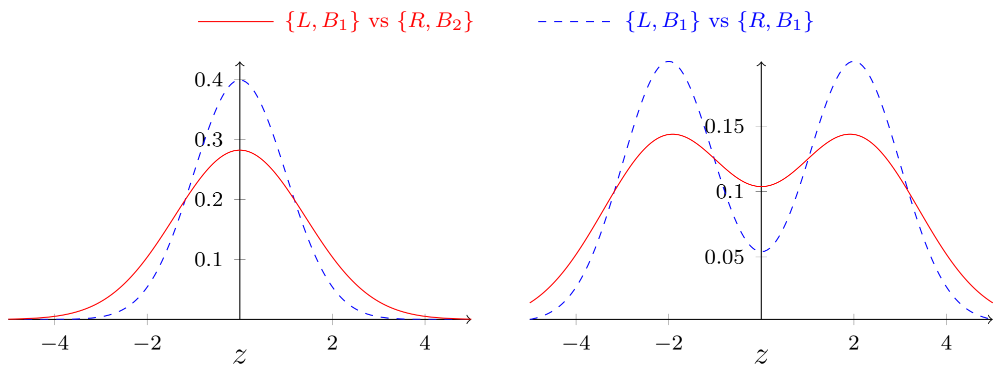
Proposition 6. *(i) If* (1) *holds then B component differentiation maximizes downstream profits. Upstream bundling prevents differentiation and is profitable if* $r > \frac{1}{2\int_{\mathbb{R}} g(-x)f(x)\,dx} - \frac{1}{2f(0)}$. *(ii) If* (1) *fails then downstream firms never differentiate in B components and bundling is unambiguously profitable.*

A special case is when consumers draw a firm-specific taste shock, x_i, for each downstream firm such that $x \equiv x_L - x_R$. If x_L and x_R are independently and identically distributed then the implied $f(x)$ is uni-modal and (1) is guaranteed to hold.

More generally, tastes for L and R may be correlated in which case $f(x)$ need not be single-peaked. Writing $\Phi(\cdot : \mu, \sigma^2)$ for the CDF of the normal distribution with mean μ and variance σ^2, suppose we let $F(x, \mu, \sigma) = \frac{1}{2}\Phi(x : \mu, \sigma^2) + \frac{1}{2}\Phi(x : -\mu, \sigma^2)$ and $G(y, \sigma) = \Phi(y : 0, \sigma^2)$. In this formulation, for μ large enough, F is a bi-modal distribution with peaks at $\pm\mu$. Thus, μ measures the polarization of tastes over downstream firms and condition (1) becomes $\mu < \sigma\sqrt{2\ln(2)}$.[26] If μ is large then the peaks of F are far apart and each downstream firm has many consumers who are quasi-captive. Installing different B components causes some of these 'captive' consumers to become contested (because they have a strong preference for the other firm's chosen B component). Conversely, if μ is small then many consumers are close to being indifferent between the two firms and installing different components is then the only way to soften competition. Figure 1 illustrates.

Bundling and consumer surplus If (1) fails then bundling does not change downstream firms' prices or their choice of B components, and

[26] We require σ to be not too small for there to be a symmetric equilibrium in pure strategies (see Figure 2).



(a) $\mu = 0$, $\sigma = 1$

(b) $\mu = 2$, $\sigma = 1$

Figure 1: Distribution of consumers' relative preferences between L and R, when they install different B components (solid lines) or the same (dashed lines) and charge the same price. $x \sim F(\cdot, \mu, \sigma)$ and $y \sim G(\cdot, \sigma)$. When μ is small (left panel), there are more marginal consumers (s.t. $z = 0$) when both L and R install B_1, and equilibrium price is lower. The right panel depicts the reverse situation, for larger values of μ.

therefore has no effect on consumer surplus or total welfare. When (1) holds, bundling reduces the price that consumers pay for the finished good (by eliminating a source of downstream differentiation). In this setup with unit demand and a covered market the final price does not affect total welfare, and preventing differentiation is socially inefficient. However, the falling price raises the intriguing prospect that bundling might leave consumers better-off overall.

To investigate this possibility, suppose that (1) holds. In a symmetric equilibrium, consumers choose $\{L, B_1\}$ over $\{R, B_2\}$ before bundling if $x > -y$. They choose $\{L, B_1\}$ over $\{R, B_1\}$ after bundling if $x > 0$. A consumer who switches from R to L gains x, while one who switches from B_2 to B_1 gains y. Putting these changes in match utility together with the effect of bundling on prices, bundling causes consumer surplus to increase if

$$\int_0^{+\infty} \int_{-\infty}^{-x} f(x)g(y)(x + y)\, dy\, dx + \int_{-\infty}^{0} \int_{-\infty}^{-x} f(x)g(y)y\, dy\, dx - \int_{-\infty}^{0} \int_{-x}^{+\infty} f(x)g(y)x\, dy\, dx + p^* - p^{**} > 0. \quad (2)$$

For example, if $F(x) = \frac{1}{2}\Phi(x : \mu, \sigma^2) + \frac{1}{2}\Phi(x : -\mu, \sigma^2)$ and $G(y) =$

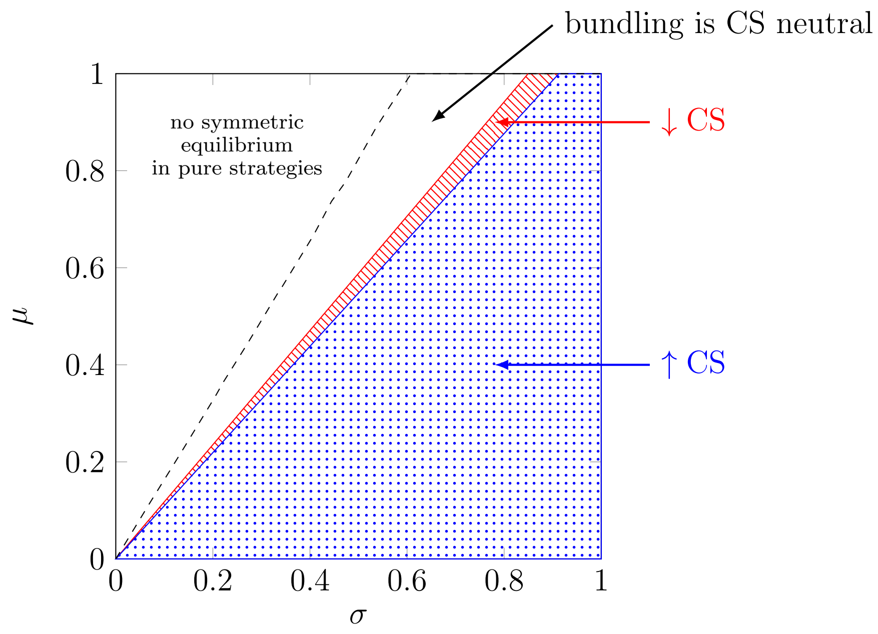


Figure 2: Effect of bundling on consumer surplus. Condition (1) holds in the shaded areas. Bundling causes consumer surplus to fall in the hatched area but increase in the dotted area.

$\Phi(y : 0, \sigma^2)$ then the effect of bundling on consumer surplus is illustrated in Figure 2. Bundling increases consumer surplus in the dotted area.[27] If μ is small then most consumers have x close to zero and eliminating the ability to differentiate B components significantly intensifies competition and lowers prices.

As another example, suppose that consumers draw an independent and identically distributed taste shock x_i for each downstream firm i, with $x_i \sim \Phi(x : 0, \frac{\sigma^2}{2})$. Then the aggregate preference, $x = x_L - x_R$, is distributed according to $F(x) = \Phi(x : 0, \sigma^2)$. If $G(y) = \Phi(y : 0, \sigma^2)$ then Figure 2 with $\mu = 0$ applies and consumers benefit from bundling.

As an aside, although not formally modelled in this paper, the fact that bundling can benefit consumers through lower downstream prices provides another possible justification for bundling by Google. Indeed, low prices

[27]We have verified that the first-order condition is sufficient over the relevant range in this example (to the right of the dashed line). For σ small and μ large, consumers have such polarized tastes over downstream firms that a symmetric pure strategy equilibrium cannot be sustained: firms would prefer to give up on competing for the few marginal consumers and exploit their (large) mass of pseudo-captive customers.

for Android devices serve to commodify the hardware, which should help Google in the ecosystem competition against Apple's rival platform.

5.4 Uniform versus discriminatory bundling

In the preceding analysis we allowed U_1 to offer a bundle to both firms (we call this situation 'uniform bundling'). An alternative, especially if bundling is contractual, would be to discriminate by offering a bundle to L, while offering A and B_1 separately to R (a practice we call 'discriminatory bundling'). Under no bundling or discriminatory bundling there are a multiplicity of equilibria; for concreteness, we select the equilibrium that maximizes U_1's profit. This assumption minimizes the size of the range over which uniform bundling is profitable.

By making U_2 less aggressive in its bid to L, discriminatory bundling allows U_1 to extract more surplus from L while still permitting differentiation in B components. It therefore always dominates no bundling. Thus, some form of bundling will occur in equilibrium and the relevant question is when discriminatory bundling is preferred to uniform bundling.

Proposition 7. *If $\Pi_D > \Pi_S$ then U_1 chooses discriminatory bundling when $rQ < 2(\Pi_D - \Pi_S)$ and uniform bundling otherwise. If $\Pi_D < \Pi_S$ then U_1 is indifferent between discriminatory and uniform bundling.*

Compared to uniform bundling, discriminatory bundling allows U_1 to extract less of the B-market surplus but has the advantage of allowing B component differentiation. Thus, discriminatory bundling is preferred when differentiation is especially important and when the potential B market revenues to be captured are not too large. Conversely, when differentiation in B components is not important and B-market revenues are large, U_1 prefers uniform bundling to extract more of the B-market surplus.

6 Conclusion

Our contribution in this paper is twofold. The first—and main—one is to suggest a new mechanism through which an upstream multi-product firm can leverage its market power through bundling. The mechanism works in environments that exhibit the following features: (i) Downstream firms have a limited number of "slots", which implies that upstream firms compete to be selected; (ii) there are positive externalities among products (what we call retail-complementarity): the presence of product A increases the demand for the B product. This could be because the downstream firm itself offers a bundle whose demand increases with the number of components, or because consumers incur shopping costs to visit the downstream firm. (iii) contractual frictions (e.g. upstream moral hazard) prevent sell-out contracts and leave upstream firms with a positive unit margin.

In such environments, bundling reduces the rival upstream firms' willingness to pay to be selected by the downstream firm. This can result in inefficient exclusion of the rivals if their product is slightly better than that of the multi-product firm. Interestingly, when the multi-product firm is more efficient than its rivals, bundling does not cause exclusion (which would happen anyway), but is still profitable as it relaxes the competition for slots. The mechanism does not require a strong level of commitment,[28] and can be "virtually" achieved through an appropriate choice of fees. This point suggests that a mere ban on contractual bundling may be insufficient to prevent anticompetitive outcomes.

Our second contribution concerns the effect of upstream bundling on downstream competition. While the above mechanism continues to apply in competitive settings, a new effect appears: upstream bundling prevents downstream firms from horizontally differentiating through their choice of B supplier. We show that under some conditions this intensifies downstream competition and can even result in larger consumer surplus.

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[28]The only requirement is that U_1 does not offer A as a stand-alone product if D chooses to buy B_2, a necessary commitment for bundling to have any effect.

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A Omitted Proofs

A.1 Proof of Proposition 2

(1) Case with $r_2 > r_1$. Suppose that U_1 bundles A and B_1. Let $T_1 = (w_1, F_1)$ be U_1's offer, with $w_1 = -r_1$.

First, in equilibrium, U_2 must offer $w_{B_2} = -r_2$ and $F_{B_2} = 0$. Indeed, D must be indifferent between $\{A, B_1\}$ and $\{B_2\}$, and if $w_{B_2} \neq -r_2$ than U_2 could profitably deviate and induce D to choose $\{B_2\}$. Given that $w_{B_2} = -r_2$, we obtain $F_{B_2} = 0$ using standard weak dominance arguments.

Given U_2's offer, U_1's accepted offer must then satisfy $\Pi_1 - F_1 = \pi_2$ for D to be indifferent between $\{A, B_1\}$ and $\{B_2\}$. U_1's profit is then $\hat{V}_1 = \Pi_1 - \pi_2$.

Suppose instead that U_1 chooses not to bundle A and B_1 and sets $w_A = 0, w_{B_1} = -r_1$ and $F_{B_1} = 0$ (i.e., it makes the best possible offer for B_1). For D to choose $\{A, B_2\}$, three conditions must hold: (i) $F_{B_2} \leq \Pi_2 - \Pi_1$ (so that D prefers $\{A, B_2\}$ to $\{A, B_1\}$), (ii) $F_A \leq \Pi_2 - \pi_2$ (so that D prefers $\{A, B_2\}$ to $\{B_2\}$), and (iii) $F_A + F_{B_2} \leq \Pi_2 - \pi_1$ (so that D prefers $\{A, B_2\}$ to $\{B_1\}$). The worst configuration for U_1 is when constraints (i) and (iii) are binding. In this case its profit is $V_1 = F_A = \Pi_1 - \pi_1$, which is still larger than $\hat{V}_1$. Bundling is therefore not profitable.

(2) Case with $r_1 > r_2$. Under bundling, B_2's rejected offer must be $w_{B_2} = -r_2$ and $F_{B_2} = 0$. The profit of U_1 is therefore equal to the maximal fee it can charge D, i.e. $\hat{V}_1 = \Pi_1 - \pi_2$.

If U_1 does not bundle its products and offers $w_A = 0$ and $w_{B_1} = -r_1$, then D installs $\{A, B_1\}$ in equilibrium. Again, B_2's rejected offer must be $w_{B_2} = -r_2$ and $F_{B_2} = 0$. The constraints that F_A and F_{B_1} must satisfy are (i) $F_{B_1} \leq \Pi_1 - \Pi_2$ (so that D prefers $\{A, B_1\}$ to $\{A, B_2\}$), (ii) $F_A \leq \Pi_1 - \pi_1$ (so that D prefers $\{A, B_1\}$ to $\{B_1\}$), and (iii) $F_A + F_{B_1} \leq \Pi_1 - \pi_2$ (so that D prefers $\{A, B_1\}$ to $\{B_2\}$). By Assumption 1(b), constraint (iii) is binding, so that $V_1 = \Pi_1 - \pi_2 = \hat{V}_1$.

A.2 Proof of Lemma 3

If U_1 bundles A and B_1, in equilibrium D must be indifferent between $\{A, B_1\}$ and $\{B_2\}$ (otherwise U_1 could demand higher fixed fees). B_2's rejected offer must be $w_{B_2} = -r_2 + k/\Delta$ and $F_{B_2} = -q_2 k/\Delta$: $w_{B_2} = -r_2 + k/\Delta$ maximizes the joint profit, and $F_{B_2} = -q_2 k/\Delta$ allocates all the profit to D. Lower values of F_{B_2} are dominated strategies, while higher values could not constitute an equilibrium (U_2 could reduce F_{B_2} and profitably induce D to install B_2). Thus, D's profit if choosing $\{B_2\}$ is $\pi_2 + q_2 k/\Delta$.

In equilibrium U_1 must offer $w_1 = -r_1 + k/\Delta$, so that the maximal fixed fee it can charge is given by $\Pi_1 - F_1 = \pi_2 + q_2 k/\Delta$. U_1's profit is therefore $\hat{V}_1 = F_1 + (r_1 + w_1)Q_1 - k = \Pi_1 - \pi_2 + (Q_1 - q_2)k/\Delta - k$.

A.3 Proof of Lemma 4

Efficient equilibria First, in an efficient equilibrium, we must have $w_A = 0$ and $w_{B_2} = -r_2 + k/\Delta$ to maximize the realized joint profit. w_{B_1} is not uniquely pinned down in equilibrium but, for our purpose, we can focus on equilibria where the rejected B_1 offer would have induced effort if accepted, i.e. $w_{B_1} = -r_1 + k/\Delta$. Let F_{B_1} be the rejected offer's fixed fee.

For D to select $\{A, B_2\}$ rather than respectively $\{A, B_1\}$, $\{B_2\}$ or $\{B_1\}$, we must have (i) $F_{B_2} \leq \Pi_2 - \Pi_1 + F_{B_1}$, (ii) $F_A \leq \Pi_2 - \pi_2$ and (iii) $F_A + F_{B_2} \leq \Pi_2 - \pi_1 + F_{B_1}$. By Assumption 1(b), (iii) is always binding. There is then a continuum of (F_A, F_{B_2}) compatible with (i)-(iii). U_1's associated profit ranges from $\underline{V}_1^E \equiv \Pi_1 - \pi_1$ (when (i) also binds) to $\overline{V}_1^E \equiv \Pi_2 - \pi_2$ (when (ii) also binds). Let us check that these constitute equilibria of the subgame without bundling.

Let us take a (F_A, F_{B_2}) compatible with (i)-(iii). Neither D nor U_2 have a profitable deviation from such a strategy profile. Could U_1 profitably deviate? The only possibility would be to make offers such that D chooses $\{A, B_1\}$. One constraint would then be that D prefers $\{A, B_1\}$ to $\{B_2\}$, i.e. $\Pi_1 - F'_A - F'_{B_1} \geq \pi_2 - F_{B_2}$. Because (iii) is binding, we have $F_{B_2} = \Pi_2 - \pi_1 + F_{B_1} - F_A$. Therefore the deviation must satisfy $\Pi_1 - F'_A - F'_{B_1} \geq \pi_2 - (\Pi_2 - \pi_1 + F_{B_1} - F_A)$. Now, we know that in an $\{A, B_2\}$ equilibrium, U_1's profit V_1 is equal to F_A. So the previous constraint rewrites as $\Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B_1} - V_1 \geq F'_A + F'_{B_1}$. The best deviation by U_1 is therefore to make this constraint binding. Its new profit is then $F'_A + F'_{B_1} + Q_1 k/\Delta = \Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B_1} - V_1 + Q_1 k/\Delta$. The deviation is not profitable if $\Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B_1} - V_1 + Q_1 k/\Delta \leq V_1$ i.e. if

$$2V_1 \geq \Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B_1} + Q_1 k/\Delta. \quad (3)$$

The lowest profit that can accrue to U_1 in an efficient equilibrium is such that (3) binds and F_{B_1} takes on its minimum possible value, $-Q_1 k/\Delta$. We then have $V_1 = \frac{1}{2}(\Pi_1 - \pi_1 + \Pi_2 - \pi_2)$. The highest profit is found when $V_1 = \overline{V}_1^E = \Pi_2 - \pi_2$. We can check this is compatible with equilibrium by substituting into (3) to yield $F_{B_1} \leq \Pi_2 - \pi_2 - (\Pi_1 - \pi_1) - Q_1 k/\Delta$. This is not ruled out by weak dominance, since weak dominance only rules out $F_{B_1} < -Q_1 k/\Delta$.

Inefficient equilibria Take ϵ arbitrarily close to zero and consider the following strategy profile: $w_A = r_2 - r_1 + \epsilon$, $F_A = \Pi_1 - \pi_2 - \epsilon q_2$, $w_{B_2} = -r_2 + \frac{k}{\Delta}$, $F_{B_2} \in [\Pi_2 - \Pi_1 - \frac{Q_1 k}{\Delta} + k + \epsilon q_2, \frac{-q_2}{\Delta}]$, $w_{B_1} = w_{B_2} - \epsilon$, $F_{B_1} = F_{B_2}$.

D's profit if it installs $\{A, B_1\}$ is $\Pi_1 - F_A - F_{B_1} = \pi_2 + \epsilon q_2 - F_{B_2}$. If it installs $\{A, B_2\}$, its profit is $\Pi_1 - \epsilon Q_1 - F_A - F_{B_2} = \pi_2 - \epsilon Q_1 - F_{B_2}$. If it installs B_1 alone, its profit is $\pi_2 + \epsilon q_2 - F_{B_2}$. If it installs B_2 alone, its profit is $\pi_2 - F_{B_2}$. So D chooses $\{A, B_1\}$ whatever the value of F_{B_2}.

The key aspect of U_1's strategy is that (w_A, F_A) are chosen such that D always strictly prefers $\{B_2\}$ to $\{A, B_2\}$ for any value of F_{B_2}. Therefore, given that $F_{B_2} \leq -\frac{q_2 k}{\Delta}$, U_2 is not willing to increase the slotting fee it offers (i.e. to offer $F'_{B_2} < F_{B_2}$) because it would lose money by doing so.

Under this strategy profile, U_1's profit is $V_1 = F_A + F_{B_1} + \frac{Q_1 k}{\Delta} - k = \Pi_1 - \pi_2 - \epsilon q_2 + F_{B_2} + \frac{Q_1 k}{\Delta} - k$. The best possible deviation for U_1 would be to induce D to install $\{A, B_2\}$ by choosing $w'_A = 0$ (so as to maximize the joint profit) and $F'_A = \Pi_2 - \pi_2$ (along with high prices for B_1). The resulting profit would be $V'_1 = \Pi_2 - \pi_2$. When $F_{B_2} \geq \Pi_2 - \Pi_1 - \frac{Q_1 k}{\Delta} + k + \epsilon q_2$ such a deviation is not profitable.

As the possible equilibrium values of F_{B_2} cover the interval $[\Pi_2 - \Pi_1 - \frac{Q_1 k}{\Delta} + k + \epsilon q_2, \frac{-q_2 k}{\Delta}]$, V_1 goes from $\Pi_2 - \pi_2$ to $\Pi_1 - \pi_2 + \frac{(Q_1 - q_2)k}{\Delta} - k - \epsilon q_2$.

A.4 Proof of Lemma 5

Suppose that one downstream firm, say L, does not install A in equilibrium. Then, because offers are secret, firm U_1 could increase its profit by requiring a small payment from L in exchange for installing A. This offer would be accepted by L.

Suppose now that L expects R to choose A and B_i. If firms U_1 and U_2 expect L to install A, they are willing to offer L a slotting fee up to $F^L_{B_i} = -rQ$ to be installed by L. If $\Pi_D > \Pi_S$, firm j can convince L to install B_j, even when i offers $F^L_{B_i} = -rQ$, by offering $F^L_{B_j} = -rQ + (\Pi_D - \Pi_S) - \epsilon > -rQ$. A symmetric reasoning applies when $\Pi_D < \Pi_S$.

A.5 Proof of Proposition 4

Let us start with the case of independent pricing. We know from Lemma 5 that the downstream firms install different B components in equilibrium. Suppose that L installs A and B_1 whereas R installs A and B_2.

First, we know that if B_j is not chosen by downstream firm k then j must offer $F^k_{B_j} = -rQ$, because of our focus on non-dominated strategies.[29]

Second, we look at the conditions for L to choose $\{A, B_1\}$ given offers $F^L_A, F^L_{B_1}$ and $F^L_{B_2} = -rQ$, and given that R installs A and B_2. L must prefer $\{A, B_1\}$ to $\{A, B_2\}$, i.e.

$$F^L_{B_1} \leq -rQ + \Pi_D - \Pi_S \tag{4}$$

It must also prefer $\{A, B_1\}$ to $\{B_1\}$, which implies

$$F^L_A \leq \Pi_D \tag{5}$$

Last, it must prefer $\{A, B_1\}$ to $\{B_2\}$, i.e.

$$F^L_A + F^L_{B_1} \leq -rQ + \Pi_D \tag{6}$$

Condition (6) is actually binding, and therefore the profit that firm U_1 obtains from its interaction with L is $rQ + (F^L_A + F^L_{B_1}) = \Pi_D$: all the profit

[29]As in the model with downstream monopoly, rigorously speaking $F^k_{B_j}$ is chosen randomly over an interval $(-rQ, -rQ + \epsilon)$ with ϵ close to zero. See footnote 13.

from selling the final product to consumers is captured by firm U_1, but the downstream firm still enjoys a rent of rQ due to the competing offer by firm U_2.

We now turn our attention to manufacturer R. There are multiple equilibria here, but for our purpose (finding sufficient conditions for bundling to be profitable), we can focus on the best equilibrium for firm U_1. U_1 cannot charge more than Π_D for installing A, but there is an equilibrium in which it charges exactly this: $F_A^R = \Pi_D$, $F_{B_1}^R = -rQ$ and $F_{B_2}^R = -rQ$. With such offers, R chooses A and B_2 and gets a profit equal to rQ. Firm U_2 gets a profit of zero but cannot offer less to R, as otherwise R would simply install B_1 alone and get rQ.

Putting the two previous paragraphs together, firm U_1's total profit under independent pricing is $2\Pi_D$.

When U_1 bundles A and B_1, U_2 cannot ask for a positive fixed fee in exchange for installing B_2 because A is essential. U_1 can therefore offer $F_A^L + F_{B_1}^L = F_A^R + F_{B_1}^R = -\Pi_S$ and generates a profit of $2(\Pi_S + rQ)$. Comparing this profit to the maximal profit without bundling ($2\Pi_D$) gives the result.

A.6 Proof of Proposition 5

Under separate marketing, we know that both downstream firms install the same B component, and that the losing B component must offer $F_{B_j}^k = -rQ$ to both $k = L$ and $k = R$.

If L and R install B_2, the best equilibrium for U_1 is such that $F_A^L = F_A^R = \Pi_S$, $F_{B_1}^L = F_{B_1}^R = -rQ$, and $F_{B_2}^L = F_{B_2}^R = -rQ$ (U_2 cannot demand a larger payment because downstream firms would deviate by installing B_1 and not installing A). Firm U_1's profit is $2\Pi_S$.

If L and R install B_1 instead, the best equilibrium for U_1 is such that $F_A^L = F_A^R = \Pi_S$, $F_{B_1}^L = F_{B_1}^R = -rQ$, and $F_{B_2}^L = F_{B_2}^R = -rQ$. U_1's profit is $2\Pi_S$.

In both cases firm U_1 extracts the whole profit generated by sales to consumers ($2\Pi_S$), but relinquishes a rent equal to $2rQ$ to downstream firms.

Under bundling, $F_{B_2}^k = 0$ and firm U_1 offers $F_A^L + F_{B_1}^L = F_A^R + F_{B_1}^R = 2\Pi_S$, for a profit of $2(\Pi_S + rQ)$.

A.7 Proof of Proposition 7

Suppose U_1 offers a bundle to L while allowing R to choose A or B_1 separately. This can only be optimal if L chooses the bundle.

First, suppose $\Pi_D > \Pi_S$. R must install $\{A, B_2\}$ in equilibrium (by Lemma 5). The most that U_1 can charge L is the F_1^L such that L is indifferent between $\{A, B_1\}$ and its outside option of zero: $F_1^L = \Pi_D$. Turning to R, U_1 cannot charge more than Π_D for installing A but there is an equilibrium in which it charges exactly this: $F_A^R = \Pi_D$, $F_{B_1}^R = -rQ$ and $F_{B_2}^R = -rQ$. Putting the profit from L and R together, U_1 earns $2\Pi_D + rQ$. Comparing this to the profits from no bundling and uniform bundling (given in the proof of Proposition 5) yields the result.

Now suppose $\Pi_D \leq \Pi_S$. In equilibrium R must install $\{A, B_1\}$ (by Lemma 5). The most that U_1 can charge L is the F_1^L such that L is indifferent between $\{A, B_1\}$ and its outside option of zero: $F_1^L = \Pi_S$. Turning to R, if A is expected to be installed then U_2 must offer $F_{B_2}^R = -rQ$, implying all of the B-market revenues accrue to R. U_1 cannot charge more than Π_S for installing A but there is an equilibrium in which it charges exactly this: $F_A^R = \Pi_S$, $F_{B_1}^R = -rQ$ and $F_{B_2}^R = -rQ$. Putting the profit from L and R together, U_1 earns $2\Pi_S + rQ$. This is the same as the profits from uniform bundling (given in the proof of Proposition 4).