Upstream Bundling and Leverage of Market Power*

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Abstract

Motivated by the recent Google-Android antitrust case, we present a novel rationale for bundling by a multiproduct upstream firm. Consider a market where downstream firms procure components from upstream suppliers. U_1 is the only supplier of component A, but faces competition for component B. Suppose that component A increases demand for the downstream product and that contractual frictions induce positive wholesale markups. By bundling A and B, U_1 reduces its B-rivals' willingness to offer slotting fees to the downstream firm, thereby allowing U_1 to capture more of the industry profit. Bundlig harms the downstream firm and the B rivals, and can be anticompetitive.

1 Introduction

Competition authorities in Europe and in the US have recently been investigating potentially anti-competitive practices by Google on the mobile applications market. Google, which develops the open-source mobile operating system Android and many mobile applications, has in particular been accused by the European Commission of abusing its dominant position by imposing restrictions on Android device manufacturers.[1] One such restriction is application bundling: manufacturers who want to install Google Play also have to pre-install other Google applications (notably Google Search and the Google

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[1] The EC's statement of objections is summarized at `http://europa.eu/rapid/press-release_IP-16-1492_en.htm`. See Edelman and Geradin (2016) for an analysis criticizing Google's practices. A Google response is available at `https://blog.google/topics/google-europe/androids-model-of-open-innovation/`.

Chrome browser). Because Google Play is by far the largest Android application store,[2] the Commission argues that it is commercially important for manufacturers to be able to offer it to their customers. On the other hand, the "tied" applications (Search, Chrome and others) face stronger competition, and Google's practices prevent its competitors from being installed either exclusively or in a prominent position on most devices.

The question of whether a dominant firm can leverage its market power into a competitive adjacent market has a rich intellectual history (see Rey and Tirole, 2007 and the literature review below). Motivated by features of the Google-Android case, we present a new mechanism through which leverage is indeed possible for an upstream firm, and can be achieved through bundling at the wholesale level.

Suppose a final product, sold by a downstream firm D, is made of various components provided by upstream firms. There are two categories of components, A and B. 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. For our theory to apply, the following three conditions need to hold: (i) substitutability between the two versions of B leads the downstream firm to install at most one version; (ii) the demand for the final product is higher if component A is installed than if it is not (*retail-complementarity*); (iii) *contractual frictions* leave upstream firms with a positive mark-up. In other words, upstream firms cannot offer efficient two-part tariffs. An example of such frictions is if upstream firms can exert some non-contractible effort to increases final demand.[3]

In such an environment, because of contractual frictions, providers of the B component obtain a positive markup for each consumer served. Since D can only choose one B provider, each one is willing to offer a positive slotting fee. This slotting fee is increasing in the expected demand for D's product. By bundling A and B_1, U_1 can reduce the slotting fee offered by U_2: 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. Such a strategy is always profitable when B_1 is more efficient than B_2, but also when the reverse is true provided that the presence of A has a large enough effect on the final demand. In the latter case, bundling is anti-competitive.

After discussing the relevant literature in Section 2, we present our mechanism in Section 3 by focusing on the simplest form of contractual friction, where upstream firms can only offer fixed fees. There we discuss how our mechanism differs from the standard rationales for bundling. In Section **??** we allow for more general contracts. There we show that some form of contractual friction is necessary for bundling to be profitable. We then

[2]An application store allows consumers to search for and install applications that are not already on their device.

[3]Another example of friction is downstream risk aversion coupled with a stochastic demand.

discuss a model with upstream moral hazard and two-part tariffs which delivers results that are qualitatively similar to those of the model with fixed fees. One difference is that two-part tariffs enable U_1 to leverage its market power without actually bundling A and B_1. This suggests that a ban on bundling would not be sufficient to restore efficiency, even though the anticompetitive outcome would no longer be the unique equilibrium.

2 Literature review

Bundling and foreclosure 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). [4] Our mechanism does not rely on entry deterrence and is thus quite different from these.

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 from different angles (see, e.g., Burstein, 1960; Shaffer, 1991a; O'Brien and Shaffer, 2005; Ho, Ho, and Mortimer, 2012). Closest to us is Ide and Montero (2016), who show how bundling by an upstream multiproduct firm can be profitably used to exclude an upstream rival. The mechanisms are different though, as 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.

In our model, contracting frictions introduce cross group externalities between upstream firms and consumers : upstream firms derive benefity from greater downstream demand. 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. 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.

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

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

preventing 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. The difference with the standard models of exclusive dealing (e.g., Aghion and Bolton, 1987; Rasmusen, Ramseyer, and Wiley Jr, 1991; Segal and Whinston, 2000) is that the upstream firm can commit not to deal with a firm who rejects the exclusivity clause. Within that literature, Calzolari, Denicolò, and Zanchettin (2016) recently emphasized the role of contractual frictions in making exclusive dealing profitable. While they also focus on frictions that lead upstream firms to charge unit prices above marginal costs, their mechanism is quite different from ours. In particular, they do no rely on the kind of strategic effect (making rivals softer competitors) that is at the core of our argument.

3 Baseline model

Basic institutional environment A downstream firm, D, sells a finished 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.[5]

Our main motivating example is the market for smartphones (where 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".[6]

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.[7] 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 perfect substitutes from consumers' perspective (this assumption is not essential but makes the exposition cleaner).

[5]The debate around bundling of smartphone applications has mostly focused on the manufacturer's choice of a default application (or on which application makes it onto the phone's home screen). Capacity is constrained because there can be only one default for each task and space on the home screen is limited.

[6]For brevity, we normalize application A_1's revenue to zero. But our analysis easily extends to positive revenues for A.

[7]For brevity we assume that component B is essential.

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 profit 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

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

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. To make the mechanism clear, we begin with a very simple such friction: upstream firms can only offer lump-sum transfers (implying that U_i earns r_i per consumer served). We write F_X for the lump-sum that the upstream producer of component X demands from D ($F_X < 0$ corresponds to a payment to D, i.e. a slotting fee).

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. We restrict attention to subgame-perfect equilibria in undominated strategies. We will compare two situations: a benchmark in which components A and B_1 are marketed separately, and one in which they are bundled.

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.[8]

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

ii *B_j's (rejected) offer is* $F_{B_j} = -(Qr_j - \epsilon)$.[9]

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* $V_D = \pi + \min\{r_1, r_2\}Q$.

Proof. (i) Suppose $S = \{A, B_j\}$. B_j cannot offer a slotting fee above Qr_j. 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 $F_{B_j} = -r_jQ$. (iii) Given $F_{B_j} = -r_jQ$, 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 $F_A + F_{B_i} \leq \Pi - \pi - r_jQ$. 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 $F_{B_i} = -r_jQ$. (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, it cannot capture this indirect value. This is a key difference with standard models of bundling with complements, where, if consumption of A increases the utility from B by some Δ the A firm can charge $v_A + \Delta$ and therefore capture all its marginal value. To see why such a logic does not work here, suppose that $r_i = r_j = r$, and that $F_A = \Pi - \pi + r(Q - q)$ so that firm 1 fully captures the marginal value of A. The downstream firm would never agree to pay such a fee, as it would be better-off only buying from the B firm making the most generous offer.

As we now show, jointly marketing the two components through bundling will allow firm 1 to capture more of the marginal value of A.

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:

[9] 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).

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

The proof follows immediately as a corollary of Lemmas 1 and 2. When $r_1 < r_2$, bundling creates an inefficiency. The gain for U_1 stems from the weaker competition from U_2, who now only bids $r_2 q$ instead of $r_2 Q$. 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).

When $r_1 \geq r_2$, there is no inefficiency associated with bundling. 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

Novelty of the mechanism That joint marketing of complementary products can increase profit is certainly not a new result. However the mechanism we highlight here is novel, to the best of our knowledge. Let us briefly discuss how it differs from well-established theories of joint marketing and bundling.

First, the increase in profit does not come from solving the double-marginalization problem (Cournot, 1838). This point is made clearer by our focus on a reduced form setup: indeed, because unit fees are fixed, there are no externalities between the products, and joint control cannot be used to raise overall demand for the two products.

Second, bundling can also be profitable when there are no externalities, by reducing the level of heterogeneity in the population (Adams and Yellen, 1976; Schmalensee, 1984). Again, this is not what is driving our result: we only have one buyer (the downstream firm), and therefore no heterogeneity.

Third, our theory differs from the one offered by Whinston (1990). We do not rely on firm U_2 incurring entry costs (or other economies of scale). Indeed, while Whinston (1990)'s theory is one of entry deterrence, ours can also be interpreted as exclusion of an established rival. In particular bundling is profitable in the short run even if the rival does not exit immediately.

Timing and commitment The simultaneity of the offers plays a role in making bundling profitable. To see this, suppose that $r_2 > r_1$. If negotiation over component A occurred first, 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 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.

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.

4 More general contracts

In this section we allow upstream firms to offer more general contracts, in the form of two-part tariffs. Under a two part 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.

In this section, the analysis can be extended to the more standard case where upstream firms derive no revenues besides the contract and incur costs to produce their components. This would be captured by $r_i < 0$.

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.

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.[10] We denote this maximal joint profit by Π_i,[11] and Q_i is the corresponding quantity sold given that the price is chosen optimally. 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.

We make the following set of assumptions:

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

i $\Pi_i \geq \Pi_j$, $Q_i \geq Q_j$, $\pi_i \geq \pi_j$ *and* $q_i \geq q_j$.

ii $\Pi_i - \pi_i \geq \Pi_j - \pi_j$

[10] In that case the marginal cost of B_i is negative.

[11] i.e., $\Pi_i = \max_p\{(p + r_i)Q(p, \{A, B_i\})\}$.

iii $\Pi_j \geq \pi_i$ *and* $Q_j \geq q_i$

By part (i), the most efficient component facilitates higher sales and a larger joint profit. Part (ii) means that adding A to the product is more valuable if the chosen B component is the most efficient one. Part (iii) implies that the asymmetry between B_1 and B_2 is not too large compared to the value of installing A.

Our first result is a negative one:

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 online appendix. Intuitively, competition in two-part tariffs leads firms to offer the efficient level of the unit fee, $w_{B_i} = -r_i$ and $w_A = 0$. Competition therefore only takes place with respect to the fixed fees. But this set-up is equivalent to one in which the "Single Monopoly Profit" 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.

We now discuss the profitability of bundling when some contracting friction prevents firms from designing contracts that achieve the joint first-best. For our purpose, any friction leading to a positive upstream mark-up ($w_i > -r_i$) would work.

4.2 Upstream 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.[12] Such effort could consist in 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.

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

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.

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

Optimal fee and notations If D has opted for component B_i, U_i finds it optimal to exert effort if and only if $(w_{B_i} + r_i)\Delta \geq 1$. 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 $w_{B_i} = -r_i + 1/\Delta$. 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 n/Δ if n units are sold.

We define Π_i, Q_i, π_i and q_i as the joint profits (excluding the cost of effort) and quantities, with and without A, when $w_{B_i} = -r_i + 1/\Delta$ and U_i exerts effort.[13] Let $\tilde{\Pi}_i$, $\tilde{Q}_i$, $\tilde{\pi}_i$ and $\tilde{q}_i$ be the corresponding objects when $w_{B_i} = -r_i$ and U_i does not exert effort. 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 $\Pi_1 - \pi_2 + Q_1/\Delta - 1$.*[14]

In the equilibrium with bundling, D's outside option equals the joint profit of D and U_2 if D only installed B_2. U_1's offer makes D indifferent

4.2.2 No bundling

There is now a multiplicity of equilibria in the subgame without bundling, some of which deliver outcomes that are similar to the equilibrium under bundling.[15]

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 $\Pi_1 - \pi_1$ to $\Pi_2 - \pi_2$.*

[13] i.e. $\Pi_i \equiv (p^* + r_i)(Q(p^*, \{A, B_i\}) + \Delta)$ with $p^* = \text{argmax}_p (p + r_i - 1/\Delta)(Q(p, \{A, B_i\}) + \Delta)$.

[14] The term -1 is the cost of effort.

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

2. *There also exist* ***inefficient equilibria****, i.e. such that D installs $\{A, B_1\}$, whenever $(Q_1 - q_2)/\Delta - 1 \geq \Pi_2 - \Pi_1$. U_1's profit ranges from $\Pi_2 - \pi_2$ to $\Pi_1 - \pi_2 + (Q_1 - q_2)/\Delta - 1$.*

Efficient equilibria follow a similar logic as in Lemma 1: U_2 anticipates that D will also install A and is therefore willing to offer a large slotting fee (along with the efficient unit fee). U_1's best-response is to let D install B_2, as outbidding U_2 would be too expensive.

In an inefficient equilibrium, U_1 requires a very large unit fee for A, along with a very small unit fee for B_1, such that the total unit fee if D chooses $\{A, B_1\}$ is efficient ($-r_1 + 1/\Delta$). By doing so, U_1 prevents D from jointly installing A and B_2, because the associated unit fee would be too high. Anticipating this, U_2 offers a smaller slotting fee, which corresponds to D only installing B_2. In other words, U_1 can achieve de facto bundling through contract design, although only as one of many equilibria.

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

Proposition 3. *When $(Q_1 - q_2)/\Delta - 1 > \Pi_2 - \Pi_1$, the unique equilibrium under bundling delivers the same profit to U_1 as the best equilibrium under no bundling.*

When $(Q_1 - q_2)/\Delta - 1 < \Pi_2 - \Pi_1$, bundling is not profitable for U_1.

With two-part tariffs and upstream moral hazard, explicitly bundling A and B_1 is no longer necessary to foreclose B_2. 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 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 Conclusion

Upstream bundling can reduce rivals' willingness to pay slotting fees and thereby enable profitable leverage. This can be achieved as the unique equilibrium through strict bundling, or as one equilibrium among many with appropriately designed contracts.

A motivation for our analysis is the case of smartphone application bundling. In this market consumers can modify the downstream firm's offering by installing alternative applications. It is fairly straightforward to allow this in our model. Bundling can continue to be profitable, provided some consumers will not change the default application configuration (because, e.g., they have high switching costs, they are indifferent between applications, or they suffer from default bias).

In companion work we extend the model to allow competition at the downstream level. If the most profitable industry configuration is for downstream firms to choose the same components (e.g., because components exhibit network effects) then the analysis largely parallels that above. If having different components increases downstream profit (e.g., because it makes downstream products more differentiated) then a new consideration enters: Bundling forces downstream firms to have the same component configuration and they must be compensated for the loss of differentiation. Thus, bundling tends to be profitable only when component differentiation is not too important. By lowering differentiation, bundling can force downstream firms to compete harder for consumers, increasing consumer surplus even as product variety decreases.

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A 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(2), constraint (iii) is binding, so that $V_1 = \Pi_1 - \pi_2 = \hat{V}_1$.

B 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 $w_{B_2} = r_2 + 1/\Delta$ and $F_{B_2} = -Q_2/\Delta$: $w_{B_2} = r_2 + 1/\Delta$ maximizes the joint profit, and $F_{B_2} = -Q_2/\Delta$ 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).

In equilibrium U_1 must offer $w_1 = r_1 + 1/\Delta$, so that the maximal fixed fee it can charge is given by $\Pi_1 - F_1 = \pi_2$. U_1's profit is therefore $\hat{V}_1 = F_1 + (r_1 + w_1)Q_1 - 1 = \Pi_1 - \pi_2 + Q_1/\Delta - 1$.

C Proof of Lemma 4

Efficient equilibria First, in an efficient equilibrium, we must have $w_A = 0$ and $w_{B_2}+r_2 = 1/\Delta$ to maximize the realized joint profit. w_{B_1} is not uniquely pinned down in equilibrium. For our purpose, we can focus on equilibria where the rejected B_1 offer would have induced effort if accepted, i.e. $w_{B_1} = r_1 + 1/\Delta$. 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(3), (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. $\Pi_1 - F'_A - F'_{B_1} \geq \pi_2 - F_{B2}$. because (iii) is binding, we have $F_{B2} = \Pi_2 - \pi_1 + F_{B1} - F_A$. Therefore the deviation must satisfy $\Pi_1 - F'_A - F'_{B_1} \geq \pi_2 - (\Pi_2 - \pi_1 + F_{B1} - F_A)$. 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 $\Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B1} - V_1 \geq F'_A + F'_{B_1}$. The best deviation by U_1 is therefore to make this constraint binding. Its new profit is then $F'_A + F'_{B_1} + Q_1/\Delta = \Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B1} - V_1 + Q_1/\Delta$. The deviation is not profitable if $\Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B1} - V_1 + Q_1/\Delta \leq V_1$ i.e. if $2V_1 \geq \Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B1} + Q_1/\Delta$.

To sustain $V_1 = \underline{V_1}^E$ as an equilibrium, we must have $F_{B_1} \leq \Pi_2 - \pi_2 - (\Pi_1 - \pi_1) - Q_1/\Delta$. This is not ruled out by weak dominance, since weak dominance only rules out $F_{B_1} < -Q_1/\Delta$. Therefore any $V_1 \in [\Pi_1 - \pi_1, \Pi_2 - \pi_2]$ can be sustained in an efficient equilibrium.

Inefficient equilibria First, in equilibrium, we must have $w_A + w_{B_1} = r_1 + 1/\Delta$ so as to induce effort by U_1. U_2's rejected offer must also satisfy $w_{B_2} = r_2 + 1/\Delta$. Indeed, if that was not the case, U_2 could profitably induce D to install B_2 instead of B_1 (because in equilibrium D must be indifferent).

In an inefficient equilibrium, D cannot be indifferent between $\{A, B_1\}$ and $\{A, B_2\}$. If that was the case, then we would either have $F_{B_2} = -Q_2/\Delta$ and U_1 would be better-off not serving B_1, or $F_{B_2} > -Q_2/\Delta$ and U_2 could lower its fee and profitably induce D to switch to $\{A, B_2\}$. Therefore D must be indifferent between $\{A, B_1\}$ and either $\{B_1\}$ or $\{B_2\}$.

But D must be indifferent between $\{A, B_1\}$ and $\{B_2\}$, otherwise U_1 could increase its fixed fee. This means that D strictly prefers $\{B_2\}$ to $\{A, B_2\}$ in an inefficient equilibrium. One way for U_1 to achieve this is by setting a large w_A and a w_{B_1} such that $w_A + w_{B_1} = r_1 + 1/\Delta$.

D's indifference between $\{A, B_1\}$ and $\{B_2\}$ implies that $F_A + F_{B1} = \Pi_1 - \pi_2 + F_{B2}$. U_1's profit is then $V_1 = \Pi_1 - \pi_2 + F_{B2} + Q_1/\Delta - 1$.

We cannot have $F_{B2} > -q_2/\Delta$. If that was the case U_2 could lower its fixed fee and induce D to install only B_2, with a profit. Thus we must have $F_{B_2} \leq -q_2/\Delta$.

Let us now check whether any strategy profile described above such that $V_1 = \Pi_1 - \pi_2 + F_{B2} + \mu Q_1 - 1$ and $F_{B_2} \leq -\mu q_2$ is an equilibrium.

U_2's only available instrument is its fixed fee (because the unit fee maximizes the joint profit). But offering a lower fixed fee cannot make D prefer $\{A, B_2\}$ to $\{B_2\}$. So if U_2 induces adoption of B_2, it will be on its own. Given that $F_{B_2} \leq -\mu q_2$, U_2 would lose money by further lowering it. So U_2 does not have a profitable deviation.

U_1's only potential deviation would be to induce D to install $\{A, B_2\}$. Such a deviation would entail $w'_A = 0$ (joint profit maximization). By setting F_{B1} arbitrarily large and F_A such that D is indifferent between $\{A, B_2\}$ and $\{B_2\}$, i.e. $F_A = \Pi_2 - \pi_2$, U_1 can secure a profit of $\Pi_2 - \pi_2$ with the deviation. This implies that, for F_{B_2} to be part of an inefficient equilibrium, we must have $F_{B2} \geq \Pi_2 - \Pi_1 - Q_1/\Delta + 1$ and $F_{B_2} \leq -q_2/\Delta$. This is possible only under the condition $(Q_1 - q_2)/\Delta - 1 \geq \Pi_2 - \Pi_1$