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UPSTREAM BUNDLING AND LEVERAGE OF MARKET POWER*

Alexandre de Cornière and Greg Taylor

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). If a multi-product upstream firm faces competition for a subset of its products, we show that tying the monopolised product with the competitive ones can reduce upstream rivals' willingness to offer slotting fees to retailers. This strategy does not rely on entry deterrence and can be achieved through contractual or even virtual tying. The model is particularly relevant to the Google-Android case.

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 show, this implies that there must be some kind of friction in contracting between upstream and downstream firms (the exact friction is not important, provided it leads to positive mark-ups). 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 anti-trust cases in history: the European Commission's (EC's)

* Corresponding author: Greg Taylor, Oxford Internet Institute, University of Oxford, 1 St Giles, Oxford, OX1 3JS, UK. Email: greg.taylor@oii.ox.ac.uk

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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 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 (or lawfully) be installed by end users,[3] the European Commission argued that consumer demand for a phone is likely to be low if Google Play is not pre-installed.[4] 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 \$12 billion per year to be the default search engine on iPhone (where Google's application store is not available).[5]

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 that 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). Component 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 that (*i*) sellers of the B component can offer slotting fees 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 positive mark-up.[6]

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

[1] The Commission imposed a €4.3 billion fine upon Google in 2018. See http://europa.eu/rapid/press-release_IP-18-4581_en.htm, accessed 19 October 2020. See also Kotzeva *et al.* (2019) for the Chief Economist's Team's perspective. In October 2020 the US Department of Justice launched legal action against Google motivated, in part, by the same bundling practices.

[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 Subsections 1.1 and 2.4 of the agreement visible at http://www.benedelman.org/docs/htc-mada.pdf, accessed 24 July 2019).

[3] The installation process has several steps, including requiring the user to disable a security feature that prevents installation of potentially harmful software and unlawfully downloading Google Play from a third party website. For an installation tutorial, see https://www.androidpolice.com/2020/07/25/install-play-store-guide/, and for EC commentary, see http://europa.eu/rapid/press-release_IP-18-4581_en.htm, accessed 19 October 2020.

[4] Various observations support the EC's belief. First, evidence submitted to the EC during its investigation (European Commission, 2018) indicates that competing app stores lack important popular apps from firms such as Netflix, Amazon or Facebook (p. 134); and that consumers are unlikely to buy a device that does not have access to the apps they want (e.g., pp. 130–131). Second, 'forked' Android devices sold without the Google Play store have invariably failed to achieve significant market penetration—even when, as in the case of Amazon's ill-fated Fire Phone, they receive hundreds of millions of dollars of investment and promotion by a major technology company.

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

[6] Note that contractual frictions should not prevent upstream firms from offering slotting fees for our theory to apply, unlike, e.g., Calzolari *et al.* (2020) (see the literature review below).

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 anti-competitive. 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.

Unsurprisingly, the result that inefficient foreclosure of firm U_2 may happen in equilibrium hinges 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—a result reminiscent of Bernheim and Whinston (1998) among others (see our discussion in the literature review). However, we tend to view this efficient benchmark as an extreme case, and argue in Section 4 that inefficient foreclosure may still be an equilibrium outcome when firms can offer more general contracts, provided that a friction such as upstream moral hazard or downstream risk aversion prevents the perfect alignment of upstream and downstream's incentives.

In Section 5 we show that the logic of our argument continues to operate under downstream competition.

1. 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.[7]

1.1. *Bundling and Price Discrimination*

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.

1.2. *Bundling and Foreclosure*

Another potential role for bundling is to extend (or leverage) a multi-product 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).

[7] Fumagalli *et al.* (2018) provided an up-to-date review of the various theories of bundling, and their applications.

In these papers, bundling is profitable only to the extent that it deters entry.[8] 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 commitment, compatible with contractual bundling.[9] Other papers show that foreclosure may happen even absent commitment power, simply because bundling is optimal in the presence of rivals (Greenlee *et al.*, 2008; Peitz, 2008). Buyers' heterogeneity (or imperfect rent extraction) plays 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.

1.3. *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 *et al.*, 2012). Closest to us are Chambolle and Molina (2018) and Ide and Montero (2019), who showed how bundling by an upstream multi-product firm can be profitably used to exclude an upstream rival.

We share with Ide and Montero (2019) the important feature that stocking a product may boost a retailer's sales of another product even if products are not complements. Similarly to Chambolle and Molina (2018), slotting fees play a key role in our analysis (more on this below). However, these papers rely on different sets of assumptions: consumer heterogeneity and downstream competition for Ide and Montero (2019), downstream bargaining power and substitute products for Chambolle and Molina (2018). In neither of these papers does bundling soften upstream rivals' behaviour, which is the core mechanism our this paper.[10]

1.4. *Exclusive Dealing and Bundling with Contracting Frictions*

The presence of a contracting friction, which takes the form of a positive upstream mark-up, is a necessary ingredient for inefficient bundling to be profitable. With frictionless contracting, the 'single monopoly profit' theory would apply, and inefficient bundling would never be an equilibrium. This point is well understood in the literature on exclusive dealing (Bernheim and Whinston, 1998), where contracting frictions are now well accepted as a starting point for analysis. In a recent paper, Calzolari *et al.* (2020) showed that positive mark-ups due for instance to moral hazard or asymmetric information may make the quantity boosting effect of exclusive dealing dominate its surplus reducing effect, unifying earlier insights from Mathewson and Winter (1987) or Calzolari and Denicolò (2013).

Our logic is quite different, as the profitability of bundling in our model stems in large part from its softening effect on the upstream rival's behaviour (whereas exclusive dealing makes

[8] 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.

[9] 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.

[10] 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.

rivals bid more aggressively). Quantity boosting is also not required for upstream bundling to be profitable, as illustrated by Proposition 1 in the case where $r_1 \geq r_2$. Importantly, unlike Calzolari *et al.* (2020), our theory requires slotting fees to be feasible, as this is the channel through which bundling makes B_2 a softer competitor. In contrast, Calzolari *et al.* (2020) modelled contractual frictions as a deadweight loss associated to the use of fixed fees, and thus admited as a polar case the setup where fixed fees are not feasible. We provide a micro-foundation in Appendix A.

Contractual frictions of a different kind play a role in the literature on bundling in two-sided markets (Choi, 2010). There, firms' inability to charge negative prices to one side of the market can generate a pro-competitive effect of bundling (Amelio and Jullien, 2012), but can also allow anti-competitive foreclosure (Etro and Caffarra, 2017; Choi and Jeon, 2021 are also motivated by the Android case). Such a friction is not at play in our paper, as we allow payments between the upstream and downstream firms to flow in both directions.

1.5. *Slotting Fees*

Earlier literature has emphasised the role of slotting allowances as signalling/screening mechanisms (Chu, 1992), as well as their potential anti-competitive effects (Shaffer, 1991b; 2005; Foros and Kind, 2008; Caprice and Schlippenbach, 2013). In our paper slotting fees result both from the positive wholesale mark-up induced by the contractual friction (a mechanism discussed by Farrell, 2001) and from the constraint 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. A different mechanism is at play in Jeon and Menicucci (2012), who also showed that bundling can reduce the competition that a seller faces from a rival's products in the context of competition for slots.[11]

1.6. *Competitive Bundling and Compatibility*

Some papers study the effects of bundling (or incompatibility) on competition among multi-product firms (e.g., Matutes and Regibeau, 1988; Gans and King, 2006; Armstrong and Vickers, 2010; Kim and Choi, 2015; Zhou, 2017; Hurkens *et al.*, 2019), or among a multi-product firm and an asymmetric one (Carbajo *et al.*, 1990; Chen, 1997; Chen and Rey, 2018). In the former setup, Zhou (2017) for instance showed that bundling is more likely to intensify competition when there are few firms, and to soften it otherwise. When a multi-product 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.

[11] More specifically, in Jeon and Menicucci (2012) the buyer's capacity constraint is over the whole set of products, whereas we impose a constraint on a subset of products (i.e., product A does not compete with the B products for a slot). Moreover, in their setup bundling is always efficient.

2. Baseline Model

2.1. *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.

2.2. *Capacity Constraint*

The first key ingredient of our model is a capacity constraint: we assume that D can only install one version of component B. Our main motivating example is the market for smartphones (where components are pre-installed applications). There, 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.

2.3. *Upstream Revenues*

In keeping with the smartphone application, 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'.[12]

2.4. *Downstream Demand and Profit*

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.[13] We assume that, for any S, D's revenue function $pQ(p, S)$ is quasi-concave in p and maximised at p_S. We also assume that $Q(p, \{A, B_1\}) = Q(p, \{A, B_2\})$ and $Q(p, \{B_1\}) = Q(p, \{B_2\})$—the two B components are equally attractive to consumers.

In the baseline version of the model, the heterogeneity among firms rests entirely in the possibly different values of r_1 and r_2. In particular, assuming that $r_2 > r_1$ would imply that bundling is inefficient. Because we think of r_i mostly as an advertising revenue and not as a price paid by consumers, the assumption that $Q(p, \{A, B_i\}) = Q(p, \{A, B_j\})$, and $Q(p, \{B_i\}) = Q(p, \{B_j\})$, merely implies that consumers view B_1 and B_2 as perfect substitutes. We could allow heterogeneity in Q at the cost of notational complexity without much additional insight. In any case, when we allow for more general contracts (in Section 4), we show that our results hold when the downstream price and thus the final demand depend on r_i.

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 other two key ingredients of our theory are retail complementarity and a contractual friction leading to positive mark-ups.

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

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

2.5. *Retail Complementarity*

Our second key ingredient is 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 and (*ii*) downstream sales revenue is larger.

2.6. *Contractual Friction Leading to Positive Mark-ups*

Our final ingredient is a contractual friction that leaves upstream firms with a positive mark-up from each consumer. As we discuss in Section 4, the exact nature of this friction is not important provided it generates such a positive mark-up, because the latter is the reason upstream firms are willing to offer slotting fees to the downstream firm. 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 normalise the exogenous unit fee to zero, so that the unit mark-up for U_i is r_i.[14] 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).

2.7. *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.

2.8. *Timing and Equilibrium*

The game proceeds as follows. At $t = 0$, U_1 announces whether it bundles A and B_1.[15] At $t = 1$, upstream firms make simultaneous offers to the downstream firm.[16] At $t = 2$ the downstream firm decides which component(s) to install, and chooses a final price. Payoffs are realised 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.

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

[15] Allowing U_1 to offer mixed bundling to D does not change the results. Suppose that U_1 charges F_A and F_{B_1} for each component separately, and F_1 for $\{A, B_1\}$ together. If D chooses $\{A, B_1\}$ then U_1 optimally lets $F_A, F_{B_1} \to \infty$ (to make D's outside options as unattractive as possible). In other words, conditional on the bundle being accepted, pure bundling is weakly better than mixed. If D installs $\{A, B_2\}$ then U_1's profit is F_A. To satisfy D's incentive compatibility, we must have $\Pi - F_A - F_{B_2} \geq \pi - F_{B_2} \Rightarrow F_A \leq \Pi - \pi$, which is weakly worse than the profit without bundling. Thus, U_1 cannot do better by mixed bundling.

[16] 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.

3. Baseline Analysis

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, the following statements hold.*

(i) The downstream firm chooses components A and B_i in equilibrium.[17]
(ii) The (rejected) offer of B_j is $F_{B_j} = -(Qr_j - \epsilon)$.[18]
(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 that $S = \{A, B_j\}$. Then 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 $F_{B_j} = -r_jQ$. (*iii*) Given $F_{B_j} = -r_jQ$, the downstream firm prefers to install A and B_i rather than B_i alone if and only if $\Pi - F_A - F_{B_i} \geq \pi - F_{B_i}$. Similarly, $\{A, B_i\}$ is preferred to $\{B_j\}$ if and only if $F_A + F_{B_i} \leq \Pi - \pi - r_jQ$. Lastly, $\{A, B_i\}$ being preferred to $\{A, B_j\}$ requires $F_{B_i} \leq F_{B_j}$. Together, these constraints imply that $F_A = \Pi - \pi$ 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, 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 the following result.

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 $\hat{V}_D = \pi + qr_2$.

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

[18] Here we assume that ϵ, small, is the minimal size of a price change. In the remainder of the paper we simplify the notation 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 small enough ϵ, leading to equivalent outcomes. See Kartik (2011).

PROOF. (*i*) Observe that $\hat{F}_{B_2} < -r_2 q$ is dominated: if it were accepted U_2's profit would be $r_2 q + \hat{F}_{B_2} < 0$. Suppose that $\hat{F}_{B_2} > -q r_2$ and firms do not expect B_2 to be installed. Then 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*) Firm U_1's profit is $\hat{V}_1 = \hat{F}_1 + r_1 Q$. Firm 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, $\pi + q r_2$. 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. *Bundling is profitable for firm 1 (i.e., $\hat{V}_1 > V_1$) if and only if $r_1 Q > r_2 q$.*

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, under bundling, 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. Note in particular that bundling is always profitable when A is essential ($q = 0$), an assumption we use in Section 5.

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 detail how it differs from 'standard' models of bundling, and the sensitivity of our results to some of the assumptions.

3.3.1. *Cost complementarity*

We have already emphasised 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 consumption of at most one unit of each product. The cost of producing A is normalised to zero, but the cost of producing B is smaller if the buyer also consumes A, going from c_{B_i} to $c_{B_i} - \Delta_c$.[19] We assume that product B_2 is cheaper to produce.

[19] 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.

In the more common model with consumption complementarity we would have $\Delta_v > 0$ and $\Delta_c = 0$.[20] 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).

3.3.2. *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 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.

3.3.3. *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.[21] 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, $F_{B_i} =$

[20] Perfect complementarity corresponds to $v_A = v_B = 0$. Chen and Nalebuff (2006) studied a different case, where A is essential, but B is not, so that $v_B = 0$.

[21] Note however that in this equilibrium, there is no strict incentive to bundle given U_2's behaviour.

$r_1 q$ otherwise. Firm U_1's profit would be $\Pi - \pi + r_1(Q - q)$, greater than the profit under bundling, $\hat{V}_1$.

Firm 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. Anecdotally, a few firms have attempted to launch Android phones without accepting the bundle offered by Google. In these cases, we see no sign of Google breaking its commitment to bundling and renegotiating: the phones are never sold with only part of the bundle and, instead, they have been brought to market without Google apps. Generally, these attempts have ended in failure, most prominently in the case of Amazon's ill-fated Fire Phone, which was lambasted until its demise for lacking important Google applications.[22]

3.3.4. *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).

3.3.5. *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 allow consumers to buy A and B 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

[22] See, e.g., https://www.cnet.com/news/fire-phone-one-year-later-why-amazons-smartphone-flamed-out/, accessed 20 October 2020.

it only offers B. For brevity, we do not replicate our analysis in such a setup. Ide and Montero (2019) analysed upstream bundling in such a setup, but their argument is quite different from ours. When consumers are heterogeneous with respect to their shopping costs and valuations for the products, they showed that the multi-product manufacturer can use asymmetric bundling offers to competing retailers in order to soften downstream competition and extract the associated profit, without fully foreclosing its upstream competitors. Note that the associated mechanism does not rely on softening upstream rivals' behaviour, as they consider the case of a competitive fringe offering its product at marginal cost.

4. More General Contracts

The mechanism presented above relies on a positive externality that the presence of A exerts on the chosen B supplier. Because A boosts the final demand and upstream mark-ups are positive, the presence of A increases the willingness to offer slotting fees. Bundling A and B_1 prevents U_2 from benefiting from the presence of A, thereby softening competition in slotting fees.

Suppose now that upstream firms can offer general contracts without any friction. In Appendix A we show that equilibrium contracts are efficient and do not leave any mark-up to the selected B supplier. Intuitively, B_i can maximise the joint surplus of B_i and D (taking as given the negotiation over A) by paying D a unit fee equal to its per-consumer revenue r_i, as this ensures D fully internalises the upstream revenues when pricing. In the absence of upstream mark-ups, U_i no longer wishes to offer a positive slotting fee, instead charging D a fixed fee. Then, bundling by U_1 makes U_2 more aggressive (demanding a smaller fixed fee), and is not profitable. This result is reminiscent of Bernheim and Whinston (1998) in the context of exclusive dealing.

While a useful benchmark, we view this frictionless environment as a polar case. Frictions such as upstream moral hazard or downstream risk aversion (when demand is stochastic) will often deter firms from using these sell-out contracts, and leave upstream firms with a positive mark-up (Rey and Tirole, 1986; Calzolari *et al.*, 2020), thereby restoring a potential role for bundling. Let us discuss two environments with frictions. The first one provides a micro-foundation for our baseline model, while the second one extends the analysis and delivers some new results.

4.1. *Downstream Risk Aversion*

Suppose that final demand is subject to a random shock whose variance is arbitrarily small. Suppose also that the downstream firm is infinitely risk averse. In that case upstream firms never find it optimal to offer non-zero unit fees, and only compete through slotting fees. This is essentially our baseline model, and our results carry over. Of course, the assumptions of infinite risk aversion and arbitrarily small variance are very strong, but the purpose of the exercise is to show that our model can be thought of as a limit case of a game with stochastic demand and risk aversion. Under more plausible assumptions of risk aversion and distribution of shocks, firms would use a mix of unit fees and slotting fees and qualitatively similar results would arise.

4.2. *Upstream Moral Hazard*

In Appendix A we study a richer extension, in which we introduce upstream moral hazard in the following way. Suppose that, after D has chosen which B component to install but before it chooses its price, the selected upstream firm can exert a non-contractible effort that increases the final demand. 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 mark-ups so as to induce effort, meaning the same mechanism studied in the baseline model now comes into effect to make bundling profitable.

Focusing on the case where $r_2 > r_1$, we show that tying A and B_1 reduces U_2's willingness to pay for being selected, thus resulting in inefficient foreclosure, as in Lemma 2. Interestingly, the same outcome can be obtained through what Carlton and Waldman (2002) call a 'virtual tie': U_1 can increase w_A and decrease w_{B_1} 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.[23] Unlike the model in Section 3, inefficient foreclosure reduces consumer surplus. Indeed, B_1 offers a smaller unit fee than B_2 would offer absent foreclosure, and this is passed on to consumers through a higher final price. The formal results of Appendix A can be summarised as follows.

PROPOSITION 2. *With upstream moral hazard, when A has a sufficiently large effect on downstream demand, inefficient foreclosure of B_2 is profitable for U_1. Foreclosure can be achieved through explicit or virtual tying, and leads to higher downstream prices, thereby reducing consumer surplus.*

5. Downstream Competition

We now introduce downstream competition and show that the mechanisms that can make bundling profitable continue to operate. The main change is that the profitability of bundling now also depends on its effect on downstream competition.

We maintain the same setup as in Section 3, with exogenous unit mark-ups r_i. For the sake of conciseness, we assume that A is essential, i.e., that a downstream firm cannot make any sales without component A (results would go through even if A was not essential).[24] We also assume that B firms are symmetric ($r_1 = r_2 = r$), allowing us to focus more cleanly on the effects of downstream competition.

We introduce an additional downstream firm to the market, and denote the two downstream competitors by L and R. The timing 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. This choice is publicly observed. At $t = 3$, L and R compete. Sales and payments are realised. 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.[25]

A downstream firm's profit (excluding fixed fees) depends on which B components are installed. Let Π_S be the equilibrium gross profit when they both choose the same B component,

[23] The best such virtual bundle yields the same profit for U_1 as does explicit bundling. However, unlike explicit bundling, a virtual tie equilibrium co-exists with other (efficient) no-bundling equilibria in which D chooses $\{A, B_2\}$. The value of explicit rather than virtual bundling, therefore, comes from the first-mover advantage it gives to U_1, allowing it to select its preferred equilibrium.

[24] In the preceding analysis, this corresponds to the particular case where $q = 0$.

[25] Because upstream firms compete in fixed fees, an out-of-equilibrium offer by U_i to one downstream firm does not affect U_i's payoff in its interaction with the other downstream firm. Passive beliefs are therefore consistent in the sense that, given passive beliefs, an upstream firm that deviates in its offer to one downstream firm does not gain a new incentive to deviate in its offer to the other.

and Π_D when they choose different ones. We assume that in both cases the number of consumers served is Q.[26] The condition $\Pi_S > \Pi_D$ might correspond, for example, to the case where components exhibit network effects that intensify downstream competition, whereas $\Pi_D > \Pi_S$ would naturally arise if component choice is a way for downstream firms to differentiate. The following lemma characterises situations in which firm U_1 offers A and B_1 separately. The proofs of this section can be found in Appendix B.

LEMMA 3. *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 maximises the profits of the industry, by an 'efficiency effect' logic. However, equilibrium payments are not uniquely determined, as there is a multiplicity of offers that are compatible with the equilibrium allocation described by Lemma 3.

Despite this multiplicity, we can provide sufficient conditions for bundling to always be profitable (when U_1's profit under bundling is higher than under the best equilibrium for U_1 under separate marketing), and for bundling to never be optimal (when U_1's profit under bundling is lower than its profit in the worst equilibrium under separate marketing). When $\Pi_D > \Pi_S$, the best equilibrium for U_1 is such that it charges Π_D for component A while the revenues on the B market ($2rQ$) are competed away and accrue to downstream firms. Firm U_1's profit is then $2\Pi_D$. In the worst equilibrium for U_1, the price of A is Π_S while the extra profit due to differentiation ($\Pi_D - \Pi_S$) is incorporated in the price of the B components. Firm U_1's profit is then $\Pi_D + \Pi_S$. When $\Pi_S > \Pi_D$, the best equilibrium for U_1 is such that both downstream firms choose B_1, and its profit is $2\Pi_S$. The worst equilibrium is such that both downstream firms choose B_2, and B_2 extracts the difference $\Pi_S - \Pi_D$, so that U_1's profit equals $2\Pi_D$.

If U_1 chooses to bundle A and B_1 then both downstream firms install the bundle in equilibrium. Firm U_1's profit is $2(\Pi_S + rQ)$.

Comparing the equilibrium under bundling to the best and the worst equilibria (for U_1) under separate marketing, we obtain the following result.

PROPOSITION 3. *If $rQ > \Pi_D - \Pi_S$ then bundling is strictly profitable for firm U_1. If $2rQ < \Pi_D - \Pi_S$, bundling is not profitable.*

To understand the result, it is instructive to distinguish cases depending on the sign of $\Pi_D - \Pi_S$. If $\Pi_S > \Pi_D$ then both downstream firms choose the same B provider regardless of whether U_1 bundles or not. But bundling benefits U_1 for two reasons. Firstly, it lowers the price that U_1 has to pay the downstream firms, given that U_2 becomes less aggressive. Secondly, it ensures that the B component the two downstream firms coordinate on is B_1. Bundling is thus always profitable.

If $\Pi_D > \Pi_S$ then downstream firms would like to choose different B components, and do so under separate marketing. Bundling forces both downstream firms to install B_1 and removes the competitive constraint exerted by B_2, thereby allowing U_1 to increase the price of B_1 by rQ. On the other hand, U_1 must lower the price of A by $\Pi_D - \Pi_S$, which leads to the first condition in Proposition 3. When $\Pi_D - \Pi_S > 2rQ$, the necessary price reduction to compensate downstream firms for the increased competition is so large that it is not offset by the extra revenue from the B product.

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

In an earlier version of the paper (de Cornière and Taylor, 2017) we studied the case with product differentiation using a discrete choice model. If components are an important source of downstream differentiation then, by eliminating that differentiation, bundling intensifies downstream competition and lowers downstream prices. This can result in consumers benefiting from bundling (despite the loss of product variety).

6. Conclusion

In this paper we have presented a new mechanism by 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*) Upstream firms earn positive mark-ups (e.g., because contractual frictions prevent sell-out contracts).

In such environments, bundling reduces the rival upstream firm's 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,[27] 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 anti-competitive outcomes.

Appendix A. Proofs and Results from Section 4

In this appendix we 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.

A.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. At $t = 2$, D selects the set of components it installs, and chooses a final price p. At $t = 3$ payoffs are realised.

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 maximised 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.[28] We denote this maximal joint profit by Π_i, and Q_i is the corresponding quantity sold

[27] 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.

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

given that the price is chosen optimally.[29] 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 by π_i and q_i.

Note 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 $q_i \geq q_j$.[30]

We also make the following set of assumptions.

ASSUMPTION 1. *If $r_i \geq r_j$, we have (a) $\Pi_i - \pi_i \geq \Pi_j - \pi_j$ and (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 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 4. *Without contractual frictions, bundling A and B_1 is not profitable for U_1.*

PROOF. *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 $w_{B_2} \neq -r_2$ then 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 $\{B_2\}$. Firm 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.

Case with $r_1 > r_2$. Under bundling, B_2's rejected offer must be $w_{B_2} = -r_2$ and $F_{B_2} = 0$. Firm U_1's profit 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. Model with Moral Hazard: Setup

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.[31] Such effort could consist of advertising or product improvement. A two-part tariff such that $w_i = -r_i$ would leave U_i with

[29] That is, $\Pi_i = (p_i^* + r_i)Q(p_i^*, \{A, B_i\})$ and $Q_i = Q(p_i^*, \{A, B_i\})$, where $p_i^* \equiv \arg\max_p\{(p + r_i)Q(p, \{A, B_i\})\}$.
[30] That $\Pi_i \geq \Pi_j$ follows from a revealed preferences argument. We have $Q_i \geq Q_j$ because the optimal price is a decreasing function of r.
[31] Only the supplier of the B component can exert such effort. Later we discuss the possibility of investment by the A supplier.

no incentives to exert effort because its profit would be independent of the number of units sold. Equilibrium contracts should therefore involve positive upstream mark-ups so as to induce effort.

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

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. At $t = 2$, 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.

Suppose that effort is binary, $e \in \{0, 1\}$, with cost ke, $k > 0$. A positive effort increases demand by Δ. 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 always optimal to induce effort by U_i, the unit fee that maximises 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-marginalisation 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 $Q_i \equiv Q(p^*_{\{A,B_i\}}, \{A, B_i\}) + \Delta$, $q_i \equiv Q(p^*_{\{B_i\}}, \{B_i\}) + \Delta$ and

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

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.[32] We maintain Assumption 1, and assume that the value of component A is not reduced when the B supplier exerts effort.

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

A.3. Moral Hazard: Equilibrium under Explicit 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 4. *There is a unique equilibrium under (explicit) bundling in which U_2 is foreclosed and U_1's profit is* $\Pi_1 - \pi_2 + (Q_1 - q_2)k/\Delta - k$.

Proof. 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). The rejected offer of B_2 must be $w_{B_2} = -r_2 + k/\Delta$ and $F_{B_2} = -q_2 k/\Delta$: $w_{B_2} = -r_2 + k/\Delta$ maximises 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 $\pi_2 + q_2 k/\Delta$.

[32] That is, $\widetilde{\Pi}_i = \max_p \{(p + r_i) Q(p, \{A, B_i\})\}$, and $\widetilde{\pi}_i = \max_p \{(p + r_i) Q(p, \{B_i\})\}$.

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

In equilibrium both upstream firms offer the efficient unit fee that induces effort, $w_i = -r_i + k/\Delta$. Firm U_2's losing bid offers all the joint profit (without A), $\pi_2 + q_2 k/\Delta$, to D. Firm 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.

A.4. Moral Hazard: Equilibrium without (Explicit) Bundling, and Profitability of Bundling

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.[33]

LEMMA 5. *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 $(1/2)(\Pi_1 - \pi_1 + \Pi_2 - \pi_2)$ to $\Pi_2 - \pi_2$.*
(2) There also exist ***inefficient equilibria****, i.e., such that D installs $\{A, B_1\}$, whenever $(Q_1 - q_2)k/\Delta - k \geq \Pi_2 - \Pi_1$. Firm U_1's profit ranges from $\Pi_2 - \pi_2$ to $\Pi_1 - \pi_2 + (Q_1 - q_2)k/\Delta - k$.*

The proof of Lemma 5 is given in the next subsection. But first let us take stock of what this result means. In an efficient equilibrium, unit fees are $w_A = 0$ and $w_{B_i} = -r_i + (k/\Delta)$. 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 $F_A = \Pi_2 - \pi_2$, $F_{B_2} = \pi_2 - \pi_1 - (Q_1 k/\Delta)$ and U_1's rejected offer for B_1 is $F_{B_1} = -Q_1 k/\Delta$.

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 $w_A = r_2 - r_1$, $w_{B_1} = -r_2 + (k/\Delta)$, $F_A = \Pi_1 - \pi_2$ and $F_{B_1} = -q_2 k/\Delta$. Firm U_2's rejected offers are $w_{B_2} = -r_2 + (k/\Delta)$ and $F_{B_2} = -q_2 k/\Delta$.[34]

As a corollary from Lemmas 4 and 5, we obtain the following result.

PROPOSITION 5. *When $(Q_1 - q_2)k/\Delta - k > \Pi_2 - \Pi_1$, the unique equilibrium under explicit bundling delivers the same profit to U_1 as the best equilibrium without explicit bundling. In such an equilibrium, U_2 is inefficiently foreclosed and consumer surplus is lower. 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, or through an appropriate

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

[34] Off the equilibrium path, if U_2 offers $F_{B_2} < -q_2 k/\Delta$, 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.

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.

Proposition 2 follows from the preceding analysis.

A.5. Proof of Lemma 5

***Efficient equilibria*:** First, in an efficient equilibrium, we must have $w_A = 0$ and $w_{B_2} = -r_2 + k/\Delta$ to maximise the realised joint profit. Here 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*). Firm 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

$$2V_1 \geq \Pi_1 - \pi_1 + \Pi_2 - \pi_2 + F_{B_1} + Q_1 k/\Delta. \tag{A1}$$

The lowest profit that can accrue to U_1 in an efficient equilibrium is such that (A1) binds and F_{B_1} takes on its minimum possible value, $-Q_1 k/\Delta$. We then have $V_1 = (\Pi_1 - \pi_1 + \Pi_2 - \pi_2)/2$. 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 (A1) 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: $w_A = r_2 - r_1 + \epsilon$, $F_A = \Pi_1 - \pi_2 - \epsilon q_2$, $w_{B_2} = -r_2 + (k/\Delta)$, $F_{B_2} \in [\Pi_2 - \Pi_1 - (Q_1 k/\Delta) + k + \epsilon q_2, -q_2/\Delta]$, $w_{B_1} = w_{B_2} - \epsilon$, $F_{B_1} = F_{B_2}$.

Firm 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 $F_{B_2} \leq -q_2 k/\Delta$, 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 $V_1 = F_A + F_{B_1} + (Q_1k/\Delta) - k = \Pi_1 - \pi_2 - \epsilon q_2 + F_{B_2} + (Q_1k/\Delta) - k$. 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 maximise 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 $F_{B_2} \geq \Pi_2 - \Pi_1 - (Q_1k/\Delta) + k + \epsilon q_2$, such a deviation is not profitable.

As the possible equilibrium values of F_{B_2} cover the interval $[\Pi_2 - \Pi_1 - (Q_1k/\Delta) + k + \epsilon q_2, -q_2k/\Delta]$, V_1 goes from $\Pi_2 - \pi_2$ to $\Pi_1 - \pi_2 + ((Q_1 - q_2)k/\Delta) - k - \epsilon q_2$.

A.6. 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 mark-up on B_1, but not on B_2, to induce effort. This logic is similar to the logic of double marginalisation 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 $r_2 > r_1$.

Appendix B. Proofs from Section 5

Proof of Lemma 3. 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 $\Pi_D < \Pi_S$. □

Proof of Proposition 3with $\Pi_D > \Pi_S$. Let us start with the case of independent pricing. We know from Lemma 3 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.[35]

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. Firm L must prefer $\{A, B_1\}$ to $\{A, B_2\}$, i.e., $F^L_{B_1} \leq -rQ + \Pi_D - \Pi_S$. It must also prefer $\{A, B_1\}$ to $\{B_1\}$, which implies that $F^L_A \leq \Pi_D$. Last, it must prefer $\{A, B_1\}$ to $\{B_2\}$, i.e., $F^L_A + F^L_{B_1} \leq -rQ + \Pi_D$. The last constraint 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 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.

[35] 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 18.

We now turn our attention to manufacturer R. There exist multiple equilibria. We focus on the best and the worst from U_1's point of view. First, 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. In this equilibrium, firm U_1's total profit is $2\Pi_D$.

The worst equilibrium for U_1 corresponds to the case where U_2 offers $F_{B_2}^R = \Pi_D - \Pi_S - rQ$ (making R indifferent between $\{A, B_2\}$ and $\{A, B_1\}$). In this case U_1 must offer $F_A^R \leq \Pi_S$, and its total profit is $\Pi_D + \Pi_S$.

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. Firm 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. □

Proof of Proposition 3 with $\Pi_S > \Pi_D$. 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 $k = R$.

The best equilibrium from U_1's point of view is such that B_1 is chosen by downstream firms. Payments are as follows: $F_A^L = F_A^R = \Pi_S$, $F_{B_1}^L = F_{B_1}^R = -rQ$ and $F_{B_2}^L = F_{B_2}^R = -rQ$. Firm U_1's profit is $2\Pi_S$.

The worst equilibrium for U_1 is such that both downstream firms choose B_2, and payments are $F_A^L = F_A^R = \Pi_D$, $F_{B_2}^L = F_{B_2}^R = \Pi_S - \Pi_D - rQ$ and $F_{B_1}^L = F_{B_1}^R = -rQ$. Firm U_1's profit is then $2\Pi_D$.

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 $2(\Pi_S + rQ)$. This is always larger than the profit obtained in the best equilibrium under separate marketing. □

Toulouse School of Economics, University of Toulouse Capitole, France
University of Oxford, UK

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