The Competitiveness of Upstream Markets with Vertically Integrated Firms*

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Abstract

We analyze price competition between vertically integrated firms which interact on a downstream and an upstream markets. The upstream market allows downstream-only firms to buy inputs needed to compete on the final market. The upstream product offered by the vertically integrated firms is perfectly homogenous whereas the downstream market is differentiated. The setting is relevant to analyze the role of upstream markets in network industries, the licensing of (substitute) innovations or patents to potential rivals in oligopolistic markets, or the impact of resale markets.

As common sense suggests, there always exists an equilibrium in which upstream prices are equal to the unit cost of providing the intermediate product. However, even in a static framework, two other equilibria appear: one in which the upstream market becomes endogenously monopolistic, and another one in which vertically integrated firms set identical prices strictly larger than their average cost but strictly smaller than the joint profit-maximizing upstream price.

In light of these results, we then examine the determinants of the competitiveness of the upstream markets. An application to the analysis of wholesale markets in telecommunications is proposed.

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1 Introduction

In the telecommunications industry, two types of competitors are observed. "Facility-based" firms roll out proprietary networks, which requires substantial investments, and rely mainly on their own infrastructures to provide services to end customers. Contrary to facility-based firms, "service-based" firms do not (or only partially) invest in facilities but lease access to the networks of facility-based firms to offer services on retail markets.[1]

For instance, in the broadband market, broadband cable networks, the broadband units of incumbent local exchange carriers (ILECs) and the competitive local exchange carriers (CLECs) which have installed modems (DSLAM) in the local exchanges of ILECs can be viewed as facility-based firms. They compete with service-based entrants, which use bitstream access or resale offers as inputs for their broadband services. In the mobile telephony market, mobile network operators (facility-based firms) compete with "mobile virtual network operators" (service-based firms), which do not own a mobile network but lease access to existing mobile networks.

Since service-based firms need access to the networks of facility-based firms to offer services to end customers and cannot enter in the downstream market otherwise, an important policy question is whether competing facility-based firms are likely to offer access to their networks on a voluntary basis. In other words, in the absence of regulation, when facility-based competition is in place, is a wholesale market likely to emerge?

There is no clear consensus on this question. Some regulators question that a wholesale market can emerge. For instance, in 2005, the French regulatory authority, ARCEP, proposed to regulate the conditions of access to mobile networks for MVNO, as it believed that mobile networks would not give access to their facilities otherwise.[2] In some European countries (e.g., in Denmark, France, Italy, the UK),[3] bitstream access offers are regulated on such grounds too.[4] But others challenge this view. For instance, Hazlett (2005) argues that unregulated infrastructure-based competition should lead to the emergence of a wholesale market. According to him, this was observed in the mobile telephony market in the US.[5] The UK regulatory authority, OFCOM, in its review of the wholesale broadband market (OFCOM, 2004), considers that, in an unregulated environment, facility-based firms would lease access to their infrastructures: "*Under competitive market conditions, both cable and BT would have an incentive to offer a wholesale product.*" (OFCOM, 2004, §2.154, p. 49).

Once a wholesale market has emerged, will it be competitive? The usual presump-

[1]Note that facility-based firms might lease some network elements to ILECs, and that service-based firms might have to install some telecommunications equipments. But, roughly, a facility-based firm *builds* more than it *leases*, and a service-based firm *leases* more than it *builds*.

[2]ARCEP finally withdrew its project (see: ARCEP, 2005).

[3]See ERG (2005).

[4]In a recent theory-oriented paper, Woroch (2004) assumes too that infrastructure-based firms do not voluntarily give access to their facilities to service-based firms.

[5]"*The arrival of physical networks drove free entry into the wholesale market, not vice versa*" (Hazlettt, 2005, p. 32).

tion is that it will be indeed the case: under competitive conditions, two facility-based firms would have incentives to cut prices to gain wholesale revenues until the marginal cost is attained. For instance, in the US, according to Hausman and Sidak (2005), the Federal Communications Commission believed that facility-based competition would lead to the development of a competitive wholesale market.[6] According to OFCOM (2004), too: "*In a competitive market, cable's and BT's upstream (network) and downstream (retail) divisions would each earn a normal return*". However, evidence in the mobile industry suggests that wholesale prices granted to MVNOs remain relatively high. In the broadband market too, there is no evidence of a highly competitive wholesale market.

The objective of the paper is to provide a formal framework to address these questions, that is, to study under which conditions a wholesale market is likely to emerge, and, if it emerges, whether it is likely to be competitive.

Though we shall apply our setting to the telecommunications industry, our framework remains general. "Facility-based" firms are vertically integrated firms which interact both on a downstream (retail) market and an upstream (wholesale) market, whereas the "service-based" firms operate on the downstream market only.

We analyze the competition between two vertically integrated firms and a potential pure downstream rival. The rival firm can enter in the downstream market only it gets access to the upstream good. The vertically integrated firms compete on the upstream market with homogeneous goods, whereas the firms which are active on the downstream market compete with differentiated goods.

We show that the wholesale market is active at the equilibrium, that is, the downstream rival firm is not foreclosed at the equilibrium. Integrated firms have two motivations to give access to their upstream unit to the rival downstream firm. First, providing a wholesale product generates additional revenues. Second, and more fundamentally, serving the rival downstream firm with a relatively high upstream price mitigates competition on the downstream market.

As common sense suggests, there is an equilibrium in which the wholesale market is competitive, that is, the vertically integrated firms set prices equal to marginal cost for the upstream input. However, our game has other non-competitive equilibria. First, there is an infinity of equilibria in which the integrated firms share the upstream market at an upstream price that is higher than the marginal cost and lower than the joint profit maximizing upstream price. Second, there are equilibria in which the upstream market becomes endogenously monopolistic. This latter type of equilibrium is weakly preferred by the two vertically integrated firms.

Hence, even though a wholesale market is likely to emerge, the same economic forces

[6] "*Competition among facilities-based providers to supply network elements to future generations of CLECs would decrease the price of those network elements. The next generation of CLECs would, in turn, pass those savings along to end users in the form of lower retail prices. At some point in the process, the regulator could, in theory, withdraw and allow a competitive market for inputs to discipline the price of retail service.*" (Hausman and Sidak, 2005, p. 19).

that favor its development will mitigate the intensity of competition.

Our paper is related to the literature on network competition, which has developed following the pioneer work of Laffont, Rey, and Tirole (1998a, 1998b). In contrast with this literature, we do not study the interconnection strategies of infrastructure-based firms. We focus on the competition between infrastructure- and service-based firms in wholesale and retail markets, and study the emergence and competitiveness of this wholesale market. The closest works to ours in the literature are the ones that study the conditions of access to the network of a facility-based firm for a service-based firm.[7] However, these papers do not consider competition between facility-based firms, and hence do not study the wholesale market.

Our paper is related to the literature on ex post licensing strategies too. In this literature, it has been shown that a patent holder (an "essential facility" owner), which operates on a downstream market, has incentives to refuse to license to a pure downstream competitor when the innovation is drastic (for instance, see: Tirole, 1988). Our model extends this analysis to a situation in which two competing patent holders can sell a license to a pure downstream firm. In our setting too, the pure downstream firm can enter in the market only if it gets a license from one of the patent holders. We show that, when patent holders set royalties rates, at the equilibrium, the pure downstream firm gets a license. However, with fixed fees only, there is an equilibrium in which the patent holders refuse non-cooperatively to offer a license to the downstream firm.

The rest of the paper is organized as follows. We begin by describing the model in Section 2. In Section 3, we solve for the equilibrium and derive the main results of the paper. In Section 4 we highlight the main mechanisms of the model and provide some extensions. We provide an application to the broadband and mobile markets in the telecommunications industry in Section 5. Finally, we conclude.

2 The Model

We consider two vertically-related markets: firms active in the downstream market sell services to end-users. In order to provide the final products, these firms need an upstream input (on a one-to-one basis). We now describe the building blocks of our model.

The firms. There are two vertically integrated firms, denoted by 1 and 2, and sometimes referred as i and j in the following, where $i \neq j$ is always implicitly assumed. There is also one pure downstream competitor, denoted by e. Each vertically integrated firm is composed of an upstream and a downstream unit which produce the upstream input and the final good respectively. The pure downstream competitor may be active on the downstream market if it can get access to the upstream input from either of the vertically integrated firms.

[7] See, among others, De Bjil and Peitz (2005).

The downstream market. We consider a model of competition along the lines of Salop (1979).[8] A unit mass of consumers is uniformly distributed around a circle of unit length; consumers have unit demands for a service or good. A consumer located in x who buys from operator $k \in \{1, 2, e\}$ located in x_k incurs a cost $t|x - x_k|$, where t is the usual transportation cost and is a proxy for the intensity of competition at the downstream level. Its net utility is $u_k - p_k - t|x - x_k|$, where u_k and p_k denote respectively the gross utility associated to the final good offered by firm k and the price charged by that firm on the downstream market.

Throughout most of the paper, we shall consider that operators provide consumers with the same gross utility: $u_k \equiv u$, $\forall k$. u is also assumed to be large enough to ensure that the market remains covered in all equilibrium configurations studied later on. Firm k incurs a unit downstream cost per consumer c_{dk} due to advertising, marketing, billing, etc; we again assume that $c_{dk} \equiv c_d$, $\forall k$.[9] Finally, firms are located symmetrically on the circle.

At this stage, we can derive the demands of final services for each operator.[10] For instance, the downstream demand faced by firm 1 is:

$$D_1(p_1, p_2, p_e) = \frac{1}{3} - \frac{1}{2t}\left(2p_1 - p_2 - p_e\right).$$

The downstream demands addressed to firms 2 and e are obtained by permuting indices.

The upstream market. In order to provide one unit of final service, firm e must get access to the upstream service produced by either of the vertically integrated firms.

We denote by a_i the upstream price offered by vertically integrated firm i to the pure downstream firm, $i \in \{1, 2\}$. We consider that the upstream services offered by firm 1 and firm 2 are perfectly homogeneous. Let c_{ui} be the unit cost of providing the upstream service for firm i; we assume that $c_{ui} \equiv c_u$, $\forall i$.[11]

Timing. The sequence of decision making is as follows:

- In a first stage, the vertically integrated firms offer simultaneously and non-cooperatively their prices on the upstream market.
- In a second stage, the pure downstream competitor decides which upstream offer(s) to accept; concomitantly, firms choose non-cooperatively their prices in the downstream market.

[8] This specification of the demand functions allows to obtain simple closed-form solutions. Our results carry over to the case of a linear variable demand (detailed computations are available at the following url: `http://ceco.polytechnique.fr/home/pouyet`).

[9] Subscript 'd' stands for 'downstream'.

[10] See Tirole (1988) for instance.

[11] Subscript 'u' stands for 'upstream'.

We look for the subgame-perfect Nash equilibria (in pure strategies) of this two-stage game and proceed as usual by backward induction.

Profits. Given that the choices of downstream prices and the choice of the upstream provider(s) by the pure downstream firm are simultaneous, the choice of upstream provider(s) has no strategic impact on the product market competition: hence, firm e elects as its upstream provider the cheapest vertically integrated firm; if prices in the upstream market are equal, then we consider that firm e shares its demand across the two upstream suppliers.[12]

The profit of the pure downstream firm is given by:

$$\pi_e = [p_e - \min\{a_1, a_2\} - c_d]\, D_e.$$

The vertically integrated firm i earns profit from the downstream market and, possibly, from the upstream market; its profit can be expressed as follows:

$$\pi_i = [p_i - c_u - c_d]\, D_i + [a_i - c_u] \left[\mathbb{I}_{\{a_i<a_j\}} D_e + \mathbb{I}_{\{a_i=a_j\}} \frac{1}{2} D_e \right].$$

Notice that if the lower upstream price coincides with the upstream marginal cost, i.e., $\min\{a_1, a_2\} = c_u$, then all firms would compete on a level-playing field in the downstream market.

3 Upstream-Downstream Competition

We proceed in two steps: first, we consider the competition on the downstream market for given upstream prices set by the vertically integrated firms. Second, we focus on the competition between integrated firms on the upstream market.

3.1 Competition on the downstream market

Depending on the level of upstream prices, three cases must be considered: the demand for upstream services is supplied by one firm only (i.e., either $a_1 < a_2$ or $a_2 < a_1$); both vertically integrated firms are active on the upstream market (i.e., $a_1 = a_2$); none of the vertically integrated firms supply the upstream market, thereby implying that the pure downstream firm e is foreclosed from the downstream market.

A unique supplier on the upstream market. Suppose that $a_i < a_j$ so that firm i is the unique supplier of upstream services for firm e. For the sake of clarity, the analysis

[12] We comment and refine this argument in Section 4. In particular, we investigate an alternative timing in which firm e chooses its upstream supplier(s) before the downstream price competition stage.

proceeds by considering that the price of the upstream product is larger than its marginal cost: $a_i \geq c_u$; we show later on that $a_i < c_u$ actually never arises at equilibrium.

Firm i derives profit from both upstream and downstream levels and its problem is:

$$\max_{p_i} (p_i - c_d - c_u)D_i + (a_i - c_u)D_e.$$

By contrast, firm j and firm e earn profit from the downstream market only. However, they have different unit costs for the upstream product since the integrated firm j produces the upstream good in-house at unit cost c_u, whereas the pure downstream firm e buys this good at unit price $a_i \geq c_u$. Their problem can thus be written respectively as follows:

$$\max_{p_j} (p_j - c_d - c_u)D_j,$$
$$\max_{p_e} (p_e - c_d - a_i)D_e.$$

Solving the set of necessary and sufficient first-order conditions yields the equilibrium downstream prices. In that case with firm i as the unique upstream supplier, denote by $p_k^{(i)}$ the equilibrium price set by firm k and $\pi_k^{(i)}(a_i)$ its total profit.[13]

The following inequalities hold:

$$p_e^{(i)}(a_i) \geq p_i^{(i)}(a_i) \geq p_j^{(i)}(a_i).$$

Intuitively, the pure downstream competitor e is less competitive than the other firms since it must buy the upstream product at a price a_i larger than the upstream marginal cost. Since firm i internalizes that a consumer lost on the downstream market can be recovered on the upstream market, it behaves less aggressively than the rival integrated firm j on the downstream market.[14]

It is interesting to focus on the impact of the upstream price on the firms' profits.

Lemma 1. (When being the unique upstream supplier is individually optimal) *Let $\{i, j\} = \{1, 2\}$. $\pi_i^{(i)}(.)$ is non-monotonic strictly concave and $\pi_j^{(i)}(.)$ is strictly increasing. There exists $a_* > c_u$ such that $\pi_i^{(i)}(a_i) \geq \pi_j^{(i)}(a_i)$ iff $c_u \leq a_i \leq a_*$ (with equalities only for $a_i = c_u$ and $a_i = a_*$).*

Proof. See Appendix A.1. □

Intuitively, if the upstream price is below the average cost, each vertically integrated firm prefers not to supply the upstream market. More surprisingly, a vertically integrated firm prefers to be the sole supplier of the upstream market if the upstream price is not

[13] Superscripts in parentheses refer to the firms which actively supply the upstream market, if any.

[14] When the upstream price is too high, $\pi_e^{(i)}(a_i)$ becomes negative; define thus $a_{\max} = \sup\{a_i | \forall k, \pi_k^{(i)}(a_i) > 0\}$. Similarly, when the upstream price is too low, some profits may become negative; define thus $a_{\min} = \inf\{a_i | \forall k, \pi_k^{(i)}(a_i) > 0\}$. In the following, to streamline the analysis, we always implicitly assume that $a_{\min} < a < a_{\max}$.

too high. Indeed, still assuming that firm i is the unique upstream supplier, consider an increase in the upstream price a_i:

(i) The price on the upstream market affects the unit cost of firm e on the downstream market. This raise-the-rival's-cost effect implies that competition on the downstream market is softened since firm e is led to behave less aggressively.[15] In addition, since prices are strategic complement, both integrated firms react by increasing their downstream prices.

(ii) The upstream revenue $(a_i - c_u)D_e$ earned by the unique upstream provider is affected; typically, a high upstream price tends to contract the demand for the upstream good.

(iii) The unique upstream provider's behavior on the downstream market changes: indeed, since firm i fully internalizes the revenue from the upstream market, it tends to behave less aggressively on the downstream market to 'protect' firm e.

Since firm j earns profit from the downstream market only, it always benefits from an increase of the price that prevails on the upstream market. Indeed, this deteriorates the competitiveness of firm e (see (i)) and leads firm i to behave less aggressively (see (iii)). For these reasons, firm j's profit is strictly increasing in the upstream price. By contrast, firm i's profit is non-monotonic strictly concave. Indeed, it benefits from the raise-the-rival's-cost effect (see (i)), but a large upstream price tends to reduce its upstream revenue (see (ii)). As a result, from the viewpoint of a vertically integrated firm, it is preferable to be the unique upstream provider only if the price that prevails on the upstream market is not too large.

Let us now define the 'unique provider monopoly upstream price':[16]

$$a_m = \arg\max_{a_i} \pi_i^{(i)}(a_i).$$

Loosely speaking, a_m relates to the best upstream price set by a non-cooperative vertically integrated firm that would be the sole provider on the upstream market. The following lemma is shown in Appendix.

Lemma 2. (Upstream market's curse) *The profit of a unique supplier of upstream services at the unique provider monopoly upstream price is smaller than the profit of the vertically integrated firm which does not supply the upstream market:* $\pi_i^{(i)}(a_m) < \pi_j^{(i)}(a_m)$, $i \neq j \in \{1, 2\}$.

[15]Formally, firm e's best-response is characterized by:

$$R_e(p_i, p_j, a_i) = \arg\max_{p_e} (p_e - c_d - a_i)D_e = \frac{1}{2}\left[a_i + c_d + \frac{t}{3} + p_i + p_j\right],$$

which increases in a_i.

[16]Since $\pi_i^{(i)}(.)$ is non-monotonic strictly concave, a_m is well-defined and characterized by a first-order condition.

Proof. See Appendix A.2. □

In terms of upstream prices, this result amounts to $a_m > a_*$. Therefore, if the vertically integrated firm i supplies the upstream market and sets the most profitable upstream price, i.e., $a_i = a_m$, then firm j has no incentive to undercut firm i on the upstream market. This result already highlights one of the specificities of price competition on the upstream market: some firms on this market might prefer not to compete at all since the loss in terms of foregone upstream revenues might be more than offset by higher downstream profits due to a softer downstream competition. In the following, we shall show that this intuition although correct is also incomplete.

Two vertically integrated firms supply the upstream market. This case arises when $a_1 = a_2 \equiv a$. Again, we give the intuitions in the case $a \geq c_u$. As expected, the equilibrium final prices are such that $p_e^{(1-2)}(a) \geq p_1^{(1-2)}(a) = p_2^{(1-2)}(a)$. Let us denote by $\pi_k^{(1-2)}(a)$ the profit of firm k in that case.[17] Then, we obtain the following lemma.

Lemma 3. (When sharing the upstream market is individually optimal) *Let* $\{i, j\} = \{1, 2\}$. *There exist* $\underline{a}$ *and* $\overline{a}$ *such that* $c_u < \underline{a} < \overline{a} = a_m$ *and:*

- *for* $a \leq c_u$, $\pi_i^{(i)}(a) \leq \pi_i^{(1-2)}(a) \leq \pi_i^{(j)}(a)$;
- *for* $c_u \leq a \leq \underline{a}$, $\pi_i^{(j)}(a) \leq \pi_i^{(1-2)}(a) \leq \pi_i^{(i)}(a)$;
- *for* $\underline{a} \leq a \leq \overline{a}$, $\max\{\pi_i^{(j)}(a), \pi_i^{(i)}(a)\} \leq \pi_i^{(1-2)}(a)$;
- *for* $a \geq \overline{a}$, $\pi_i^{(i)}(a) \leq \pi_i^{(1-2)}(a) \leq \pi_i^{(j)}(a)$

(where all weak inequalities can be replaced by strict ones).

Proof. See Appendix A.3. □

In the case of a unique upstream provider, Lemma 1 states that the vertically integrated firms value differently an increase in the upstream price: in a nutshell, the upstream provider benefits from the upstream profit while the other vertically integrated firm benefits from a stronger competition moderation effect.

Consider now that vertically integrated firms share the upstream market and set the same upstream price a. When $a \leq \underline{a}$, a vertically integrated operator is mostly interested in deriving additional revenues from the upstream market. When $a \geq \overline{a} = a_m$, a reverse conclusion holds: this firm prefers letting its rival be the unique upstream provider in order to benefit from a stronger moderation of the downstream competition. For intermediate values of the upstream price, $\underline{a} \leq a \leq \overline{a}$, sharing the upstream market is the most profitable strategy for a vertically integrated firm: it allows to earn some upstream profit and contributes to softening the downstream competition.

[17] As in the unique upstream provider case, we restrict attention to values of a such that all profits are positive.

In our model, the following inequality holds:

$$\pi_i^{(1-2)}(a) \geq \frac{1}{2}\pi_i^{(i)}(a) + \frac{1}{2}\pi_i^{(j)}(a).$$

This implies first that $\pi_i^{(1-2)}(a_*) \geq \pi_i^{(i)}(a_*) = \pi_i^{(j)}(a_*)$. Hence, from the viewpoint of the non-cooperative behavior of a vertically integrated firm on the upstream market, in the neighborhood of a_*, each integrated firm prefers to share the upstream market with its rival than either to exit or to be the sole upstream supplier. Therefore supra-competitive equilibria may emerge, as will be confirmed later on.[18]

Second, consider that integrated firms collude on the upstream market (but still behave non-cooperatively on the downstream market). The previous inequality shows that the best upstream collusive agreement involves sharing the upstream market at an upstream price defined by $a_c = \arg\max_a \pi_1^{(1-2)}(a) + \pi_2^{(1-2)}(a)$.[19] In the sequel, we shall show that such a perfect collusive outcome never arises at equilibrium.

Foreclosure of the pure downstream competitor. Suppose that the vertically integrated firms set prices on the upstream market such that the demand for upstream services is nil. This arises when a_1 and a_2 are both larger than the threshold value $a_{\max}$ defined in footnote 14. In this situation, the pure downstream firm e is foreclosed from the downstream market and the profits of firms 1 and 2 are given by duopoly profits $\pi_i^{(\emptyset)}$, $i = 1, 2$.

In Appendix we show the following lemma.

Lemma 4. (No equilibrium foreclosure) *The profit of vertically integrated firm i under foreclosure is lower than when it is the sole supplier of the upstream market at the upstream monopoly price: $\pi_i^{(\emptyset)} < \pi_i^{(i)}(a_m)$.*

Proof. See Appendix A.4. □

A direct implication of this lemma is that foreclosure of the pure downstream competitor never arises at equilibrium. To build the intuition, consider that firm j is not active

[18] One could legitimately question the generality of this result. From the typical IO literature, it is reasonable to assume that $\pi_i^{(i)}(.)$ is non-monotonic strictly concave and $\pi_i^{(j)}(.)$ strictly increases in the upstream price. However, the relative position of $\pi_i^{(1-2)}(.)$ w.r.t. the average of $\pi_i^{(i)}(.)$ and $\pi_i^{(j)}(.)$, and therefore the existence of a zone of upstream prices such that vertically integrated firms prefer to share the upstream market at this upstream price, depends in a complex way on the specification of the demand functions. Nevertheless, we show that our results carry over to other settings.

[19] $\pi_i^{(1-2)}(.)$ is non-monotonic strictly concave and thus admits an interior maximum. Notice that $a_c > a_m$. Indeed, a unique upstream provider faces the following trade-off: on the one hand, a high upstream price tends to lower the upstream profit, on the other hand, it helps softening its competitive environment at the downstream level. When both vertically integrated firms share the upstream market, the first effect tends to become less important, since each provider earns only one half of the upstream profit. In addition, for a given upstream price, the competitive pressure it faces on the downstream market becomes less intense, since the other integrated firm now internalizes the impact of its downstream pricing on its upstream profit, and therefore becomes less aggressive. The way both effects are modified implies that a_c is greater than a_m.

on the upstream market and that firm i decides whether to foreclose the pure downstream competitor firm or not. This decision trades off several effects: as usual, foreclosure reduces competition at the downstream level (a duopoly instead of a triopoly) at the cost of giving up the upstream profit; furthermore, removing the inefficient pure downstream firm tightens the competitive pressure exerted by firm j (since downstream prices are strategic complements).

Figure 1 offers a graphical representation of Lemmas 1-4.

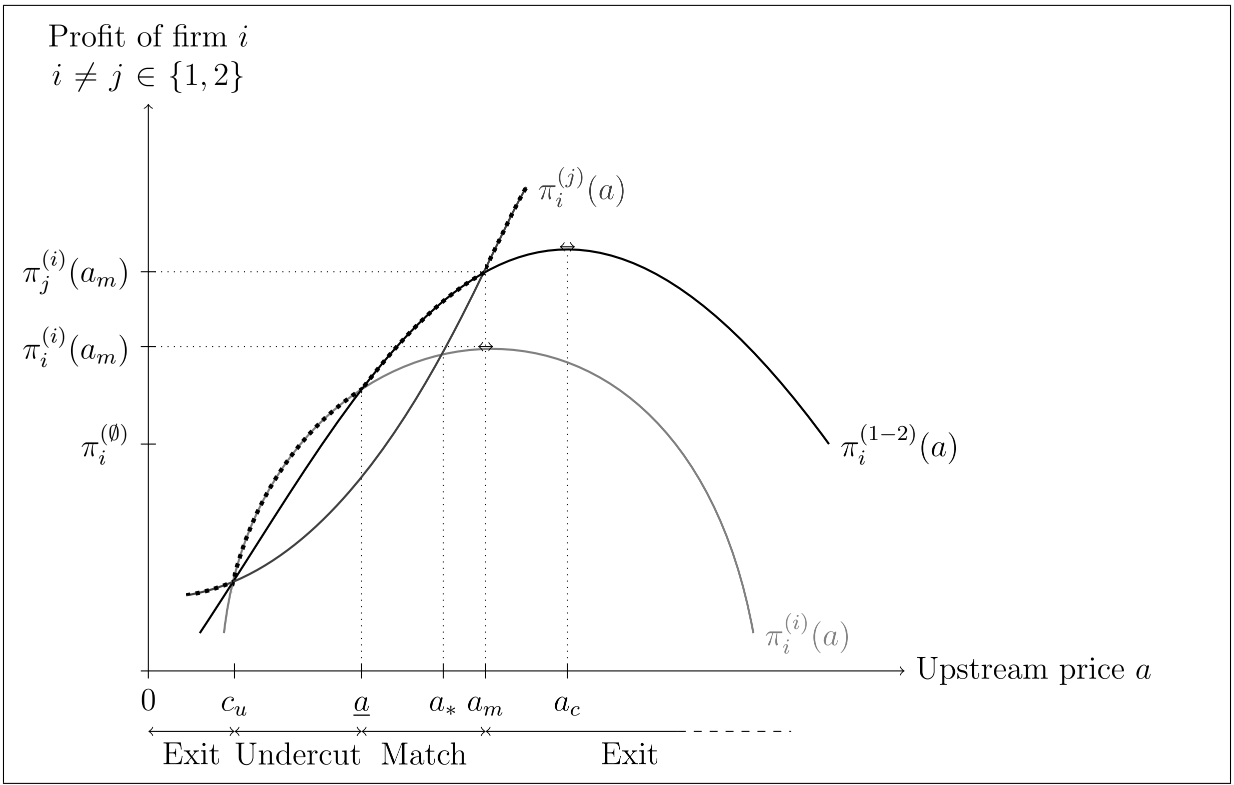


Figure 1: When only one integrated firm supplies the upstream market, it earns more profit than the other integrated firm if and only if $a \in [c_u, a_*]$ (Lemma 1). At upstream price a_m, firm i prefers that its rival be the sole supplier of the upstream market (Lemma 2) If firm i sets $a \in [\underline{a}, \overline{a}]$, firm j prefers to share the upstream market with its rival rather than undercut or exit (Lemma 3). A vertically integrated firm prefers to be the unique upstream provider at the upstream monopoly price than exclude the pure downstream competitor (Lemma 4).

3.2 Competition on the upstream market

It remains to determine the outcome of the competition at the upstream level. Given the upstream price a_j set by its rival on the upstream market, vertically integrated firm i can adopt three different strategies:

- It can *undercut* its rival on the upstream market, i.e., $a_i < a_j$; in this case, it becomes the unique provider on the upstream market and earns $\pi_i^{(i)}(a_i)$.

- It can *match* its rival on the upstream market, i.e., $a_i = a_j \equiv a$; in this case, it shares the upstream demand and earns $\pi_i^{(1-2)}(a)$.

- It can *exit* the upstream market by setting $a_i > a_j$, in which case it earns $\pi_i^{(j)}(a_j)$.

A quick inspection of Figure 1 provides the intuitions for the different equilibria that arise in our game: indeed, the upper envelope of the profit functions drawn in Figure 1 (the thick dotted curve) allows to determine the optimal strategy of firm i for a given upstream price set by rival firm j.

If firm j sets $a_j \in (c_u, \underline{a})$ then firm i has an incentive to undercut; but firm j prefers in turn to undercut firm i. Intuitively, this process continues until both vertically integrated firms offer upstream services at the upstream unit cost c_u.

By contrast, if firm j sets an upstream price $a_j \in [\underline{a}, \overline{a} = a_m]$ then firm i prefers to match and share the upstream market. Given the symmetry of firms i and j, this implies that there exists a continuum of equilibria in which vertically integrated firms share the upstream market at a common price $a \in [\underline{a}, a_m]$.

Finally, suppose that firm i sets $a_i = a_m$; then, firm j is exactly indifferent between sharing the upstream market or exiting. As a result, there exists an equilibrium in which the upstream market is supplied by one firm only at the unique upstream provider monopoly price.

The next proposition rigorously states these intuitions.

Proposition 1. *There exist three types of subgame-perfect Nash equilibria in pure strategies:*

- *A Bertrand-like outcome in which vertically integrated firms offer upstream services at the upstream unit cost:* $a_1 = a_2 = c_u$.

- *Supra-competitive outcomes in which vertically integrated firms offer upstream services at the same upstream price* $a \in [\underline{a}, a_m]$.

- *Monopoly-like outcomes in which only one vertically integrated firm offers upstream services at the unique upstream provider monopoly price* a_m.

There exist no other equilibria.

Proof. First, we show that there exists an equilibrium in which integrated firms share the upstream market at common price c_u. Consider an upward deviation by firm i: $a_i > c_u$. Then, firm j becomes the unique supplier of the upstream market and firm i's profit is $\pi_i^{(j)}(c_u) = \pi_i^{(1-2)}(c_u)$ given Lemma 3. Firm i is thus indifferent between sharing the upstream market at a price c_u and letting firm j serve the upstream market. Consider a downward deviation by firm i: $a_i < c_u$. Its profit is now $\pi_i^{(i)}(a_i) < \pi_i^{(i)}(c_u) = \pi_i^{(1-2)}(c_u)$, since $\pi_i^{(i)}$ is increasing for $a_i < a_m$; thus a downward deviation is not profitable.

Second, we show that, for all $a \in [\underline{a}, a_m]$, there exists an equilibrium in which integrated firms share the upstream market at common price a. Consider an upward deviation by firm i: $a_i > a$. Then, firm i's profit is $\pi_i^{(j)}(a)$ which is smaller than $\pi_i^{(1-2)}(a)$ given Lemma 3. Consider a downward deviation by firm i: $a_i < a$. Then, firm i's profit is $\pi_i^{(i)}(a_i)$ which is smaller than $\pi_i^{(i)}(a)$, since $\pi_i^{(i)}$ is increasing for $a_i < a_m$. $\pi_i^{(i)}(a)$ being itself smaller than $\pi_i^{(1-2)}(a)$ given Lemma 3, we deduce that a downward deviation is not profitable.

Third, we show that there exists an equilibrium in which integrated firm i supplies the upstream market at price a_m and firm j sets a price larger or equal to $a_{\max}$. Given Lemma 4, firm i does not want to foreclose the pure downstream firm e. Given that it is the unique upstream supplier, setting $a_i = a_m$ is indeed optimal for firm i. Consider now a deviation by firm j. If $a_j > a_m$, its profit is unchanged. If $a_j = a_m$, it earns $\pi_j^{(1-2)}(a_m) = \pi_j^{(i)}(a_m)$. If $a_j < a_m$, since $\pi_j^{(j)}$ is increasing for $a_j < a_m$, it earns $\pi_j^{(j)}(a_j) < \pi_j^{(j)}(a_m)$, itself smaller than $\pi_j^{(i)}(a_m)$ given Lemma 2. Hence no deviation by firm j is strictly profitable.

We now prove that there exist no other subgame perfect equilibria in pure strategies.

Claim 1. *It is not possible that the upstream market is supplied at an upstream price* $a < c_u$.

Proof. If firm i is the unique supplier of the upstream market with $a_i < c_u$, then it is a strictly profitable deviation for it to set $a_i + \epsilon$, with a small $\varepsilon > 0$ such that $a_i + \varepsilon < \min\{a_j, c_u\}$, since $\pi_i^{(i)}$ is strictly increasing for $a_i < a_m$. If both integrated firms share the upstream market at common price $a_i = a_j < c_u$, then is is a strictly profitable deviation for firm i to exit the upstream market since $\pi_i^{(j)}(a_i) > \pi_i^{(1-2)}(a_i)$ given Lemma 3. □

Claim 2. *It is not possible to have a unique upstream provider at price* c_u.

Proof. Suppose that firm i is the unique upstream supplier at price c_u and that firm j sets a price $a_j > c_u$. Then it is a strictly profitable deviation for firm i to set $c_u + \varepsilon$ with a small $\varepsilon > 0$ such that $c_u + \varepsilon < \max(a_j, a_m)$, since π_i^i is strictly increasing for $a_i < a_m$. □

Claim 3. *It is not possible that the upstream market is supplied at an upstream price* $a \in (c_u, \underline{a})$.

Proof. If firm j is the sole supplier of the upstream market at a price $a_j \in (c_u, \underline{a})$, then it is a strictly profitable deviation for firm i to undercut, since $\pi_i^{(i)}(a_j - \varepsilon) > \pi_i^{(j)}(a_j)$ for a sufficiently small ε given Lemma 3. Again, if both integrated firms share the upstream market with $a_i = a_j \in (c_u, \underline{a})$, it is a strictly profitable deviation for firm i to undercut. □

Claim 4. *It is not possible to have a unique upstream provider at a price* $a \in [\underline{a}, a_m)$.

Proof. If firm j is the sole provider of the upstream market at a price $a_j \in [\underline{a}, a_m)$, then it is a strictly profitable deviation for firm i to match and share the upstream market, since $\pi_i^{(1-2)}(a) > \pi_i^{(j)}(a)$ given Lemma 3. □

Claim 5. *It is not possible that the upstream market is supplied at an upstream price $a > a_m$.*

Proof. If firm i is the sole supplier of the upstream market at a price $a_i > a_m$, then it is a strictly profitable deviation for it to set $a_i = a_m$. If both integrated firms share the upstream market with $a_i = a_j > a_m$, it is a strictly profitable deviation for firm i to exit the upstream market, since $\pi_i^{(j)}(a) > \pi_i^{(1-2)}(a)$ given Lemma 3. □

Claim 6. *It is not possible that the upstream market is not supplied by any integrated firm.*

Proof. Immediate from Lemma 4. □

This concludes the proof of the proposition. □

In our model, the upstream providers offer perfectly homogeneous products. Hence, it seems rather intuitive that the usual Bertrand result emerges: competition on the upstream market is fierce and drives upstream prices to the upstream unit cost. Thus, competition on the upstream market allows the pure downstream firm to compete on a level playing field with both vertically integrated firms on the downstream market. However, as shown by the previous proposition, other equilibria exist, which are much less competitive.

Indeed, non-cooperative competitors may be able to implement the unique upstream provider monopoly price, i.e., a partially collusive outcome, on the upstream market. This radical departure from the Bertrand outcome stems from the fact that the upstream competitors are also present on the downstream market. Hence, when a vertically integrated firm sets its price for its upstream services, it trades off the profit derived from that market with the impact on the competition at the downstream level. If, say, firm i sets an upstream price in $[\underline{a}, a_m]$, then firm j finds it optimal to exactly match firm i and to share the upstream demand. Undercutting would imply that firm i derives no upstream profit; in turn, this would make firm i a more aggressive competitor on the downstream market, a non profitable strategy for upstream prices in $[\underline{a}, a_m]$.[20]

Notice that the equilibria in which vertically integrated firms share the upstream market at a price $a \in [\underline{a}, a_m]$ can be ranked: both vertically integrated firms unambiguously prefer to implement a larger common upstream price.

Finally, there also exists an equilibrium in which only one vertically integrated operator serves the upstream market at the upstream monopoly price. When, say, firm i is the unique upstream supplier at price a_m, firm j turns out to be exactly indifferent between

[20] Suppose that the vertically integrated firms have different cost structures (either for the upstream or the downstream markets). Then, in line with Lemma 3, we would be led to define thresholds for each vertically integrated firm: $\underline{a}_i$ and $\overline{a}_i$, $i \in \{1, 2\}$. If the costs difference is not too large, then $\max\{\underline{a}_1, \underline{a}_2\} < \min\{\overline{a}_1, \overline{a}_2\}$ and there still exist equilibria in which firms share the upstream market at a supra-competitive common price.

exiting and sharing the upstream market. However, firm i prefers that firm j shares the market and becomes a less aggressive competitor on the downstream market. Again, in the standard Bertrand game, the decision to exit the market is always weakly dominated (since the firm then earns no profit); in our model, such a strategy can be optimal for a vertically integrated firm since it allows to benefit from a less aggressive rival on the downstream market.

We conclude this discussion with the following proposition.

Proposition 2. *The partially-collusive-like equilibrium in which* $a_1 = a_2 = a_m$ *is weakly preferred to any other equilibrium by both vertically integrated firms, and strictly preferred by at least one of them.*

Proof. Immediate. □

Hence, the following presumption emerges from our analysis: vertically integrated firms which compete on an upstream market are likely to reach a partially collusive outcome; the competitiveness of the upstream market should not be taken for granted. Though there exists a potential competitive pressure on the upstream market, it is unlikely that this pressure alone drives the upstream price down, even absent any form of tacit or overt collusion.

It is also interesting to highlight the reason that makes full collusion on the upstream market impossible to implement by the vertically integrated firms. Remember that a_c is the upstream price that maximizes the sum of the vertically integrated firms' profits. If the vertically integrated firm i sets a_c then its integrated rival has an incentive to overbid, that is, to exit the upstream market. Again the logic of the standard Bertrand competition game is reversed: with respect to the collusive joint optimum, a firm has an incentive not to undercut its rival on the upstream market but rather to offer a strictly larger upstream price.

4 Discussions and Extensions

In this section we highlight the main mechanisms driving our model thanks to several thought experiments. We also provide some extensions and comparative statics results.

4.1 Fundamental Mechanisms

Pure upstream competitor. Consider the scenario in which a pure upstream competitor, that is, a firm which is active only in the upstream market, might provide the intermediate service to the pure downstream firm. That upstream firm has no direct interactions with the downstream market; thus, its best-response is to undercut its rivals as long as the upstream price remains above the average cost. Moreover, if the upstream competitor becomes the unique upstream provider, then an integrated operator has an incentive to undercut since this steals upstream profits without affecting the other firms' best-responses on the downstream market. In other words, undercutting the pure upstream firm has not the adverse interaction effect of making integrated competitors more aggressive on the downstream market.

As a result, only the Bertrand-like equilibrium can emerge when there is at least one pure upstream competitor. This result highlights the fundamental role of upstream-downstream interactions in our model.

The role of upstream pricing. Throughout our analysis, we have considered that vertically integrated firms could meter the usage of their intermediate services made by the pure downstream competitor. Hence, unit prices (or, analogously, royalties or access charges) can be implemented. In some contexts, like patent licensing, integrated firms might only be able to impose a fixed fee for the usage of their intermediate input. Denote by P_i^u the fixed fee offered by vertically integrated firm i for the access to the upstream technology. A direct consequence of this type of upstream pricing is that the pure downstream competitor buys the intermediate service from one integrated firm only.

In this context, firm e's problem is now:

$$\max_{p_e}(p_e - c_d)D_e - \min\{P_1^u, P_2^u\},$$

provided that it earns a positive profit at equilibrium. Clearly, the upstream fees do not affect the downstream outcome. Therefore, the only equilibrium in which the downstream firm is not foreclosed from the downstream market is such that vertically integrated firms set upstream fees so as to exactly cover their costs of providing the upstream services.

Hence, this upstream pricing may appear as pro-competitive. However, it modifies the incentives to foreclose the pure downstream firm. Start from a situation where this firm is foreclosed, and consider the new trade-off faced by an integrated firm deciding whether or not to serve the upstream market. On the one hand, a fixed fee does not allow to relax competition on the downstream market. On the other hand, this pricing allows to capture the whole profit of a pure downstream firm. It turns out that in our setting, when integrated firms use fixed fees, there exists an equilibrium in which the pure downstream competitor is foreclosed.[21]

What are the competitive impacts of the nature of upstream pricing? Thanks to unit pricing firms can manipulate their rivals' costs and relax competition on the downstream market. This creates strong interactions between both markets, giving rise to non-competitive equilibria with an active downstream firm. By contrast, fixed upstream fees do not give rise to these upstream-downstream interactions, but create conditions favorable to foreclosure.

[21] Computations are straightforward and left to the reader.

Strategic nonparticipation. Suppose that the vertically integrated firms can credibly commit, say in stage zero, not to serve the upstream market before the price competition stage on this market. In this case, the Bertrand-like outcome cannot be part of a subgame-perfect equilibrium. Indeed, if it were the case, an integrated firm would rather prefer not to participate to the upstream market in stage zero, thereby triggering a higher upstream price at stage one, and softening downstream competition in stage two.

This is reminiscent of the analysis in Jehiel and Moldovanu (1996) who study bidders' incentives to participate in an auction with negative externalities and derive a similar result. In fact, our price competition game on the upstream market can be viewed as an auction run by the pure downstream firm in which bidders are the vertically integrated firms. In Jehiel and Moldovanu's paper, the payoff earned by the bidders depends on who wins the auction; hence it may be interesting not to participate in order to influence the outcome of the auction. In our model, the externality depends on the level of upstream prices; a bidder may decide not to participate to avoid low-price equilibria, such as the Bertrand outcome.

This variation of our setting reinforces our result on the emergence of the monopoly-like equilibrium. Indeed, it would exist even if the upstream market curse (see Lemma 2) did not hold, provided that the decision not to participate to the upstream market is a binding commitment.

Strategic choice of the upstream provider(s). In our basic setting, we make two assumptions about the choice of the upstream provider(s). First, when $a_1 = a_2$, the pure downstream firm splits its upstream demand in equal shares across the two suppliers. Second, the upstream provider(s) is (are) chosen concomitantly with the downstream prices. Let us examine the role of these assumptions.

First, when $a_1 = a_2$, the pure downstream firm is ex post indifferent between any sharing out of its upstream demand. However, its choice can affect its the upstream providers' behavior. Consider a variation of our model in which firm e can decide how to split its upstream demand when upstream prices are equal. To simplify, we restrict its last stage strategy to constant proportional sharing rules. If it purchases a fraction $\alpha \in [0, 1]$ from firm i when $a_i = a_j = a$, then denote by $\pi_i^{(1-2)}(a, \alpha)$ (resp. $\pi_j^{(1-2)}(a_1 - \alpha)$) the profit of firm i (resp. j). Lemma 3 can be extended by defining new thresholds as functions of α. There exist $\underline{a}(\alpha)$ and $\overline{a}(\alpha)$ such that $c_u < \underline{a}(\alpha) \leq a_* \leq \overline{a}(\alpha)$, and the profits $\pi_i^{(i)}(.)$, $\pi_i^{(1-2)}(., \alpha)$ and $\pi_i^{(j)}(.)$ are ordered as in Lemma 3 between these thresholds. $\underline{a}(\alpha)$ and $\overline{a}(\alpha)$ are decreasing, $\underline{a}(1/2) = \underline{a}$, $\overline{a}(1/2) = \overline{a}$ and $\underline{a}(0) = \overline{a}(1) = a_*$. Applying this result, we obtain that the three types of perfect-subgame equilibria shown in Proposition 1 are conserved, and that the range of upstream prices sustaining a collusive-like equilibrium shrinks to $[\max\{\underline{a}(alpha_i), \underline{a}(1-\alpha)\}, \min\{\overline{a}(\alpha), \overline{a}(1-\alpha)\}] = [\underline{a}(\min\{\alpha, 1-\alpha\}), \overline{a}(\max\{\alpha, 1-\alpha\})]$. It reaches its maximal size $[\underline{a}, \overline{a}]$ for $\alpha = 1 - \alpha = 1/2$; it degenerates to the single point a_* for $\alpha = 0$ or $\alpha = 1$. Hence, our main result, the existence of collusive-like equilibria, does not crucially rely on our assumption of symmetric split of the upstream demand when upstream prices are equal.

Second, in our basic setting, the pure downstream firm determines simultaneously its price on the final market and which integrated firm to buy the intermediate input from. This choice is concomitant to the determination of downstream prices by the integrated firms. As a consequence, the choice of upstream provider has no strategic impact on competition that takes place on the downstream market. Let us now consider a variation of this baseline scenario, in which the decision to choose a provider is made before the downstream price competition game. Let denote by $\alpha \in [0,1]$ the share of the upstream demand that is bought from integrated firm i. Given upstream prices, the pure downstream firm's program is:

$$\max_{\alpha \in [0,1]} \pi_e^*(\alpha, a_i, a_j) \equiv [p_e^*(\alpha) - c_d - \alpha a_i - (1-\alpha)a_j]\, D_e(p_e^*(\alpha), p_i^*(\alpha), p_j^*(\alpha)),$$

where $p_i^*(\alpha)$, $p_j^*(\alpha)$ and $p_e^*(\alpha)$ are the equilibrium downstream prices for a given α. The choice of α has a direct effect on firm e's markup, which makes it willing to buy from the cheapest upstream provider. Interestingly, this choice has now a strategic impact on the downstream outcome. At this level of generality, this strategic effect cannot be signed. However, in our context, it turns out that the direct effect always dominates the strategic one, so that firm e always buy the intermediate input from the cheapest provider. Whether this feature continues to hold in other settings would be worth investigating: indeed, if it were not the case, this would mean that an upstream buyer would accept to buy the same intermediate input at different prices in order to alter strategically the final product market competition.

Differentiated upstream market. A natural question to ask is whether our results continue to hold when the intermediate inputs offered by vertically integrated firms on the upstream market are not perfectly substitutable. Suppose for instance that the share of the upstream demand that is served by firm i is given by $\alpha_i(a_i, a_j) = 1/2 - (a_i - a_j)/(2\tau)$, where $\tau > 0$ is the degree of differentiation between vertically integrated firms on the upstream market.[22] Straightforward computations first confirm that our results are indeed robust.[23] As soon as the ratio t/τ is large enough, then two symmetric equilibria exist, one in which upstream prices are rather low, an another in which upstream prices are rather high. Second, when the ratio t/τ becomes small enough there exists a unique symmetric equilibrium with upstream prices converging to the unit upstream cost as this ratio tends towards 0. A tentative conclusion would therefore be that as competition intensifies on the downstream market (i.e., as t goes to 0), vertically integrated firms compete more and

[22]Even though inputs are now heterogenous, we maintain the assumption that one unit of input from firm i, $i = 1, 2$, allows firm e to produce one unit of final product and that the choice of input provider does not affect the base quality of the final product.

[23]Computations are available from the authors upon request.

more fiercely on the upstream market. The conventional wisdom expressed by regulators is thus somewhat reversed: the development of competition of downstream markets is key to the emergence of competitive upstream markets.

Existence of equilibria. Notice that monopoly-like equilibria are less likely to exist than collusive-like equilibria. Indeed, assume that a monopoly-like equilibrium exists, then it must be that $a_m > a_*$ (otherwise, undercutting would be optimal). Using:

$$\pi_i^{(1-2)}(a_*) \geq \frac{1}{2}\pi_i^{(i)}(a_*) + \frac{1}{2}\pi_i^{(j)}(a_*) = \pi_i^{(i)}(a_*) = \pi_i^{(j)}(a_*),$$

we obtain that $a_1 = a_2 = a_*$ is part of a collusive-like equilibrium, since deviating cannot yield more than $\max\{\pi_i^{(i)}(a_*), \pi_i^{(j)}(a_*)\}$. Therefore, in the sequel, we will say that the upstream market is not competitive when a collusive-like equilibrium exists.

4.2 The Determinants of Effective Upstream Competition

It is obvious that fierce competition on the upstream market enhances competition on the downstream market. In turn, we will see that characteristics of the downstream market affect the outcomes that can arise on the upstream market. These results provide some insights on the strategies of firms.

Downstream differentiation strategy. It is straightforward to see that as final products become less differentiated (t goes to 0), both the values of $\underline{a}$ and $\overline{a}$ tend to the upstream unit cost c_u (the analytical expressions of $\underline{a}$ and $\overline{a}$ are given in Appendix). As competition intensifies on the downstream market, the upstream market becomes more competitive (in the following sense: whatever the equilibrium configuration, the upstream price tends to the marginal cost of the intermediate service).

Consider now the other polar case in which final products are strongly differentiated so that each firm is a local monopoly on the downstream market (which arises when the transportation cost t is large enough with respect to the base utility level u). Interactions between firms on the downstream market disappear, implying that the upstream market outcome does not help softening competition on the downstream market. As a consequence, vertically integrated firms compete head-to-head on the upstream market and, at the unique equilibrium, they share the upstream demand at the upstream unit cost.

To summarize, there is a non-monotonic link between downstream differentiation and the competitiveness of the upstream market. On the one hand a high degree of differentiation softens competition on the downstream market. On the other hand, differentiation reduces interactions between both markets and makes non-competitive outcomes on the upstream market less likely.

Incentives to quality degradation/improvement. Straightforward calculations show that an increase in the downstream cost of firm k (c_{dk}) is equivalent to a decrease of the same amount in the gross utility provided to its final consumers (u_k). It seems reasonable to assume that integrated firms can voluntarily damage the upstream good, which in turn affects the quality of the pure downstream firm, and hence its cost efficiency. To keep the analysis as simple as possible we assume that both integrated firms adopt the same level of quality degradation.

Comparative statics on c_{de} allows to study the incentives to degrade or improve the quality of the upstream good provided to firm e. The intuition goes as follows: the more efficient the pure downstream competitor is, the larger is its downstream market share, thus the more important is the potential upstream profit of an integrated firm with respect to its downstream profit. This leads to balanced conclusions. On the one hand, sharing the upstream market becomes more profitable relative to exiting it. This allows a higher non-cooperative common upstream price $\overline{a}$, and thus higher profits for the vertically integrated firms, as long as the collusive-like equilibrium with $a_1 = a_2 = \overline{a}$ exists. On the other hand, sharing the upstream market becomes less profitable relative to supplying it alone. This exacerbates the incentives of integrated firms to undercut their rival in order to be the sole supplier of the upstream market. When the pure downstream competitor is efficient enough, the former effect becomes so important that the partially collusive equilibrium disappears. In this case the Bertrand outcome becomes the only Nash equilibrium.

To conclude, as long as quality differences are not too large (c_{de} not too different from $c_{d1} = c_{d2}$), vertically integrated firms have incentives to improve the quality of the upstream good in order to raise the upstream price. However when the pure downstream firm is too efficient ($c_{de} - c_{d1}$ inferior to a certain threshold), only the Bertrand-like equilibrium can arise, so that the integrated firms want to degrade the upstream good in order to sustain non-cooperative non-competitive upstream prices.

Market structure. We now address the impact of market structure, i.e., the number of firms of each type, on competition intensity. Basically, the conventional wisdom states that more competitors leads to an increased competitive pressure. However, we argue that the presence of upstream-downstream interactions requires a more careful analysis.

The condition for the upstream market to be competitive is that there are no equilibria in which all integrated firms share the upstream market at a common upstream price, because each of them would rather undercut to the 'unique provider monopoly upstream price' and capture the whole upstream demand. As already emphasized, starting from a situation in which all integrated firms share the upstream market, the decision to undercut trades off two effects. It allows to get more upstream profits, at the cost of making the other integrated firms more aggressive on the downstream market. We now discuss informally the impact of the number of integrated and pure downstream firms on the (dis)incentives to undercut.

Consider first an increase in the number on pure downstream firms. On the one hand, the additional upstream profit of an undercutting integrated firm increases relative to its downstream profit. On the other hand, it may worsen the negative impact on its downstream profit, since the competition moderation effect of sharing the upstream market is larger with more pure downstream firms. Overall whether the entry of pure downstream firms enhances competition on the upstream market or not is ambiguous.

The entry of new vertically integrated firms has an ambiguous impact on the relative importance of upstream and downstream profits, since both profits decrease. Nevertheless one might expect the marginal profit-stealing effect of one additional integrated competitor to be greater when there are few integrated firms, since undercutting allows to get an additional fraction of the upstream market equal to $1 - 1/(\#$ of integrated firms$)$, which is concave. The competition moderation effect is ambiguously affected by the number of integrated firms. On the one hand, a higher number of integrated competitors implies that each firm supplies a smaller fraction of the upstream market, which make them less accommodating on the downstream market. On the other hand, an undercutting integrated firm faces suddenly a larger number of aggressive rivals. Again, the overall effect of the entry of vertically integrated firms is a priori undetermined, though we suspect a pro-competitive impact when there are initially few integrated firms.[24]

Predation or intense competition? We now go back to our baseline three-firm case. If the pure downstream competitor is inefficient enough (c_{de} high relative to $c_{d1} = c_{d2}$), the positions of profit curves in the neighborhood of $a = c_u$ are reversed (inequalities in the first two items of Lemma 3 are reversed). In particular, if a vertically integrated firm, say 1, offers an upstream price just below the unit cost c_u, firm 2's best response is to undercut and supply the whole upstream demand. The intuition is the following: if $a_1 < c_u$, firm 1 makes upstream losses. Therefore it is induced to behave aggressively on the downstream market in order to minimize the pure downstream operators's market share. Firm 2 prefers undercutting on the upstream market. Indeed, since the pure downstream is assumed to be inefficient, firm 2's upstream losses are small enough to be outweighed by the benefit of avoiding the aggressive behavior of firm 1.

In this case the thresholds $\underline{a}$, a_* and $\overline{a}$ are below c_u. Following the guidelines of the proof of Proposition 1 we can show that there exist a Bertrand-like equilibrium and a set of 'super-competitive' equilibria, in which vertically integrated firms share the upstream demand at a common price $a \in [\overline{a}, \underline{a}]$.

Throughout most of the paper we have emphasized that interactions between upstream and downstream markets can lead to non-competitive outcomes, in which upstream prices

[24]Numerical computations confirm this intuition. For example, when allowing for downstream cost differences between pure downstream and vertically integrated firms, the constellation of cost parameters for which there exists a collusive-like equilibrium has a maximal size for an intermediate number of integrated firms, and shrinks for extreme values.

are above unit costs without collusion. This paragraph illustrates that in some cases (an inefficient pure downstream firm), they can also lead to super-competitive outcomes, in which upstream prices are below unit prices without predation.

5 Applications: Wholesale Markets in Telecommunications

The development of wholesale markets and the competitiveness of these markets are key policy issues in the telecommunications industry. We provide below an analysis of wholesale markets in the broadband and the mobile telephony markets. We then discuss some implications of our results in terms of regulatory policy.

5.1 The Broadband Market

Broadband services enable users to access the Internet at high-speed rates. In most industrialized countries, broadband is developing fast. For instance, there were 37.9 million broadband lines in the US and 33.4 million broadband lines in the European Union in 2004, compared to 28.2 million lines and 19.4 million lines, respectively, one year earlier.[25]

Different technologies can deliver broadband, but two platforms dominate local broadband markets worldwide: the cable modem platform (which is the most widely used in the US)[26] and the copper-based digital subscriber line (DSL) platform (which is the dominant technology in the EU).[27]

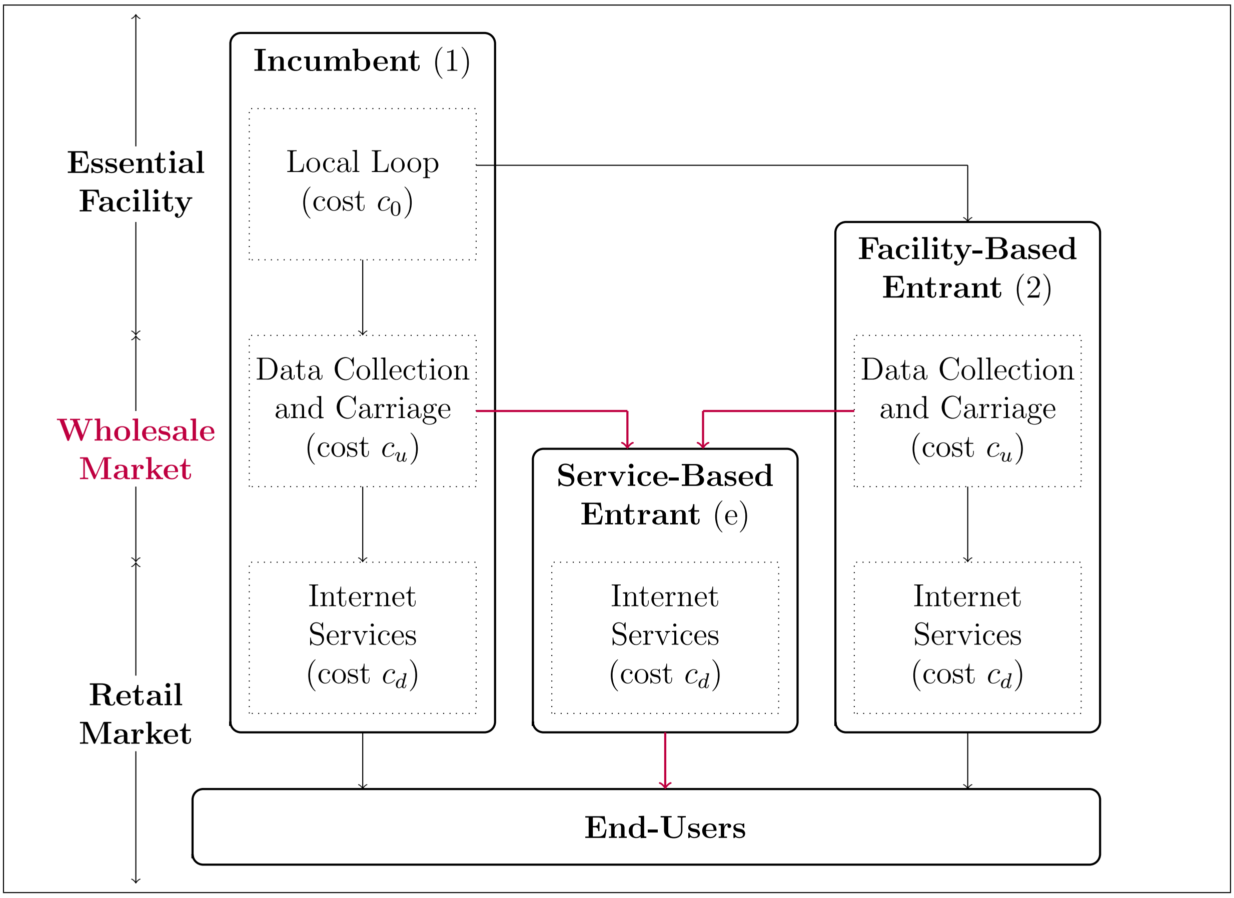
The broadband market has a three-tiered structure: the local access network market provides the local access input for wholesale services; the wholesale broadband market provides the input for broadband services; and finally, the retail market delivers broadband services to consumers. Facility-based firms either own a local access network (such as, a copper network or a cable network) or get unbundled access to the local loop of the ILEC.[28] In general, they have to upgrade the local network to offer broadband services. Service-based firms buy a wholesale broadband service to facility-based firms (if available). This is represented in Figure 1.

[25]See FCC (2005a) and EC (2006a). Data for the US indicate the number of business and residential broadband lines as of December 2003 and December 2004. Data for the EU are valid as of October 2003 and 2004.

[26]According to FCC (2005a), in 2004, cable providers served 56.4 per cent and ADSL 36.5 per cent of the broadband lines in the US. The remaining Internet access lines were delivered through wireless, fiber, etc.

[27]According to EC (2006a), in 2004, DSL platforms served 80.4 per cent of the broadband lines in the European Union, compared to 16.8 per cent of lines provided by cable and 2.8 per cent by other access technologies.

[28]Unbundled access to the local loop is a regulatory measure which obliges the ILEC to give access to its copper lines that connect the customer premises to the local exchanges. It enables entrants to install DSL equipments to offer broadband services to end customers.



The wholesale broadband market. There are two main types of wholesale offers. With resale, the service-based firm buys the service of the infrastructure-based firm on a wholesale basis, and sells this service under its brand name; however, possibilities of differentiation are limited, since the two services are identical. With bitstream access, the service-based firm buys data interconnection to the infrastructure-based firm's broadband network; some differentiation from the infrastructure-based firm's services is possible. Bitstream access can be delivered on different platforms, and in particular, on the cable modem and DSL platforms.[29]

Though there is no legal obligation on cable networks to open their facility to rivals, wholesale broadband offers over cable can be found in Europe,[30] the US,[31] Canada and Israel.[32] Wholesale offers on DSL platforms exist in many countries. Whereas in some countries (e.g., Denmark, France or Italy), bitstream access over the ILEC's network

[29]For instance, the European Regulators Group (ERG) considers that "it appears quite possible that a data over cable network will be able to provide each and every one of the key elements of bitstream access functionality" (ERG, 2005, p. 16).

[30]For instance, in the UK, one of the two cable operators has signed a wholesale broadband agreement with a third-party ISP (see Ofcom, 2004, §3.15, p. 69).

[31]In the US, there are a few examples of wholesale broadband offers over cable. For instance, following its merger with AOL Time Warner signed wholesale agreements with Earthlink and other few ISPs (see Hausman and Sidak (2005) for other examples). "Open access" of cable networks gave rise to a heated debate around 2000.

[32]See also ERG (2005).

is regulated, in other countries (e.g., Austria or Finland) it is subject to commercial negotiation. Wholesale services might also be provided by (DSL) infrastructure-based CLECs. For instance, in France, in 2005, two DSL network operators, Cegetel and Neuf Telecom, owned between 30 and 50 percent of the national wholesale broadband market.[33]

The broadband market corresponds well to the assumptions of our setting; there is limited or no horizontal differentiation between wholesale broadband offers, whereas some degree of differentiation is observed in the retail market. Besides, consistently with our modeling, in some countries, pure downstream firms appear to purchase the wholesale product from different suppliers. For instance, this used to be the case for AOL in France.

Though we gave examples of wholesale broadband offers, neither in the US nor in the EU, there is evidence of a competitive wholesale market. This is consistent with our results; though a broadband wholesale market is likely to emerge, there are high chances that it will not be competitive.

Asymmetric regulation of the wholesale market. The broadband market provides an example of asymmetric regulation on the wholesale market. Indeed, in some countries, ILECs have been obliged to offer a bitstream access offer and/or this offer is regulated.

Is regulation likely to dominate the unregulated outcome? From another point of view, could deregulation lead to a "competitive" wholesale market? For instance, in France, the regulation of the ILEC's wholesale broadband offer has been removed to favor the development of competition in the wholesale broadband market.[34]

It might be argued that a relatively low regulated price for the ILEC's wholesale service hinders entry in the wholesale market, and hence, that deregulation could stimulate entry. Our setting suggests that this intuition is shortsighted. Indeed, if the price of the ILEC's wholesale product is relatively high, infrastructure-based competitors have no incentives to enter in the wholesale market; they prefer to remain outside of this market. This is by setting a relatively low price for the ILEC's wholesale product that the regulator can stimulate competition in the wholesale market.

Local loop unbundling and the wholesale broadband market. In our setting, we assumed that the vertically integrated firms have an infrastructure of their own. In the broadband market, however, some facility-based firms lease unbundled access to the local loop of the ILEC. What is the effect of the regulated unbundling rate on the market equilibrium? In our setting, it has a neutral role, since the total demand is assumed to be fixed. In other settings, the unbundling rate could introduce asymmetries between firms, which would modify the equilibrium in a non trivial way.

[33]See: DGCCRF, Decision C2005-44 related to the merger between Neuf Telecom and Cegetel.

[34]The French ILEC's wholesale broadband offer was subject to the approval of the French regulatory authority (ARCEP) until Decision n°05-281 of 28 July 2005 removed the approval procedure.

5.2 The Mobile Market

Together with broadband the mobile telephony market is one of the most dynamic telecommunications market. In 2004, there were 184.7 million mobile users in the US and 383 million users in the EU. In the EU, the average penetration rate in the 25 Member States in 2005 was above 90 per cent.[35]

However, due to very high fixed (spectrum license and network) costs, entry in the mobile markets has been limited, and most national markets currently host only a few mobile network operators (MNOs). For instance, in most European countries, there are typically 3 to 4 MNOs offering 2G services.[36] But since 1999 a new class of service-based competitors has emerged, known as "mobile virtual network operators" (MVNOs).[37]

MVNOs do not have a spectrum license, and lease access to the networks of MNOs.[38] In general, MVNOs position themselves as "low cost" service providers (e.g., Easy Mobile in the UK) or target specific market segments (e.g., teenagers for Virgin Mobile in the UK or NRJ Mobile in France).

It is often argued that, though MVNOs represent a competitive threat for MNOs, MNOs have incentives to contract with MVNOs. The first motivation is to use spare wholesale capacity (in particular, following 3G investments) to generate additional wholesale revenues. The second motivation is to address market niches that the existing mobile firms do not reach very effectively (like teenagers or specific ethnic groups).

The wholesale mobile market. There are MVNOs in most national markets. According to Hazlett (2005), in 2005, there were around 20 MVNOs in the US. The two main MVNOs were TracFone which served over 3.5 million customers and Virgin Mobile USA which served over 3 million customers. In the European Union, there were a total of 214 MVNOs in 14 Member States out of 25 (EC, 2006b).

In most countries contracts between MNOs and MVNOs are commercial agreements, and access charges are typically set on a retail minus basis. In some countries (e.g., in Norway), mobile operators have been forced to give access to their networks to MVNOs. In some other countries (e.g., Hong Kong and Ireland), 3G licenses included the obligation to give access to MVNOs. Finally, in some countries (e.g., France and Ireland), regulators have been willing to regulate conditions of access for MVNOs, but with no success so far.[39]

The MVNO case fits well with our model. MNOs represent vertically-integrated firms, where MVNOs represent pure-downstream firms, which lease access to MNOs on a whole-

[35] See: FCC (2005b) and EC (2006a). As for the EU, there were 332 million mobile users in the 15 Members States and 383 in the 25 Member States.

[36] In 2005, there were 79 2G mobile operators in the EU (EC, 2006a).

[37] In 1999, the first MVNO, Virgin Mobile, entered in the UK market.

[38] Some MVNOs are merely resellers, hence do not have any infrastructure. Others (e.g., "full" MVNOs) own some mobile network elements, which gives them higher possibilities of differentiation.

[39] The Irish decision was eventually annulled while the French regulation project was rejected by the European Commission.

sale upstream market. Besides, the wholesale mobile services offered by MNOs are relatively identical, whereas there is differentiation on the downstream market.[40]

Should MNOs be obliged to open their networks? Currently, in most countries, MNOs are not obliged to give access to their networks to MVNOs. The rationale for not imposing an obligation is that, so far, MVNOs have been able to enter in most markets without regulatory intervention. Our model suggests that this position is correct; a wholesale mobile market can be expected to emerge in an unregulated environment. We point out that MNOs are willing to contract with MVNOs not only because it generates additional wholesale revenues, but also because it contributes to moderating competition on the retail market.

Competition in the wholesale mobile market. The structure of the wholesale mobile market varies across countries. In some countries, the wholesale market is almost monopolized. For instance, this is the case in Finland, Norway, the Netherlands and the UK, where the leading suppliers control more than 85 per cent of the wholesale mobile market. In other markets, there is some degree of competition in the wholesale market. For instance, in Denmark, the leading supplier, TDC Mobil, has 58 per cent of the wholesale market.[41] These different patterns of competition in the wholesale market are consistent with our analysis. We found that there are different potential market equilibria: some in which the wholesale market is monopolized; others in which a few firms may be active (though, in the case, the wholesale market is not necessarily competitive).

5.3 Implications for Regulation

Price cap. Though a wholesale market is likely to emerge without regulatory intervention, competition might fail to develop. One possibility to stimulate competition in the wholesale market would be to introduce a sufficiently low price cap on the price of the upstream good of at least one of the firms, and let the competitive process drive the wholesale prices to the average costs.

Indeed, a price cap, a_r, set at a level such that $a_r < \underline{a}$ implies that the Bertrand-like outcome becomes the unique equilibrium. If the price is such that $\underline{a} \leq a_r < a_m$, then the monopoly-like equilibria disappear; collusive-like equilibria in which firms share the wholesale market are preserved and are strictly preferred by the wholesale providers to the Bertrand-like equilibrium. Finally, if the cap is too high, that is when $a_r \geq a_m$, then regulation has almost no impact: only the equilibrium in which the incumbent exits the wholesale market does not survive.

[40]Though there is no horizontal differentiation on the wholesale market, there might be vertical differentiation;

[41]Source: David Spector, "What exactly is the Airtours retaliation criterion? A case study: the analysis of the French wholesale mobile market", Panel on collective dominance in mobile telephony ACE meeting, Copenhagen, December 1, 2005.

Structural separation. It is sometimes advocated that another solution to promote competition in telecommunications industry consists in separating vertically the incumbent operator. In that scenario, an upstream division independently sets the price of the wholesale offer without taking into account the impact on the downstream division, and reciprocally. In the broadband market, in some countries, this scenario has been observed.[42]

In our model, under vertical separation, the independent upstream unit has no direct interaction with the retail market and thus compete head-to-head on the wholesale market. Given the access price set by the other facility-based firm, the upstream unit always prefers to supply alone the wholesale market at that price since it is not affected by the intensity of competition on the retail market. As a result, only the Bertrand-like equilibrium can emerge under vertical separation of the incumbent.

Mergers. A merger between facility-based firms can affect the market equilibrium in a profound way. Consider the simplest case of two facility-based firms which would decide to merge. According to our setting, before the merger, the wholesale market is active; there are multiple equilibria, one of which is competitive. After the merger, a unique facility-based firm remains; a standard analysis suggests that it decides to foreclose the pure-downstream firm to protect its monopoly profits.

Now, consider that there are three facility-based firms and a unique pure downstream firm. It can shown that in this situation, only the competitive equilibrium is maintained. If two facility-based firms merge (and firms relocate), a new set of supra-competitive equilibria appears. Hence, following the merger, it is possible that the market switches from a competitive to a supra-competitive equilibrium.

This analysis highlights that a merger can not only affect the competition *per se*, but also through the change of market equilibrium.

The merger in 2005 of Neuf Telecom and Cegetel, two French infrastructure-based companies, provides a good illustration of this discussion. Before the merger, these two firms were competing in the broadband wholesale market with the ILEC, France Télécom (they had between 30 and 40 per cent of this market). The merger led to a reduction of the number of competitors in the wholesale broadband market from three to two. As a condition for the merger, the French Ministry of Economy required Neuf Telecom and Cegetel to maintain their activity in the wholesale broadband market for a period of three. Indeed, it was suspected that these two firms would exit the wholesale market after the merger otherwise.

[42]For instance, in France, some years ago, the ILEC's Internet service provider, Wanadoo, was independent from its parent company, France Télécom.

6 Conclusion

A Appendix

A.1 Proof of Lemma 1

Define $\tilde{p}_l = p_l - c_u - c_d$, $l \in \{1, 2, e\}$ and $\tilde{a}_i = a_i - c_u$, $i \in \{1, 2\}$; define accordingly the vector of margins $\tilde{p} \equiv (\tilde{p}_1, \tilde{p}_2, \tilde{p}_e)$. Consider that firm i is the unique provider on the upstream market.

Then simple manipulations lead to:

$$\begin{aligned}
\pi_i^{(i)}(\tilde{a}_i, \tilde{p}) &= \tilde{p}_i D_i(\tilde{a}_i, \tilde{p}) + \tilde{a}_i D_e(\tilde{a}_i, \tilde{p}),\\
\pi_j^{(i)}(\tilde{a}_i, \tilde{p}) &= \tilde{p}_j D_j(\tilde{a}_i, \tilde{p}),\\
\pi_e^{(i)}(\tilde{a}_i, \tilde{p}) &= (\tilde{p}_e - \tilde{a}_i) D_e(\tilde{a}_i, \tilde{p}).
\end{aligned}$$

Solving for the system of first-order conditions associated to the downstream price competition stage, we obtain:

$$\tilde{p}_e^{(i)} = \frac{t}{3} + \frac{7\tilde{a}_i}{10} \geq \tilde{p}_i^{(i)} = \frac{t}{3} + \frac{\tilde{a}_i}{2} \geq \tilde{p}_j^{(i)} = \frac{t}{3} + \frac{3\tilde{a}_i}{10}. \tag{1}$$

Profits are thus equal to:

$$\begin{aligned}
\pi_i^{(i)}(\tilde{a}_i) &= \tfrac{t}{9} + \tfrac{\tilde{a}_i(-30\tilde{a}_i + 50t)}{100t},\\
\pi_j^{(i)}(\tilde{a}_i) &= \tfrac{t}{9} + \tfrac{\tilde{a}_i(9\tilde{a}_i + 20t)}{100t},\\
\pi_e^{(i)}(\tilde{a}_i) &= \tfrac{t}{9} + \tfrac{\tilde{a}_i(9\tilde{a}_i - 20t)}{100t}.
\end{aligned} \tag{2}$$

The difference $\pi_i^{(i)}(\tilde{a}_i) - \pi_j^{(i)}(\tilde{a}_i)$ is a second order polynomial expression in $\tilde{a}_i$ which admits two roots: 0 and $\frac{10t}{13}$. This expression is positive (resp. negative) between (resp. outside) the roots. This gives $a_* \equiv c_u + c_d + \frac{10t}{13}$.

A.2 Proof of Lemma 2

Define $\tilde{a}_m = \arg\max_{\tilde{a}_i} \pi_i^{(i)}(\tilde{a}_i)$ (computed previously). Straightforward computations show that: $\tilde{a}_m = \frac{5t}{6}$; hence, $a_m = c_u + c_d + \frac{5t}{6} > a_*$.

A.3 Proof of Lemma 3

When the upstream market is supplied by both vertically integrated firms at common price a, profits are given by:

$$\begin{aligned}
\pi_i^{(1-2)}(\tilde{a}, \tilde{p}) &= \tilde{p}_i D_i(\tilde{a}, \tilde{p}) + \tfrac{\tilde{a}}{2} D_e(\tilde{a}, \tilde{p}),\\
\pi_j^{(1-2)}(\tilde{a}, \tilde{p}) &= \tilde{p}_j D_j(\tilde{a}, \tilde{p}) + \tfrac{\tilde{a}}{2} D_e(\tilde{a}, \tilde{p}),\\
\pi_e^{(1-2)}(\tilde{a}, \tilde{p}) &= (\tilde{p}_e - \tilde{a}) D_e(\tilde{a}, \tilde{p}),
\end{aligned}$$

where $\tilde{p}_l = p_l - c_u - c_d$, $l \in \{1, 2, e\}$, and $\tilde{a} = a - c_u$.

Solving for the system of first-order conditions associated to the downstream price competition stage, we obtain:

$$\tilde{p}_e^{(1-2)} = \frac{t}{3} + \frac{7\tilde{a}}{10} \geq \tilde{p}_1^{(1-2)} = \tilde{p}_2^{(1-2)} = \frac{t}{3} + \frac{2\tilde{a}}{5}. \tag{3}$$

Profits are thus equal to:

$$\begin{array}{l} \pi_1^{(1-2)}(\tilde{a}) = \pi_2^{(1-2)}(\tilde{a}) = \frac{t}{9} + \frac{\tilde{a}(-9\tilde{a}+35t)}{100t}, \\ \pi_e^{(1-2)}(\tilde{a}) = \frac{t}{9} + \frac{\tilde{a}(9\tilde{a}-20t)}{100t}. \end{array}$$

Comparing these profits with those obtained when the upstream market is served by one firm only (given by (2)) is straightforward and allows to prove the inequalities claimed in Lemma 3; this also gives $\underline{a} \equiv c_u + c_d + \frac{5t}{7}$ and $\overline{a} \equiv c_u + c_d + \frac{5t}{6} = a_m$.

A.4 Proof of Lemma 4

Consider the final prices given by (1) and (3). Given upstream prices a_1 and a_2, the final demand that faces firm e is equal to $\frac{1}{3} - \frac{3}{10t} \min\{a_1 - c_u, a_2 - c_u\}$ (whether a_1 and a_2 are equal or not). This shows that firm e is foreclosed if and only if $\min\{a_1, a_2\} \geq c_u + c_d + \frac{10t}{9} \equiv a_{\max}$. In this case, the final demand addressed to firm $i \in \{1, 2\}$ is $D_i^{(\emptyset)} = \frac{1}{2} + \frac{p_i - p_j}{t}$, $j \neq i \in \{1, 2\}$, and the profits are given by:

$$\pi_i^{(\emptyset)}(\tilde{p}_1, \tilde{p}_2) = \tilde{p}_i D_i^{(\emptyset)}(\tilde{p}_1, \tilde{p}_2),$$

where $\tilde{p}_i = p_i - c_u - c_d$.

Solving for the system formed by the first order conditions immediately leads to the corresponding equilibrium final margins: $\tilde{p}_1^{(\emptyset)} = \tilde{p}_2^{(\emptyset)} = \frac{t}{2}$. Profits are therefore equal to: $\pi_1^{(\emptyset)} = \pi_2^{(\emptyset)} = \frac{t}{4}$. This profit must be compared with the profit of a unique upstream supplier i at the upstream price a_m, which is equal to $\pi_i^{(i)}(a_m) = \frac{23t}{72}$ (see the proof of Lemma 1), and thus strictly lower than $\pi_i^{(\emptyset)}$.

B References

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