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Upstream Competition between Vertically Integrated Firms[1]

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Abstract

We propose a model of two-tier competition between vertically integrated firms and unintegrated downstream firms. We show that, even when integrated firms compete in prices to offer a homogeneous input, the Bertrand result may not obtain, and the input may be priced above marginal cost in equilibrium, which is detrimental to consumers' surplus and social welfare. We obtain that these partial foreclosure equilibria are more likely to exist when downstream competition is fierce. We then use our model to assess the impact of several regulatory tools in the telecommunications industry.

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1 Introduction

In several industries, production has a two-tier structure: firms need to obtain an intermediate input in order to serve final consumers. In this paper, we focus on industries in which the intermediate input is produced by vertically integrated firms only. Examples of such a market structure abound. In the broadband market, Digital Subscriber Line (DSL) operators and cable networks own a broadband infrastructure and compete at the retail level. They can also compete to provide wholesale broadband services to unintegrated downstream firms, which have not built their own network. Similarly, in the mobile telephony market, Mobile Virtual Network Operators (MVNOs) do not have a spectrum license nor a mobile network and therefore have to purchase a wholesale mobile service from Mobile Network Operators (MNOs).

Other examples can be found in licensing contexts. For instance, at the end of the 1990s, Dow Chemicals and Exxon had developed rival metallocene technologies, which enabled them to produce polyethylenes. They also licensed their technologies to downstream polyethylenes producers.[2] In the video game industry, some firms (e.g., Epic Games, Valve Corporation) have designed their own 3D engines to develop 3D video games. They also license these engines to rival downstream firms (e.g., Electronic Arts).

This raises the following question: does competition between vertically integrated firms on the upstream market level the playing field between the downstream rivals? More specifically, we notice that in all the examples mentioned above, downstream entrants have managed to get access to the intermediate input.[3] Yet, should we expect competition on the upstream market to drive the input price down to marginal cost?

To answer this question, we propose a model in which two vertically integrated firms and an unintegrated downstream firm compete in prices with differentiated products on a downstream market. The goods sold to end-users are derived from an intermediate input that the integrated firms can produce in-house. Integrated firms compete, first on the upstream market to provide the input to the unintegrated downstream firm, and second on the downstream market with the unintegrated downstream firm. The upstream market exhibits the usual ingredients of tough competition: integrated firms compete in (linear) prices, produce a perfectly homogeneous upstream good and incur the same constant marginal cost. Yet, we show that upstream competition may not drive the input price down to marginal cost,

[2] See Arora, Fosfuri, and Gambardella (2001), and Arora (1997) for other examples in the chemical industry.

[3] In the broadband market, there were 453 agreements between incumbent operators and new entrants and 634 agreements for resale in the EU25 member states, as of January 1st, 2008 (see European Commission 2008). In the mobile market, there were 290 MVNOs in 2006 in the UE15 countries (see European Commission, 2007) and at least 60 MVNOs were operating in the first quarter of 2010 in the US (see Federal Communications Commission, 2010).

thereby giving rise to partial foreclosure equilibria. In particular, there can exist monopoly-like equilibria, in which one vertically integrated firm supplies the intermediate input at its monopoly upstream price, while its integrated rival decides optimally to make no upstream offer.

The intuition is the following. Assume that integrated firm i supplies the wholesale market at a strictly positive price-cost margin, and consider the incentives of its integrated rival j to corner that market. Notice first that, when firm i increases its downstream price, it recognizes that some of the final consumers it loses will eventually purchase from the unintegrated downstream firm, thereby increasing upstream demand and revenues. This implies that firm i charges a higher downstream price than its integrated rival j at the downstream equilibrium. This effect obviously benefits firm j, which faces a less aggressive competitor on the final market: this is the softening effect. Now, if firm j undercuts firm i on the upstream market and becomes the upstream supplier, the roles are reversed: firm i decreases its downstream price, while firm j increases it. To sum up, firm j faces the following trade-off when deciding whether to undercut. On the one hand, undercutting yields wholesale profits; on the other hand, it makes integrated firm i more aggressive on the downstream market. When the latter effect is strong enough, the incentives to undercut vanish and the Bertrand logic collapses.[4]

This implies that, when the softening effect is strong enough, the monopoly outcome on the upstream market may persist even under the threat of competition on that market. Other equilibria may exist, but monopoly-like equilibria are Pareto-dominant from the integrated firms' viewpoint. Besides, as expected, partial foreclosure equilibria tend to degrade both social welfare and consumer surplus.

The degree of differentiation at the downstream level has an important impact on the strength of the softening effect, hence on the competitiveness of the upstream market. Intuitively, when final products are strongly differentiated, downstream demands are almost independent and the softening effect is consequently weak. As a result, undercutting on the upstream market is always profitable, and competition drives the wholesale price down to marginal cost. Conversely, when downstream products are strong substitutes, the softening effect is strong and the monopoly outcome is an equilibrium.

Another key determinant for the emergence of partial foreclosure equilibria is the efficiency of the unintegrated downstream firm. An inefficient downstream competitor sets higher downstream prices, supplies fewer downstream consumers, and therefore, demands

[4] That an integrated firm changes its downstream behavior when it supplies a non-integrated rival has already been noted in the literature. See Chen (2001), Fauli-Oller and Sandonis (2002), Sappington (2005) and Chen and Riordan (2007) among others. The novelty of our paper is to analyze the implications of these upstream-downstream interactions on upstream competition between vertically integrated firms.

less intermediate input. This tends to reduce the upstream profits, which weakens the incentives to undercut and makes partial foreclosure a more likely outcome.

We obtain an even stronger result under two-part tariff competition. We show that partial foreclosure equilibria with strictly positive upstream profits always exist when firms compete in two-part tariffs on the upstream market.

Our framework is especially relevant to analyze competition on wholesale markets in the telecommunications industry. As we have just seen, wholesale competition in telecoms may fail to develop, and therefore, there may be a scope for regulatory intervention in these markets. We show that several regulatory tools, which have been considered or implemented by telecoms regulators, can destroy all partial foreclosure equilibria. First, we derive conditions on the demand and cost functions, under which a wholesale price cap can restore the competitiveness of the upstream market. Second, the vertical separation of an integrated firm, or the entry of an unintegrated upstream competitor, can destroy partial foreclosure equilibria.

Our paper is related to several strands of the literature. The literature on one-way access pricing deals with situations in which a service-based firm must gain access to the network of a historical incumbent (Laffont and Tirole 2001, Armstrong 2002, de Bijl and Peitz 2002). These works are, by definition, silent on the issue of wholesale competition.

The question addressed in this paper closely echoes the old antitrust debate on the anticompetitive effects of vertical integration. According to the traditional foreclosure doctrine, vertical integration can be anticompetitive, since vertically integrated firms have incentives to raise their rivals' costs. This theory was criticized by Chicago School authors (see Bork 1978 and Posner 1976), on the ground that firms cannot leverage market power from one market to another one. More recently, the literature on vertical mergers has revisited these issues by analyzing extensively wholesale competition between a vertically integrated firm and an unintegrated upstream firm. Ordover, Saloner and Salop (1990) argue that such a market structure is unlikely to yield tough competition on the wholesale market when the vertically integrated firm can commit *ex ante* to its upstream price. Choi and Yi (2000) provide foundations for this commitment power through the choice of input specification. With upstream cost asymmetries and upstream switching costs, Chen (2001) shows that the integrated firm partially forecloses its unintegrated downstream rival in equilibrium. Chen and Riordan (2007) argue that an exclusive dealing contract enables the integrated firm to implement partial foreclosure in equilibrium.[5] Surprisingly, this strand of literature has not dealt with wholesale competition between vertically integrated structures, which, as we argued previously, is crucial in several industries. Our main result is that upstream competition between integrated firms may lead to equilibrium foreclosure even in the absence of upstream

[5] See also Sandonis and Fauli-Oller (2006) for an analysis of vertical integration in a licensing context.

commitment power, input choice specification, upstream cost asymmetries or switching costs, and exclusive dealing contracts.[6,7]

Two recent exceptions are Ordover and Shaffer (2007) and Brito and Pereira (2006), who present models with several vertically integrated firms and a downstream entrant. They are mainly interested in whether a wholesale market will emerge at all, i.e., whether the entrant can be completely foreclosed in equilibrium. In both papers, when non-integrated competitors are able to obtain the input, competition between integrated firms on the upstream market leads them to price the input at its marginal cost. By contrast, we work out a more general model and show that partial foreclosure can actually arise at equilibrium. Our predictions are therefore drastically different from theirs: the fact that entry does occur, as is the case in the industries mentioned earlier, is not sufficient to ensure that competition on the input market levels the playing field between the downstream rivals. Höffler and Schmidt (2008) take a complementary perspective and study the impact on consumers' surplus of the entry of unintegrated downstream firms. They show that service-based competition can be detrimental to consumers, due to the softening effect.

The paper is organized as follows. Section 2 describes the model. Section 3 presents our main results. Section 4 analyzes the efficacy of several regulatory tools. Section 5 discusses several extensions and robustness checks of our basic framework. Section 6 concludes.

2 The Model

Firms. There are two vertically integrated firms, denoted by 1 and 2, and one unintegrated downstream firm, denoted by d. Integrated firms are composed of an upstream and a downstream unit, which produce the intermediate input and the final good, respectively. The unintegrated downstream competitor is composed of a downstream unit only. In order to be active on the final market, it must purchase the intermediate input from one of the integrated firms on the upstream market.

Both integrated firms produce the upstream good under constant returns to scale at unit cost c_u. The downstream product is derived from the intermediate input on a one-to-one basis with the twice continuously differentiable cost function $c_k(.)$, for firm $k \in \{1, 2, d\}$. We assume that integrated firms have the same downstream cost function: $c_1(.) = c_2(.)$.

[6] Salinger (1988) and Nocke and White (2007) consider situations in which several integrated firms compete on the wholesale market. These papers, however, do not study tough price competition. The former assumes Cournot competition on both markets, while the latter focuses on tacit collusion on the input market.

[7] Hart and Tirole (1990) have initiated another strand of the vertical foreclosure literature, which analyzes the consequences of secret upstream offers, and focuses mainly on the commitment problem faced by an upstream monopolist.

Markets. All firms compete in prices on the downstream market and provide imperfect substitutes to final customers. Let p_k be the downstream price set by firm $k \in \{1, 2, d\}$ and $p \equiv (p_1, p_2, p_d)$ the vector of final prices. Firm k's demand, denoted by $D_k(p)$, is twice continuously differentiable; it depends negatively on firm k's price and positively on its competitors' prices: $\partial D_k/\partial p_k \leq 0$ with a strict inequality whenever $D_k > 0$, and $\partial D_k/\partial p_{k'} \geq 0$ with a strict inequality whenever $D_k > 0$ and $D_{k'} > 0$, for $k \neq k' \in \{1, 2, d\}$. We also suppose that the total demand is non-increasing in each price: for all $k' \in \{1, 2, d\}$, $\sum_{k \in \{1,2,d\}} \partial D_k/\partial p_{k'} \leq 0$. Symmetry of the integrated firms is assumed again: $D_1(p_1, p_2, p_d) = D_2(p_2, p_1, p_d)$ and $D_d(p_1, p_2, p_d) = D_d(p_2, p_1, p_d)$ for all p.

On the upstream market, integrated firms compete in prices and offer perfectly homogeneous products. We denote by a_i the upstream price set by integrated firm $i \in \{1, 2\}$.[8] The structure of the model is summarized in Figure 1.

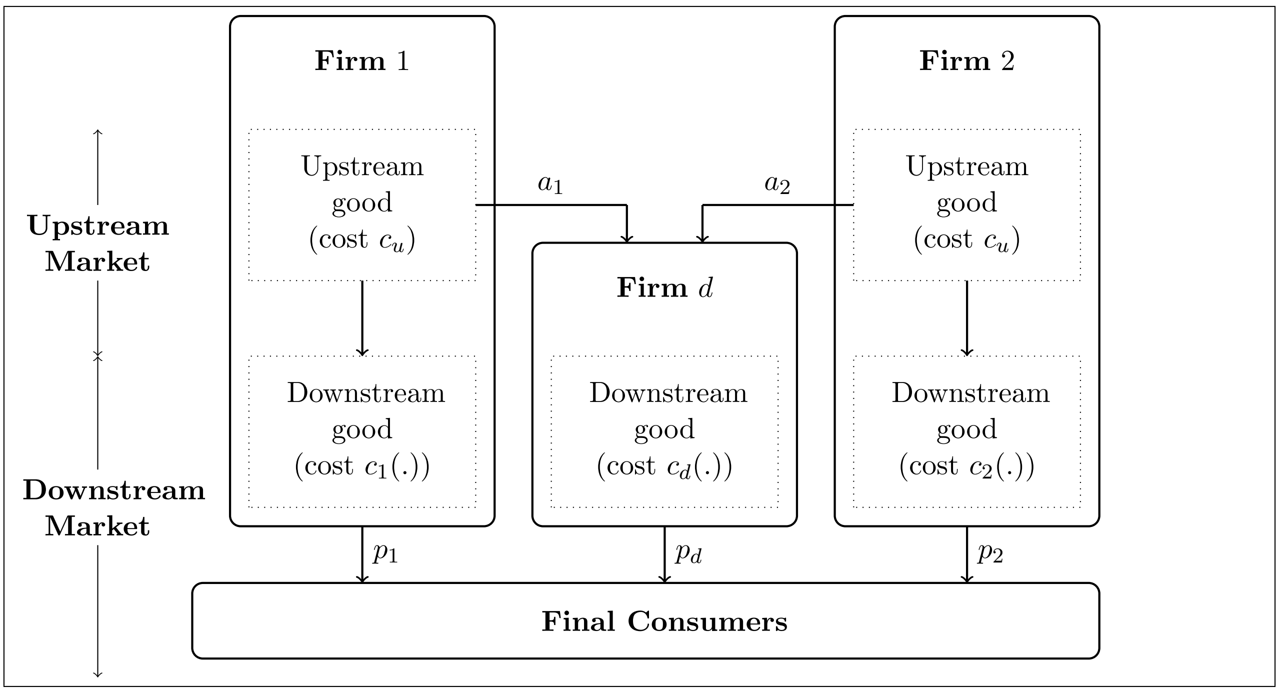

Figure 1: Structure of the model.

Timing. The sequence of decision-making is as follows:

Stage 1 – Upstream competition: Vertically integrated firms announce their prices on the upstream market. Then, the unintegrated downstream firm elects at most one upstream provider.

[8]Throughout the paper, subscripts i and j refer to integrated firms only, whereas subscript k refers either to an integrated firm or to the unintegrated downstream firm.

Stage 2 – Downstream competition: All firms set their prices on the downstream market.

We focus on pure strategy subgame-perfect equilibria and reason by backward induction.

Profits. Assume that the unintegrated downstream firm is active on the downstream market. The profit of integrated firm $i \in \{1, 2\}$ which supplies the upstream market at price a_i is:[9]

$$\tilde{\pi}_i^{(i)}(p, a_i) = (p_i - c_u)D_i(p) - c_i(D_i(p)) + (a_i - c_u)D_d(p).$$

The profit of integrated firm $j \neq i \in \{1, 2\}$ which does not supply the upstream market is given by:

$$\tilde{\pi}_j^{(i)}(p, a_i) = (p_j - c_u)D_j(p) - c_j(D_j(p)).$$

The profit of unintegrated downstream firm d is:

$$\tilde{\pi}_d^{(i)}(p, a_i) = (p_d - a_i)D_d(p) - c_d(D_d(p)).$$

Note that when the upstream price is equal to the upstream unit cost, i.e., $a_i = c_u$, there is no upstream profit and all firms compete on a level playing field. This is the perfect competition outcome on the upstream market.

3 Main Results

3.1 Preliminaries

Downstream market competition. Consider that at least one integrated firm has made an *acceptable* upstream offer, i.e., an offer that allows firm d to be active and earn strictly positive profits on the downstream market. Denote by $i \in \{1, 2\}$ the upstream supplier. For $k \in \{1, 2\}$, define $BR_k^{(i)}(p_{-k}, a_i) = \arg\max_{p_k} \tilde{\pi}_k^{(i)}(p, a_i)$ the best-response function of integrated firm k.[10] We assume that $BR_k^{(i)}(p_{-k}, a_i)$ is unique, bounded and well-defined by the corresponding first-order condition for any $p_{-k} \in [0, \infty)^2$ and any acceptable a_i. In order to obtain well-behaved comparative statics, we make the following stability assumption: $\left| \frac{\partial BR_j^{(i)}}{\partial p_{j'}}(p_{j'}, p_d, c_u) \right| < 1$, for all $j' \neq j$ in $\{1, 2\}$, for all $p_{j'},\ p_d \geq 0$.[11]

[9]Throughout the paper, the superscript in parenthesis indicates the identity of the upstream supplier.

[10]As usual, p_{-k} is the vector obtained by removing p_k from vector p.

[11]This corresponds to the stability condition in a hypothetical game, in which unintegrated downstream firm d would be supplied at price c_u and would set downstream price p_d, and both vertically integrated firms would set their downstream prices simultaneously. See Vives (2001, p. 51).

We assume that there exists a unique Nash equilibrium on the downstream market, and we denote by $p_k^{(i)}(a_i)$ the equilibrium price of firm $k \in \{1, 2, d\}$, and by $p^{(i)}(a_i)$ the vector of these downstream prices. At the equilibrium of this subgame, firms' profits are given by functions $\pi_k^{(i)}(a_i) \equiv \tilde{\pi}_k^{(i)}(p^{(i)}(a_i), a_i)$, which are defined over the set of acceptable offers. Note that, when the upstream product is priced at marginal cost, $p_i^{(i)}(c_u) = p_j^{(i)}(c_u)$ and $\pi_i^{(i)}(c_u) = \pi_j^{(i)}(c_u)$. We assume that $\pi_i^{(i)}(c_u)$ and $\pi_d^{(i)}(c_u)$ are strictly positive.

Choice of upstream supplier. If only one integrated firm has made an acceptable offer, then it is obviously chosen by the unintegrated downstream firm.

Consider now that both offers are acceptable. If $\pi_d^{(i)}(a_i) > \pi_d^{(j)}(a_j)$, then firm d chooses firm i as its upstream supplier. If both offers lead to the same profit, then firm d chooses any of them.[12] We now make the following economically meaningful assumption:

Assumption 1. $\pi_d^{(i)}(.)$ *is strictly decreasing.*[13]

If firm d preferred to choose the most expensive upstream provider, we would have another, somewhat trivial (and pathological), reason for the existence of partial foreclosure equilibria. Assumption 1 rules out these cases.

Upstream monopoly benchmark. Consider the hypothetical scenario in which the upstream market is monopolized by integrated firm i. We assume for the moment that, in this case, firm i makes an acceptable offer to firm d:

Assumption 2. *When integrated firm j has made no acceptable upstream offer, integrated firm i* cannot*, or* does not want *to, completely foreclose firm d.*

It follows immediately that complete foreclosure of the unintegrated downstream firm will never arise in equilibrium. In Section 5.2, we relax Assumption 2 and we show that it can hold because firm i actually wants to supply firm d in order to attract new consumers, or because of regulatory constraints, or because firm d can invest to start producing the input in-house.

We also assume:

Assumption 3. $\pi_i^{(i)}(.)$ *is strictly quasi-concave, and it has a unique maximum at $a_m > c_u$.*

[12]Other tie-breaking rules would not change our results. For instance, in Section 5.1, we consider the possibility that firm d splits its upstream demand between integrated firms.

[13]In line with most IO models, Assumption 1 posits that the direct effect of a cost increase on profit outweighs the strategic ones.

To summarize, if the upstream market were exogenously monopolized, the unintegrated downstream firm would not be completely foreclosed, and monopoly market power on the upstream market would lead to a strictly positive markup on the price of the intermediate input, i.e., to partial foreclosure. In the sequel, a_m is referred to as the monopoly upstream price.

At this stage, we can already notice that, under Assumptions 1 and 3, integrated firms offering $a_1 = a_2 = c_u$ is an equilibrium outcome.

Remark 1. *Under Assumptions 1 and 3, the perfect competition outcome on the upstream market is an equilibrium.*

Proof. Consider that integrated firms offer $a_1 = a_2 = c_u$. Then, if firm d elects firm i as its upstream supplier, $\pi_i^{(i)}(c_u) = \pi_j^{(i)}(c_u)$. If an integrated firm deviates upwards, then, by Assumption 1, firm d still purchases the input at marginal cost from the other integrated firm, and the integrated firms' profits are not affected. If on the other hand, an integrated firm, say i, deviates downwards by setting $a_i < c_u$, its profit becomes $\pi_i^{(i)}(a_i)$. This is less than $\pi_i^{(i)}(c_u)$, since $\pi_i^{(i)}$ is strictly quasi-concave and $a_m > c_u$. $\square$

3.2 Persistence of the monopoly outcome

We now study the first stage of our game in which integrated firms compete on the upstream market, and establish the main result of the paper. We show that the usual mechanism of Bertrand competition may be flawed and that partial foreclosure equilibria may exist.

Assume that integrated firm i has made an acceptable upstream offer to firm d, $a_i > c_u$, and let us see whether integrated firm $j \neq i$ is willing to slightly undercut to corner the upstream market, as would be the case with standard (single-market) Bertrand competition. The analysis proceeds in two steps. First, we look at prices at the downstream equilibrium. Second, we compare the profits of firms i and j.

The integrated firms' best-responses on the downstream market are characterized by the following first-order conditions:

$$\begin{aligned}
(1) \qquad \frac{\partial \tilde{\pi}_i^{(i)}}{\partial p_i}(p, a_i) &= D_i + (p_i - c_i'(D_i) - c_u)\frac{\partial D_i}{\partial p_i} + (a_i - c_u)\frac{\partial D_d}{\partial p_i} = 0, \\
(2) \qquad \frac{\partial \tilde{\pi}_j^{(i)}}{\partial p_j}(p, a_i) &= D_j + (p_j - c_j'(D_j) - c_u)\frac{\partial D_j}{\partial p_j} = 0.
\end{aligned}$$

The comparison between (1) and (2) indicates that the upstream supplier has more incentives to raise its downstream price than its integrated rival. Realizing that final customers lost on the downstream market may be recovered via the upstream market, the upstream supplier is less aggressive than its integrated rival on the downstream market. As formally shown in Appendix, this mechanism, together with our stability assumption, implies that the upstream supplier charges a higher downstream price than its integrated rival at the subgame equilibrium.

Lemma 1. *Let $a_i > c_u$ be an acceptable offer. Then the upstream supplier charges a strictly higher downstream price than its integrated rival:*

$$p_i^{(i)}(a_i) > p_j^{(i)}(a_i).$$

Proof. See Appendix A.1. □

This soft behavior favors the other integrated firm which, by a revealed preference argument, earns more downstream profit than the upstream supplier. We shall refer to that mechanism as the 'softening effect'.

Lemma 2. *Let $a_i > c_u$ be an acceptable offer. Then, the upstream supplier earns strictly smaller downstream profits than its integrated rival:*

$$\left[p_i^{(i)}(a_i) - c_u\right] D_i(p^{(i)}(a_i)) - c_i\left(D_i(p^{(i)}(a_i))\right) < \left[p_j^{(i)}(a_i) - c_u\right] D_j(p^{(i)}(a_i)) - c_j\left(D_j(p^{(i)}(a_i))\right).$$

Proof. See Appendix A.2. □

A key consequence of that result is that we cannot tell unambiguously which of the integrated firms earns more total profits. On the one hand, the upstream supplier extracts revenues from the upstream market. On the other hand, its integrated rival benefits from larger downstream profits, owing to the softening effect.

We can now come back to our initial question. When an integrated firm undercuts the upstream market, it obtains the upstream profits at the cost of making its integrated rival more aggressive on the downstream market. Therefore an integrated firm may not always want to undercut its integrated rival on the upstream market. Notice that we do not need any assumptions on the strategic interactions between downstream prices to obtain this tradeoff between capturing the upstream profits and benefiting from the softening effect. When the latter effect outweighs the former, the usual logic of Bertrand competition may not work anymore, and in particular, the monopoly outcome can be an equilibrium.

Proposition 1. *Under Assumptions 1-3, there exists an equilibrium in which the upstream market is supplied by an integrated firm at price a_m if and only if*

(3) $$\pi_j^{(i)}(a_m) \geq \pi_i^{(i)}(a_m).$$

These equilibria are referred to as monopoly-like equilibria.

Proof. Assume that condition (3) holds. Suppose firm i offers $a_i = a_m$ and firm j makes an unacceptable offer. Then, firm j has no incentives to undercut firm i and, by Assumptions 2 and 3, firm i has no incentives to deviate. Conversely, assume that condition (3) does not hold. If firm i supplies the upstream market at price a_m, then it is strictly profitable for firm j to propose $a_m - \varepsilon$ with $\varepsilon > 0$ sufficiently small, an offer which firm d would accept, by Assumption 1.[14] □

Proposition 1 might sound somewhat tautological. Yet, our contribution is to show that, contrary to the conventional wisdom and what the existing literature states, condition (3) may well be satisfied. Because losers on the upstream market become winners on the downstream market, the usual competitive forces may collapse. This effect does not hinge on any commitment device for the integrated firms to exit the upstream market;[15] nor does this rely on any kind of overt or tacit collusion. To complete the analysis, it remains to show that condition (3) is indeed satisfied with several standard demand specifications. We provide such examples in Sections 3.4 and 5.1.

As compared to the existing literature, we do not specify the downstream demand functions. This allows us to stay at a higher level of generality. Ordover and Shaffer (2007) consider a linear specification and a particular range of parameters over which condition (3) is not satisfied (see footnote 21). In Brito and Pereira (2006), there is a third integrated firm, and downstream competition takes place on the Salop circle. Two of the integrated firms are not in interaction with each other on the downstream market, and the third integrated firm does not interact with the entrant, which considerably weakens the softening effect. As a consequence, condition (3) does not hold in their framework.[16] By carefully picking apart the effects which govern firms' undercutting decisions, we show that these results have limitations, and that one cannot predict the outcome of the upstream price competition game without assessing the strength of the softening effect.

3.3 Other equilibria

In this section, we give a complete characterization of the subgame-perfect equilibria of our game.

[14] Notice that different strategies can be used to support a monopoly-like equilibrium: $a_i = a_m$ and a_j unacceptable, or $a_i = a_m$ and $a_j > a_m$ acceptable such that $\pi_i^{(j)}(a_j) \leq \pi_i^{(i)}(a_m)$.

[15] Firms cannot commit not to enter the upstream market; however, endogenously, the incentives to corner the upstream market may disappear.

[16] Brito and Pereira (2006) note that, in their framework, it could actually be satisfied if one of the three integrated firms could commit to exit the upstream market.

Proposition 2. *Under Assumptions 1 and 3, there exists an equilibrium, in which* $a_1 = a_2 = a_*$ *if and only if* $a_* \leq a_m$ *and* $\pi_i^{(i)}(a_*) = \pi_j^{(i)}(a_*)$. *These equilibria are referred to as matching-like equilibria.*

Proof. See Appendix A.3. □

In a matching-like equilibrium, both integrated firms offer the same upstream price and are indifferent between supplying the upstream market and not supplying it. Notice that the perfect competition outcome $a_1 = a_2 = c_u$ is always a (matching-like) equilibrium outcome, as already stated in Remark 1.

However, nothing precludes the existence of other matching-like equilibria featuring either a supra-competitive upstream market ($a_* > c_u$) or a super-competitive upstream market ($a_* < c_u$). The existence of these equilibria also hinges on the softening effect. For $a_* > c_u$, the integrated firm which does not supply the upstream market benefits from the softening effect and does not want to undercut. For $a_* < c_u$, the softening effect is reversed. The upstream supplier offers a low downstream price to reduce the upstream demand, which hurts its integrated rival. Even though the upstream supplier makes losses on the upstream market, it does not want to exit that market since it would then suffer from an adverse softening effect.

We conclude this paragraph with the following result:

Proposition 3. *Under Assumptions 1-3:*

- *Only monopoly-like and matching-like outcomes can arise in equilibrium.*
- *From the viewpoint of the integrated firms, any monopoly-like equilibrium Pareto-dominates any matching-like equilibrium.*

Proof. See Appendix A.4. □

Propositions 1, 2 and 3 provide a characterization of all the possible equilibria of our game. Moreover, the monopoly-like equilibria, when they exist, Pareto-dominate all other equilibria from the integrated firms' standpoint. Therefore there is a strong presumption that these equilibria will actually be played when they exist.

Last, as intuition suggests, one can show that, under additional reasonable assumptions, partial foreclosure equilibria degrade consumers' surplus and social welfare.[17]

[17] See Section IV in our web appendix (Bourreau, Hombert, Pouyet and Schutz, 2010) for the complete welfare analysis.

3.4 An illustrative example

3.4.1 The dilemma between upstream and downstream competitiveness

A key determinant of the persistence of the monopoly outcome is the degree of differentiation of the unintegrated downstream firm. Suppose that the entrant is on a niche market, in the sense that its demand does not depend on the prices set by the downstream rivals and vice-versa.[18] In that situation, the wholesale profit of the upstream supplier is fully disconnected from its retail behavior and the softening effect disappears. Hence, with an unintegrated downstream firm on a niche market, the perfect competition outcome always emerges in equilibrium.

Downstream demands are derived from the maximization of a representative consumer's utility with the following quasi-linear preferences:

$$U = q_0 + \sum_{k\in\{1,2,d\}} q_k - \frac{1}{2}\left(\sum_{k\in\{1,2,d\}} q_k\right)^2 - \frac{3}{2(1+\gamma)}\left(\sum_{k\in\{1,2,d\}} q_k^2 - \frac{(\sum_{k\in\{1,2,d\}} q_k)^2}{3}\right), \tag{4}$$

where q_0 denotes consumption of the numeraire and q_k is consumption of product $k \in \{1,2,d\}$. These preferences generate the following demand functions:

$$D_k(p) = \frac{1}{3}\left(1 - p_k - \gamma(p_k - \frac{p_1+p_2+p_d}{3})\right). \tag{5}$$

$\gamma \geq 0$ parameterizes the degree of differentiation between final products, which can be interpreted as the intensity of downstream competition. Perfect competition corresponds to γ approaching infinity and local monopolies to $\gamma = 0$. All firms have the same linear downstream costs: $c_k(q) = cq$.[19] With that specification, the assumptions we have made on the second stage demands, payoff functions, best-responses, etc. are satisfied. Assumptions 1 and 3 are satisfied as well. Finally, we also suppose that Assumption 2 holds.

Figure 2 offers a graphical representation of the profit functions $\pi_i^{(i)}(.)$, $\pi_j^{(i)}(.)$ and $\pi_d^{(i)}(.)$. As discussed in Section 3.2, when $a_i > c_u$, two opposite effects are at work. On the one hand, the upstream supplier derives profit from the upstream market; on the other hand, its integrated rival benefits from the softening effect on the downstream market. When the upstream price is not too high, the upstream profit effect dominates and $\pi_i^{(i)}(a_i) > \pi_j^{(i)}(a_i)$. When the upstream price is high enough, upstream revenues shrink, the softening effect is strengthened and $\pi_i^{(i)}(a_i) < \pi_j^{(i)}(a_i)$.

[18] Formally, $\partial D_d/\partial p_i = \partial D_i/\partial p_d = 0$ for $i \in \{1,2\}$.

[19] We assume that the total unit cost $c_u + c$ is strictly smaller than the intercept of the demand functions 1, otherwise, it would not be profitable to be active in the final market.

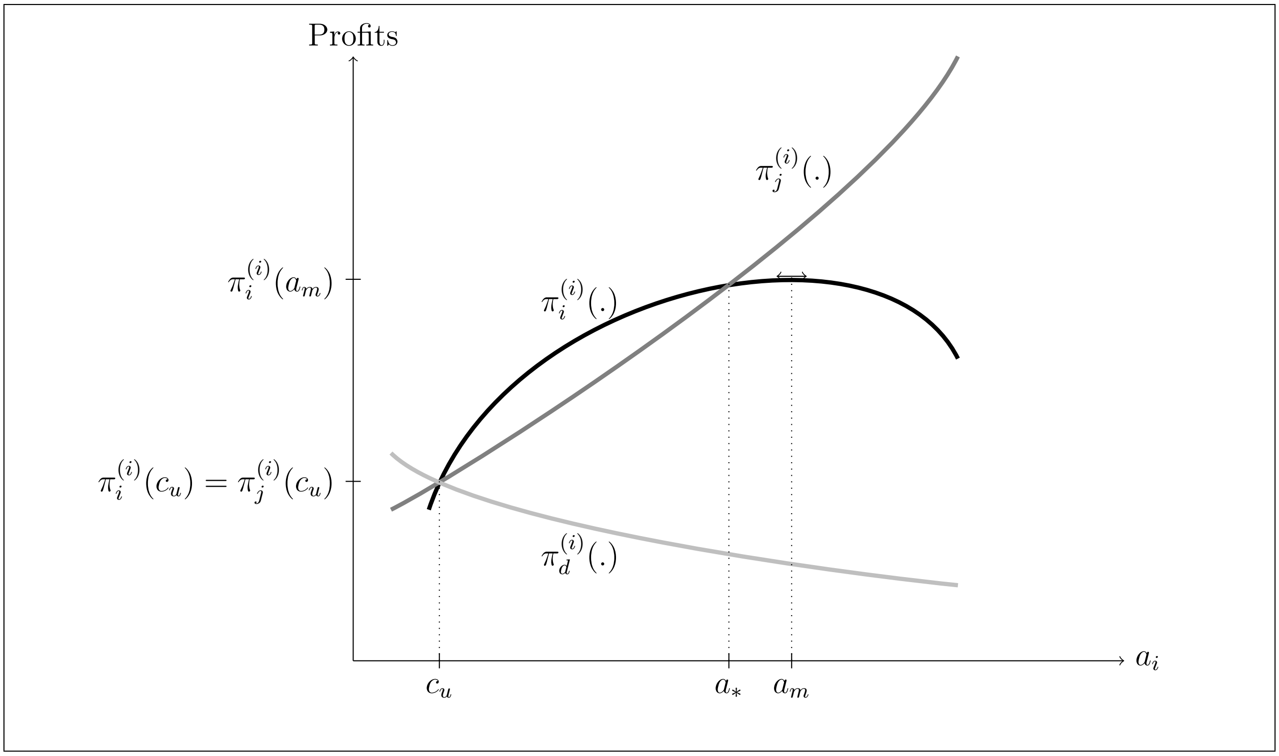

Figure 2: Profits in the symmetric linear case ($\gamma \geq \bar{\gamma}$).

We then obtain the following proposition.

Proposition 4. *Consider the symmetric linear case. There exists $\bar{\gamma} > 0$ such that: If $\gamma \geq \bar{\gamma}$, then there exist four equilibrium outcomes on the upstream market:*[20]

- *the* perfect competition *outcome;*
- *a supra-competitive* matching-like *outcome;*
- *two* monopoly-like *outcomes.*

Otherwise, the perfect competition outcome is the only equilibrium outcome.

Proof. See Appendix A.5. □

To grasp the intuition of the proposition, suppose that the upstream market is supplied at the monopoly upstream price. When the substitutability between final products is strong, the integrated firm which supplies the upstream market is reluctant to set too low a downstream price since this would strongly contract its upstream profit. The other integrated firm benefits from a substantial softening effect and, as a result, is not willing to corner the upstream market. There exists a monopoly-like equilibrium when downstream products are sufficient

[20]The perfect competition and monopoly-like equilibria are stable; the matching-like is unstable.

substitutes. By the reverse token, only the perfect competition outcome emerges when the competition on the downstream market is sufficiently weak.[21]

Proposition 4 highlights a tension between competitiveness on the downstream market and competitiveness on the upstream market. Intuitively, the same downstream interactions which strengthen the competitive pressure on the downstream market, are those which soften the competitive pressure on the upstream market. This tension is revealed in downstream prices, which turn out to be non-monotonic in the substitutability parameter (provided that a monopoly-like equilibrium is selected when it exists). The level of downstream prices results indeed from two combined forces: the level of upstream prices on the one hand, and the intensity of downstream competition/substitutability on the other hand.

This suggests that strongly differentiated unintegrated downstream firms are more likely to enter in the market, not only because entrants have incentives to differentiate to avoid head-to-head competition, but also because they are more likely to benefit from attractive wholesale offers by integrated firms. The evidence in the mobile market is consistent with this interpretation. Indeed, many MVNOs target specific market segments, either by using their brand reputation,[22] or by investing in network elements to increase their differentiation possibilities.[23]

3.4.2 Efficiency of the entrant

Another key determinant of partial foreclosure is the efficiency of the unintegrated downstream firm. Intuitively, an efficient entrant tends to obtain a large market share and to purchase large quantities of input on the upstream market. This raises the upstream profit effect and, in turn, strengthens the vertically integrated firms' incentives to cut upstream prices. Therefore, we expect the upstream market to be more competitive when the entrant is more efficient.

We confirm this intuition by adding a downstream cost differential to the linear specification used in our first example. Integrated firms still have the same downstream marginal cost c, while firm d's marginal cost is now $c + \delta$. δ is thus a measure of the relative inefficiency of the entrant.

Proposition 5. *Consider the asymmetric linear case. For any $\gamma \geq 0$, there exists $\overline{\delta}(\gamma)$ such that:*

[21] Ordover and Shaffer (2007) consider the same example, but they restrict their attention to $\gamma \leq 10$ while $\overline{\gamma} > 10$. This is the reason why the condition for monopoly-like equilibria never holds in their paper.

[22] For instance, teenagers for Virgin Mobile in the UK or NRJ Mobile in France.

[23] For instance, Euskaltel and Budget Telecom are 'full' MVNOs, i.e., they own all the network elements of a traditional mobile operator except the radio equipments. They specifically offer cross-border services.

- *If $\delta \geq \overline{\delta}(\gamma)$, then there are four equilibrium outcomes: Two monopoly-like outcomes, a matching-like outcome, and the perfect competition outcome.*

- *Otherwise, the perfect competition outcome is the only equilibrium.*

Proof. See our web appendix (Bourreau, Hombert, Pouyet and Schutz, 2010, Section I.1). □

When firm d is rather inefficient ($\delta \geq \overline{\delta}(\gamma)$) the gains from supplying the upstream market are small, as firm d purchases a small quantity of input. The upstream profit effect is weak. Moreover, the softening effect, which operates at the margin, is not affected by the size of the upstream demand. Therefore, when the entrant is rather inefficient, the incentives to undercut the upstream market are small and partial foreclosure arises in equilibrium.

4 Regulation

We have just seen that competition on wholesale markets may fail to develop, thereby giving rise to partial foreclosure equilibria. In this section, we show that several tools, which have been used or considered by telecoms regulators, such as a wholesale price cap, the entry of an unintegrated upstream competitor, or the vertical separation of an integrated operator, can restore the competitiveness of the upstream market.

4.1 Price cap

In several countries (e.g., France, Spain, Belgium, Italy), the telecoms regulator sets a price at which the broadband incumbent has to supply any service-based firm. This does not prevent the incumbent from negotiating lower tariffs with downstream firms. Therefore, the regulated price can be seen as a price cap on the incumbent's wholesale offer. In the following, we show that this kind of regulation can favor the development of tough wholesale competition, and remove all partial foreclosure equilibria, even if the price cap is strictly above marginal cost.

As a first step, let us inspect Figure 2, which depicts firms' profits in the symmetric linear case. Notice that for any $a_i \in (c_u, a_*)$, $\pi_i^{(i)}(a_i) > \pi_j^{(i)}(a_i)$: in this range of upstream prices, it is always better to be the upstream supplier. Consequently, if the regulator sets any price cap between c_u and a_*, then, the only equilibrium is the perfect competition outcome.

Now we would like to extend this result to more general demand and cost systems. A price cap $\overline{a} > c_u$ eliminates all partial foreclosure equilibria if $\pi_i^{(i)}(a_i) > \pi_j^{(i)}(a_i)$ for all $a_i \in (c_u, \overline{a}]$. Since $\pi_i^{(i)}(c_u) = \pi_j^{(i)}(c_u)$, it follows immediately that there exists a price cap strictly above marginal cost which restores the competitiveness of the upstream market if

$\frac{d\pi_i^{(i)}}{da_i}(c_u) > \frac{d\pi_j^{(i)}}{da_i}(c_u)$. The following proposition provides sufficient conditions under which this inequality is satisfied:[24]

Proposition 6. *Assume that firms' downstream divisions are identical, downstream costs are weakly convex, and*

- *downstream prices are strategic complements and* $\frac{\partial^2 D_k}{\partial p_k^2} \leq 0$ *for all* $k \in \{1, 2, d\}$.
- *or,* $\frac{\partial^2 D_k}{\partial p_k \partial p_{k'}} \geq 0$ *for all* $k \neq k'$ *in* $\{1, 2, d\}$.

A low enough price cap, strictly above the upstream marginal cost, destroys all partial foreclosure equilibria, and the perfect competition outcome remains an equilibrium.

Proof. See Appendix A.6. □

A price cap can restore the competitiveness of the wholesale market, provided that the upstream supplier earns more profits than its integrated rival when the upstream price is slightly above the marginal cost. Put differently, the upstream profit effect has to dominate the softening effect for a_i sufficiently close to c_u. A good proxy to assess the strength of the softening effect is the difference between the upstream supplier's and the integrated rival's downstream prices. This gap is small if the upstream supplier does not raise its downstream price by much when the upstream price increases, which is the case when a firm's demand is concave with respect to its own price, and downstream costs are convex. Besides, if prices are strategic complements, the integrated rival increases its price as well, which implies an even smaller gap between downstream prices, hence, a small softening effect. This is the first sufficient condition in Proposition 6.

Second, even if the upstream supplier does increase its price a lot, the gap may still be small if the integrated rival reacts by also increasing its price a lot, namely, if downstream prices are strongly strategic complements. A sufficient condition for this is $\partial^2 D_k / \partial p_k \partial p_k' \geq 0$ and convex costs. This is the second sufficient condition in the proposition.[25]

We would like to emphasize that Proposition 6 does not come from a simple mechanical effect. Of course, imposing a price cap reduces the upstream price mechanically. But, more fundamentally, under the assumptions detailed in Proposition 6, a price cap initiates a

[24] We did not manage to obtain a general result when firms are asymmetric. Still, it can be shown that when demand is linear and firm d has a cost differential δ, profit functions are as depicted in Figure 2 and a price cap can always restore the competitiveness of the upstream market.

[25] It should be noticed that this reasoning, which derives conditions for the upstream profit effect to dominate the softening effect, is only valid in the neighborhood of c_u. Therefore, the sufficient conditions given in Proposition 6 do not imply that partial foreclosure equilibria do not exist. For instance, in the symmetric linear case, both sufficient conditions hold and monopoly-like equilibria exist when γ is high enough.

process by which integrated firms will undercut each other, leading to tough competition in the wholesale market. Interestingly, a price cap can influence the outcome of the market even though the regulatory constraint does not bind (i.e., the upstream price is strictly smaller than the price cap) in equilibrium. Therefore, a regulator who observes an entrant getting access to the input at a price strictly below the price cap should not conclude that the price cap is useless. Note also that it is sufficient to impose a price cap on one of the integrated firms only to fuel competition in the wholesale market.

We conclude this subsection by noting that the threat of investment by firm d can have the same impact as a price cap on the wholesale market. Consider the following alteration of our game: between stage 1 and stage 2, after having observed the integrated firms' upstream offers, the unintegrated downstream firm can pay a sunk investment cost to build its own network. If it does so, it becomes able to produce the intermediate input at marginal cost c_u. If the investment cost is not too large, there is a threshold $\bar{a}$, such that firm d invests if, and only if the cheapest wholesale offer is above $\bar{a}$. Since integrated firms prefer to face a relatively less efficient competitor, at least one integrated firm will make an offer below $\bar{a}$ to prevent firm d from investing: firms behave exactly as if $\bar{a}$ were a price cap. If the cost of bypass is low, then $\bar{a}$ is low as well, and, under the assumptions of Proposition 6, the input price goes down to marginal cost.

This result has interesting policy implications. In the mobile industry, it means that favorable terms for spectrum licences (e.g., terms for ungranted mobile licences, or for Wimax licences) can increase MNOs' incentives to set low wholesale prices for MVNOs. In the broadband market, it implies that favorable conditions for local loop unbundling investments (e.g., low rates for colocation in the historical operator's premises) might stimulate the development of the wholesale broadband market.

4.2 Entry of an unintegrated upstream competitor

Suppose that, in addition to integrated firms 1 and 2, an unintegrated upstream competitor, firm u, is able to produce the intermediate input at constant marginal cost c_u. There are two situations in which such an upstream unit can enter the wholesale market. First, local authorities can invest in broadband networks and offer wholesale services to service-based operators.[26] Second, some private companies can decide to enter as unintegrated upstream

[26] In France, at the end of 2007, 2% of the population had no access to broadband services. In addition to these so-called 'white zones', the French regulator, ARCEP, keeps track of the 'grey zones', in which only the incumbent operator France Télécom has installed broadband equipments. ARCEP views investments by municipalities in both 'white' and 'grey' zones as legitimate; in the white zones, to offer broadband services; in the grey zones, to foster facility-based competition. In March 2008, there were 55 projects from municipalities for a total amount of 1.3 billion euros. Out of a total number of 2,674 main distribution frames in October

providers. For instance, in the broadband market, firms like Covad or Northpoint in the US, or Mangoosta in France, adopted this strategy. In the mobile market, so-called mobile virtual enablers (MVNEs) are also unintegrated upstream firms.[27] In both cases, we argue that the entry of an unintegrated upstream competitor stimulates competition in wholesale markets more surely than entry of (and competition between) integrated firms. Intuitively, an unintegrated upstream firm is not subject to the softening effect, since it does not participate to the downstream market. As a result, the entry of firm u restores the competitiveness of the upstream market:

Proposition 7. *Assume that prices are strategic complements. When an unintegrated upstream firm enters the industry, all partial foreclosure equilibria disappear, and the perfect competition outcome remains an equilibrium.*

Proof. See Appendix A.7. □

The intuition for Proposition 7 is the following. If integrated firm $i \in \{1, 2\}$ supplies the upstream market at price $a_i > c_u$, then, firm u always wants to undercut, for its sole source of profit comes from the upstream market. Conversely, if firm u supplies the upstream market at price $a_u > c_u$, then, firm 1 wants to undercut for two reasons. First, undercutting enables firm 1 to capture the upstream profits. Second, when firm 1 becomes the upstream supplier, it behaves less aggressively on the downstream market, and, by strategic complementarity, firms 2 and d react by increasing their prices as well. By a revealed preference argument, these price increases benefit firm 1.

Having said that, it becomes clear that the upstream market cannot be supplied above marginal cost in equilibrium. As noted earlier, in our basic setting, Remark 1 implies that the perfect competition outcome is always a subgame-perfect equilibrium. Obviously, adding an unintegrated upstream competitor does not affect this result.

2007, there were 988 with a municipal network.

[27] Examples of MVNEs are Versent Mobile and Visage Mobile in the US, Transatel in France and Belgium, Effortel in Belgium.

4.3 Vertical separation

Policymakers have often contemplated the structural separation of a dominant operator.[28,29] The typical argument in favor of vertical separation, which only applies when a firm has a monopoly position over a bottleneck, is that a vertically integrated firm has an incentive to use its upstream price to raise its rivals' costs; vertical separation then annihilates this incentive. Our argument is different. We claim that when several integrated firms compete on the upstream market, vertical separation of one integrated firm annihilates the softening effect and restores the firms' incentives to compete fiercely on the upstream market. To make this point, we assume that firm 2 has been vertically separated and call $d1$ and $d2$ the unintegrated downstream firms. We establish that, under an additional technical assumption, Proposition 7 extends to the vertical separation of an integrated firm.

Assumption 4. *(i) Upstream suppliers cannot discriminate between downstream firms. (ii) Downstream firms choose their upstream supplier after downstream prices have been set.*[30]

Proposition 8. *Consider the vertical separation of a vertically integrated firm in the basic model. If Assumption 4 holds and if downstream prices are strategic complements, then, the perfect competition outcome is the only equilibrium.*

Proof. See Appendix A.8. □

There is an important difference between vertical separation and the entry of an unintegrated upstream competitor in our framework: after vertical separation has taken place, there are two unintegrated downstream firms. This implies that we need both (i) and (ii) in Assumption 4 to prove Proposition 8.

To see why we need (i), consider that discrimination is allowed on the upstream market. Then, we cannot exclude that the following situation arises in equilibrium. Integrated firm 1 offers upstream price a_1 to firm $d1$, and unintegrated upstream firm u offers price a_u to firm

[28] For instance, Viviane Reding, then member of the European Commission responsible for Information Society and Media declared in May 2007: "I believe that functional separation (...) could indeed serve to make competition more effective in a service-based competition environment where infrastructure-based competition is not expected to develop in a reasonable period. It may be a useful remedy in specific cases. It is certainly not a panacea." (Viviane Reding, "How Europe can Bridge the Broadband Gap", Brussels, 14 May 2007).

[29] Since the broadband industry has a three-tiered structure (local loop-wholesale products-retail services), two types of separation could be implemented. First, the local access unit of the incumbent operator could be separated from its wholesale-retail unit. Second, the Internet service provider unit of the incumbent could be separated from the local loop-wholesale unit. The latter situation has been observed in some countries. For instance, in France, the incumbent Internet service provider, Wanadoo, was a subsidiary of its parent company, France Télécom, between 2000 and 2004.

[30] Notice that this assumption would not change the results of the previous sections, since Assumption 1 already ensured that the unintegrated downstream firm chose the cheapest supplier in our basic framework.

$d2$, where a_1 and a_u are the monopoly prices of firms 1 and u respectively.[31] Firm u prefers not to make an acceptable offer to unintegrated downstream firm $d1$, since, if that offer were eventually accepted, firm 1 would become more aggressive on the downstream market, which would erode the profit earned by firm u on firm $d2$. Similarly, firm 1 prefers not to make an acceptable offer to firm $d2$, since if that offer were accepted, firm 1 would become less aggressive on the downstream market. By strategic complementarity, firm $d1$ would increase its downstream price as well, which could lower its demand, and hence, the upstream profit that firm 1 makes on firm $d1$.

To understand point (ii) in Assumption 4, consider that firms cannot discriminate on the upstream market, but assume that unintegrated downstream firms elect their upstream suppliers before the downstream competition stage. Then, the following situation may be an equilibrium. Firms 1 and u set the monopoly upstream prices a_1 and a_u, as defined in the previous paragraph. Consider that $a_1 > a_u$, which makes sense, since a vertically integrated firm has more incentives than an unintegrated upstream firm to charge a high upstream price. It may then be that firm $d1$ purchases from firm 1 to make the integrated firm less aggressive on the final market, while firm $d2$ chooses firm u to benefit from a lower upstream price.

The situations described in the above paragraphs seem rather unlikely, and we have not been able to exhibit them using standard demand specifications. Assumption 4 enables us to rule them out in our general framework.

5 Extensions and Discussions

We now discuss some extensions and robustness checks.

5.1 Robustness Checks

Two-part tariffs. We now show that partial foreclosure equilibria with positive upstream profits always exist under two-part tariff competition on the upstream market. Denote by a_i (respectively, T_i) the variable (respectively, the fixed) part of the tariff set by firm i. In a monopoly-like outcome, firm i sets the variable part which maximizes the sum of its profit and firm d's profit, i.e., $a_{tp} = \arg\max_{a_i} \pi_i^{(i)}(a_i) + \pi_d^{(i)}(a_i)$,[32] while firm j makes no upstream offer. The fixed fee T_i captures firm d's profit, i.e., $T_i = \pi_d^{(i)}(a_{tp})$. This is an equilibrium provided that firm j does not want to undercut, or: $\pi_i^{(i)}(a_{tp}) + \pi_d^{(i)}(a_{tp}) \leq \pi_j^{(i)}(a_{tp})$.

[31] Formally, $a_1 = \arg\max_a \pi_1^{(1,u)}(a, a_u)$ and $a_u = \arg\max_a \pi_u^{(1,u)}(a_1, a)$, where $\pi_i^{(j,k)}(a_j, a_k)$ denotes the profit of firm i when firms d_1 and d_2 are supplied by firms j and k, respectively, at prices a_j and a_k.

[32] See Bonanno and Vickers (1988).

If the above inequality is not satisfied, then there exists an equilibrium in which both integrated firms charge the variable part a_{tp} and a fixed fee equal to $\pi_j^{(i)}(a_{tp}) - \pi_i^{(i)}(a_{tp})$, which makes them indifferent between supplying the upstream demand or not. Under two-part tariff competition, this is a matching-like equilibrium.[33]

Proposition 9. *Under two-part tariff competition on the upstream market, there exist either monopoly-like or matching-like equilibria.*

Proof. Immediate. □

Once again, upstream competition may not modify the outcome with respect to the monopoly benchmark. If the upstream equilibrium is monopoly-like, both the fixed and the variable parts of the tariff remain the same; obviously, downstream prices are not affected either. If the equilibrium is matching-like, competition modifies the fixed part only, without affecting any downstream prices. In other words, the only impact of competition is to redistribute some profits from the integrated firms to the unintegrated downstream firm. Besides, provided that $a_{tp} > c_u$,[34] it is straightforward to show that the upstream profit is strictly positive.[35] In this sense, competition on the upstream market may still be ineffective with two-part tariffs.

Market structure. Our results are robust to larger numbers of firms. Consider a market with $M \geq 2$ vertically integrated firms and $N \geq 1$ unintegrated downstream firms. As in the case where $M = 2$ and $N = 1$, we assume that integrated firms do not want to (or cannot) completely foreclose the unintegrated downstream firms. This amounts to assuming that the analogs of Assumptions 2 and 3 hold when $M \geq 2$ and $N \geq 1$. We also know from Section 4.3 that equilibria may be difficult to compute when there are several unintegrated downstream firms. To get around this issue, we suppose that the analog of Assumption 4 holds, namely, we assume that integrated firms cannot price discriminate on the upstream market, and that unintegrated downstream firms choose their upstream suppliers at the end of period 2, once downstream prices have been set.

It can then be an equilibrium that one integrated firm supplies all unintegrated downstream firms at its monopoly upstream price. Lemmas 1 and 2 easily extend to larger numbers

[33]For conciseness, we do not report other equilibria in which the upstream market is supplied by one firm, whose upstream offer is constrained by the offer of its integrated rival.

[34]A sufficient (but not necessary) condition for this is that prices are strategic complements.

[35]If the equilibrium is monopoly-like, this is obvious. If it is matching-like, then the upstream profit is equal to $[a_{tp} - c_u]\, D_d(p^{(i)}(a_{tp})) + \pi_j^{(i)}(a_{tp}) - \pi_i^{(i)}(a_{tp}) = \left[p_j^{(i)}(a_{tp}) - c_u\right] D_j(p^{(i)}(a_{tp})) - c_j\left(D_j(p^{(i)}(a_{tp}))\right) - \left[p_i^{(i)}(a_{tp}) - c_u\right] D_i(p^{(i)}(a_{tp})) + c_i\left(D_i(p^{(i)}(a_{tp}))\right)$, which is strictly positive by Lemma 2.

of firms: When one integrated firm sells the input at a strictly positive price-cost margin to all the entrants, it charges a strictly higher downstream price and earns a strictly smaller downstream profit than the other integrated firms. As a result, the integrated rivals may not want to undercut to benefit from the softening effect.

To go further, we prove the analog of Proposition 5 in this extended framework with M integrated firms and N downstream firms. As in Section 3.4.2, assume that downstream demands are derived from the maximization of a representative consumer's utility with the following preferences:

$$U = q_0 + \sum_{k=1}^{M+N} q_k - \frac{1}{2}\left(\sum_{k=1}^{M+N} q_k\right)^2 - \frac{M+N}{2(1+\gamma)}\left(\sum_{k=1}^{M+N} q_k^2 - \frac{(\sum_{k=1}^{M+N} q_k)^2}{M+N}\right)$$

Suppose also that integrated firms have a cost dis-advantage δ relative to unintegrated downstream firms. We obtain the following result:

Proposition 10. *Consider the asymmetric linear case with M integrated firms and N unintegrated downstream firms. For all $\gamma \geq 0$, $M \geq 2$ and $N \geq 1$, there exists $\overline{\delta}^{M,N}(\gamma)$ such that monopoly-like equilibria exist if, and only if, $\delta \geq \overline{\delta}_{M,N}(\gamma)$.*

Proof. See our web appendix, Section III (Bourreau, Hombert, Pouyet and Schutz, 2010). □

Quantity competition. The softening effect exists if the upstream supplier can enhance its upstream profits by behaving softly on the downstream market. As discussed previously, this requires that it actually interacts with the unintegrated downstream firm. One may wonder whether the softening effect hinges on the assumption of price competition on the downstream market, for if the downstream strategic variables are quantities and all firms play simultaneously, then the upstream supplier can no longer impact its upstream profit through its downstream behavior. However, if for instance integrated firms are Stackelberg leaders on the downstream market, then the upstream supplier's quantity choice modifies its upstream profit, and the softening effect is still at work. To summarize, the question is not whether firms compete in prices or in quantities, but whether the strategic choice of a firm can affect its rivals' quantities.[36]

Upstream demand sharing. Throughout the paper, we have assumed that the upstream market could be supplied by one integrated firm only. Consider now that, when upstream

[36] With a linear demand function and quantity competition, if integrated firms are Stackelberg leaders on the downstream market, then a monopoly-like equilibrium always exists. Computations are available at `http://sites.google.com/site/nicolasschutz/research`.

offers are identical, the upstream demand is split equally between integrated firms. This would be a reasonable assumption if there were several downstream firms. In that case, we can still think about the upstream market in terms of softening effect and upstream profit effect. When the integrated firms share the upstream market, they both obtain some upstream profits, and they both benefit from a softening effect, since they both have incentives to protect their upstream revenues. Behaviors on the upstream market still trade off the softening effect and the upstream profit effect.

It becomes clear that the possibility for equilibrium partial foreclosure remains. Monopoly-like equilibria feature the same outcome as in the basic model. Matching-like equilibria can also exist, in which the upstream market is shared between integrated firms.[37]

5.2 Complete vs. Partial Foreclosure.

When Assumption 2 holds, we have identified conditions under which partial foreclosure arises in equilibrium. As mentioned in Section 3.1, Assumption 2 may hold for several reasons.

To begin with, there may be a regulation in place, which forces one or more integrated firms to make an acceptable upstream offer to downstream entrants. This, of course, is relevant in the telecommunications industry. In many European broadband markets, the incumbent's wholesale bitstream access offers are regulated. In some countries (e.g., Austria, Ireland, Portugal, Sweden), the access price is set on a retail minus basis. In other countries (e.g., France, Italy, the Netherlands), the access price should be "cost-oriented." Similarly, in many European countries, MNOs are obliged to give access to their networks to MVNOs. In some countries (e.g., Denmark, Sweden), this obligation has been put in force by law. In other countries (e.g., France, Germany), mobile licenses include a clause that forces the MNO to accept MVNO access requests. For example, in 2006, the French MNO SFR was refusing access to candidate MVNO Afone. Following a complaint to the regulatory authority, SFR was forced to provide an acceptable offer to Afone, due to the access obligation in its mobile licence.[38]

There may also be bypass opportunities. A downstream firm could pay a sunk cost to start producing its own input if this input is not available in the market, as explained at the end of Section 4.1. Again, integrated firms would then prefer to make an acceptable offer

[37] For instance, using the Salop demand specification with $d = 1/3$, and assuming that the unintegrated downstream firm splits equally its demand when upstream prices are identical, we obtain the following subgame-perfect equilibria: the two monopoly-like outcomes, the perfect competition outcome, and a continuum of equilibria in which both integrated firms set the same price above marginal cost, and share the upstream demand. Computations are available at `http://sites.google.com/site/nicolasschutz/research`.

[38] See Arcep Décision 06-0406 of April 4, 2006.

rather than let that happen. In the broadband market, there is a viable bypass option for the pure service-based firm: installing its own DSL equipments and leasing unbundled access to the incumbent's local loop at a regulated price. Possibilities of bypass are more limited in the mobile market, although an ungranted mobile licence could still represent a credible threat of bypass. For example, in July 2007, Numericable, the French cable network announced that it had signed an MVNO contract with MNO Bouygues Telecom and at the same time announced that it renounced to be candidate for the French 4th mobile licence. Before this contract, Bouygues Telecom had always refused to host MVNOs on its network.

When neither of the above conditions are satisfied, Assumption 2 can still hold because integrated firms actually want to supply downstream firm d. This arises provided that $\pi_i^{(i)}(a_m)$ is greater than, π^{duo}, the duopoly profit an integrated firm earns when firm d is squeezed from the market. In that case, complete foreclosure cannot be sustained at equilibrium.

In the following we exhibit two commonly used downstream demand systems, in which an integrated firm strictly prefers supplying the entrant than squeezing it from the market. In these examples, monopoly-like equilibria continue to exist, even when Assumption 2 is not imposed.

Example 1: Representative consumer with a quasi-linear quadratic utility and downstream cost differential. The linear demand system comes from the maximization of quadratic quasi-linear utility function (4). When firm d is active on the downstream market, demand functions are given by equation (5). When firm d is squeezed, demand functions are obtained by imposing the constraint that the quantity purchased from firm d is zero in the representative consumer's program.[39] As in Section 3.4.2, firm d has a downstream cost (dis-)advantage δ (which can be positive or negative) compared to the integrated firms.

There exists a set of parameters (γ, δ) such that Assumption 2 holds together with the existence condition for monopoly-like equilibria. The following proposition precisely delineates the regions where partial foreclosure equilibria and complete foreclosure equilibria exist. These areas are depicted in Figure 3.[40]

Proposition 11. *Consider the asymmetric linear case without Assumption 2. There exist a*

[39] See Höffler (2008).

[40] Consistent with the idea that partial foreclosure is more likely when γ is large (Proposition 4), we observe that $\overline{\delta}(\gamma)$ decreases in γ up to a threshold $\hat{\gamma}$ with $\overline{\delta}(\hat{\gamma}) < 0$. However, we also find that $\overline{\delta}(\gamma)$ is negative and increasing when $\gamma > \hat{\gamma}$. The reason is that when γ increases, competition becomes fiercer and the consequences of cost differentials are magnified. This implies that the cost differential $\overline{\delta}(\gamma)$ needed to obtain equilibrium partial foreclosure goes to 0 as γ goes to infinity. This explains why $\overline{\delta}(\gamma)$ eventually increases with γ. A similar insight obtains for $\overline{\overline{\delta}}(\gamma)$. In particular, the fact that $\overline{\overline{\delta}}(\gamma)$ is initially decreasing points to the intuition that complete foreclosure is more likely when downstream competition tightens as the entrant cannibalizes more of its supplier's downstream demand.

threshold $\overline{\overline{\gamma}} > 0$ *and a cutoff function* $\gamma \mapsto \overline{\overline{\delta}}(\gamma)$ *such that* $\overline{\delta}(\gamma) \leq \overline{\overline{\delta}}(\gamma)$ *if, and only if,* $\gamma \geq \overline{\overline{\gamma}}$*, and:*

(i) if $\delta < \min\{\overline{\delta}(\gamma), \overline{\overline{\delta}}(\gamma)\}$*, then the only equilibrium outcome is the Bertrand outcome;*

(ii) if $\overline{\delta}(\gamma) \leq \delta \leq \overline{\overline{\delta}}(\gamma)$*, then there is an equilibrium with a monopoly-like outcome on the upstream market;*

(iii) if $\delta \geq \overline{\overline{\delta}}(\gamma)$*, then there is an equilibrium with complete foreclosure on the upstream market.*[41]

Proof. This proposition, as well as its extension to two-part tariffs and convex downstream costs (discussed below), is proven in Section I.2 of our web appendix (Bourreau, Hombert, Pouyet and Schutz, 2010). □

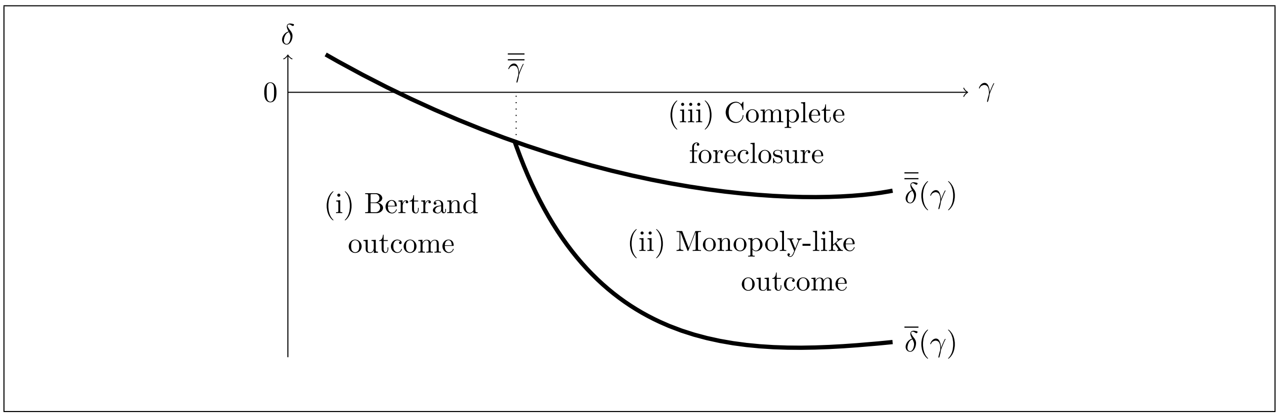

Figure 3: The three regions of Proposition 11

There exists a complete foreclosure equilibrium when the profits from supplying the entrant are small, which occurs when the entrant is rather inefficient: $\delta \geq \overline{\overline{\delta}}(\gamma)$. A monopoly-like equilibrium emerges when the cost (dis-)advantage of the entrant is between $[\overline{\delta}(\gamma), \overline{\overline{\delta}}(\gamma)]$, which, in the linear example, is non-empty when final products are sufficiently strong substitutes ($\gamma > \overline{\overline{\gamma}}$).

These results may be used to build a typology of the competitive issues faced by non-integrated entrants: inefficient entrants face a risk of complete foreclosure; fairly efficient entrants face a risk of partial foreclosure; finally, very efficient entrants enjoy a competitive upstream market and can compete on a level playing field. A similar insight obtains when integrated firms compete in two-part tariffs on the upstream market. In that case, we show

[41]To complete the characterization of all the equilibria: The Bertrand outcome is always an equilibrium, and there is an equilibrium with a matching-like outcome $a_1 = a_2 > c_u$ on the upstream market when $\delta \geq \overline{\delta}(\gamma)$.

that there exists a threshold $\overline{\overline{\delta}}_{tp}(\gamma)$ such that the entrant is (i) fully foreclosed when $\delta > \overline{\overline{\delta}}_{tp}(\gamma)$ and (ii) partially foreclosed otherwise. The equilibrium in the latter case is the matching-like equilibrium of Proposition 9.

Another intuitive determinant for the emergence of partial or complete foreclosure is the cost structure. Consider indeed that downstream costs are convex. With decreasing returns to scale, it is profitable to split the cost between a vertically integrated firm and the entrant, which makes complete foreclosure less attractive. To confirm this intuition, we add a quadratic term $c_q D_k^2$ to the downstream cost function of every firm $k \in \{1, 2, d\}$, with $c_q > 0$. By continuity of the profit functions in c_q, Proposition 11 continues to hold as long as c_q is not too large. Consistent with the intuition that diminishing returns to scale reduce the extent of complete foreclosure, we find that, as c_q increases from 0, $\overline{\overline{\gamma}}$ decreases and the partial foreclosure region expands.

Example 2: Spatial competition with exogenous locations. Firms compete on the Salop (1979) unit length circle, consumers have unit demands, transport costs are quadratic, and the gross utility is large enough to ensure that the market is covered in all equilibrium configurations. Firms 1 and 2 are at a distance 1/3 from each other and firm d, if it gets access to the input, is located at a distance $d \in (0, 2/3)$ from firm 1 on the longer segment separating the vertically integrated firms. Downstream costs are linear and identical across firms.

Note that integrated firms 1 and 2 are no longer symmetric when $d \neq 1/3$. Although our basic model has symmetric integrated firms, the assumption that their downstream divisions are symmetric is not crucial. When this assumption is relaxed, it is straightforward to adapt the proofs of Lemmas 1 and 2 to restate them as follows: For $a_i > c_u$, vertically integrated firm i charges a strictly higher downstream price and earns strictly smaller downstream profits if it supplies the upstream market at price a_i than if its integrated rival does, $p_i^{(i)}(a_i) > p_i^{(j)}(a_i)$ and $(p_i^{(i)}(a_i) - c_u)D_i(p^{(i)}(a_i)) - c_i(D_i(p^{(i)}(a_i))) < (p_i^{(j)}(a_i) - c_u)D_i(p^{(j)}(a_i)) - c_i(D_i(p^{(j)}(a_i)))$.

We can also rewrite Proposition 1 with asymmetric integrated firms. To do so, notice first that the profit functions and the monopoly upstream prices, $a_m^{(i)} = \arg\max_{a_i} \pi_i^{(i)}(a_i)$, are no longer the same for the two integrated firms. More importantly, if firm i supplies the upstream market at price $a_m^{(i)}$, then setting $a_j = a_m^{(i)} - \varepsilon$ may not be firm j's most profitable deviation. The first reason comes from the demand side: since integrated firms are no longer symmetric, firm d may actually prefer purchasing from firm i at $a_m^{(i)}$ to purchasing from firm j at $a_m^{(i)} - \varepsilon$. The second reason comes from the supply side: if $a_m^{(j)} < a_m^{(i)}$, firm j would prefer setting $a_m^{(j)}$ to setting $a_m^{(i)} - \varepsilon$. To take these new effects into account, denote by $a_u^{(j)}$ firm j's best undercutting price when firm i supplies the input at price $a_m^{(i)}$. Formally, $a_u^{(j)} \equiv \arg\max_{a_j} \pi_j^{(j)}(a_j)$ subject to the constraint $\pi_d^{(j)}(a_j) \geq \pi_d^{(i)}(a_m^{(i)})$. Then, Condition (3) in Proposition 1, which states that firm j prefers not to undercut, can be rewritten as

$\pi_j^{(i)}(a_m^{(i)}) \geq \pi_j^{(j)}(a_u^{(j)})$.

We find that, depending on the value of the distance d, either partial foreclosure or complete foreclosure can be sustained at equilibrium:

Proposition 12. *Consider the Salop specification without Assumption 2. There exists* $\overline{d} \in (0, 1/3)$ *such that:*

- *there is a monopoly-like equilibrium in which integrated firm* 1 *supplies the upstream market if, and only if,* $d \in (0, \overline{d})$*;*
- *there is an equilibrium with complete foreclosure on the upstream market if, and only if,* $d \in (\overline{d}, 2/3 - \overline{d})$*;*
- *there is a monopoly-like equilibrium in which integrated firm* 2 *supplies the upstream market if, and only if,* $d \in (2/3 - \overline{d}, 2/3)$.

Proof. This proposition, as well as the result on input differentiation (mentioned below), is proven in Section II of our web appendix. □

A monopoly-like equilibrium emerges when the entrant's product is a close substitute to one of the integrated firms' product. In addition, the upstream market ends up being monopolized by the integrated firm whose final product is closer to the entrant's product. To understand the intuition, remember that there exists a monopoly-like equilibrium, in which firm 1 supplies the upstream market if and only if $\pi^{duo} \leq \pi_1^{(1)}(a_m^{(1)})$ and $\pi_2^{(2)}(a_u^{(2)}) \leq \pi_2^{(1)}(a_m^{(1)})$.

Consider first that firm 1 supplies the input to the downstream firm and assume that distance d is small. Then, firm 1's downstream price has a strong impact on firm d's demand. The softening effect is consequently strong, and firm 2 has little incentives to undercut. Put differently, condition $\pi_2^{(2)}(a_u^{(2)}) \leq \pi_2^{(1)}(a_m^{(1)})$ is easier to meet when firm d is closer to firm 1.

Second, condition $\pi^{duo} \leq \pi_1^{(1)}(a_m^{(1)})$ is more likely to be satisfied, i.e., firm 1 has less incentives to completely foreclose firm d, when distance d is small. This is because when firm 1 starts supplying firm d, firm 2 reacts to the entry of a new rival by lowering its downstream price, which hurts firm 1. This effect is weaker if firm 2 is less threatened by entry, which occurs when firm d is located closer to firm 1. Hence we get the surprising result that integrated firm 1 has more incentives to start supplying the entrant if the products of firms 1 and d are closer substitutes.

As a straightforward extension, consider that firm d's location depends on the identity of its upstream supplier. Assume now that firm d is located at distance $d \leq 1/3$ from its upstream supplier. The interpretation is that the input is differentiated and that this differentiation translates into the final products, as in Ordover and Shaffer (2007). This implies that d's product is a closer substitute to its wholesale supplier's product than to the other integrated firm's. In this case, integrated firms are still asymmetric, but their equilibrium profit functions now satisfy $\pi_1^{(1)}(.) = \pi_2^{(2)}(.)$ and $\pi_1^{(2)}(.) = \pi_2^{(1)}(.)$. Therefore, both integrated firms have the same monopoly upstream price a_m, and monopoly-like equilibria exist if, and only if, $\pi^{duo} \leq \pi_i^{(i)}(a_m) \leq \pi_j^{(i)}(a_m)$. As in Proposition 12, we find that monopoly-like equilibria exist if, and only if, $0 < d \leq \bar{d}$, and there is a complete foreclosure equilibrium if, and only if, $\bar{d} \leq d \leq 1/3$. The intuition is the same as before. When d is small, an integrated firm which starts supplying the downstream firm does not suffer too much from the adverse reaction of its integrated rival. Besides, the softening effect is strong, which weakens the incentives to undercut the upstream supplier. We can conclude that partial foreclosure becomes a more likely outcome when the input is more differentiated.

6 Conclusion

Our analysis has focused on the links between vertically-related markets, when the upstream good is an essential input to the downstream product, and when the competitors on the upstream market are also rivals on the downstream one. One of the main insights conveyed in the paper is that undercutting decisions on the upstream market trade off the softening effect and the upstream profit effect. Because of this, competition on these upstream markets may not be effective, and the monopoly outcome may persist even when competition in that market is possible.

Our results may rationalize the concerns expressed by the French Competition Authority when reviewing the proposed merger between two broadband providers, Cegetel and Neuf Telecom. Before the merger, these operators owned together between 30 and 50 percent of the national wholesale broadband market, while the incumbent historical operator (France Télécom) supplied the rest. The merger received clearance in August 2005 under the condition that the joint entity continued to provide its wholesale services, highlighting the perceived fear that the competition between two integrated firms on the upstream market may de facto lead to a monopoly.[42] Our analysis suggests that imposing such a constraint on one of the integrated incumbents may be an appropriate remedy to ensure that the wholesale market is competitive.

[42] See DGCCRF, Décision C2005-44 related to the merger between Neuf Telecom and Cegetel.

A Appendix

A.1 Proof of Lemma 1

Assume that integrated firm $i \in \{1,2\}$ is the upstream supplier at price $a_i > c_u$, and let us show that $p_i^{(i)}(a_i) > p_j^{(i)}(a_i)$.

Let us first give a sketch of the proof. Start from a hypothetical situation, in which integrated firm i would supply the upstream market at marginal cost, and unintegrated downstream firm d would set $p_d^{(i)}(a_i)$ on the downstream market, and analyze the outcome of the ensuing price competition game between the two integrated firms. There exists a symmetric Nash equilibrium in this reduced game. Then, assume that firm i increases its upstream price from c_u to a_i. Its downstream best-response shifts upwards, while firm j's best-response remains unaffected. These curves intersect at least once, at coordinates $\left(p_i^{(i)}(a_i), p_j^{(i)}(a_i)\right)$, since $\left(p_i^{(i)}(a_i), p_j^{(i)}(a_i), p_d^{(i)}(a_i)\right)$ is a Nash equilibrium of the three-player game. Since the slopes of the best-response functions are smaller than one, we obtain that $p_i^{(i)}(a_i) > p_j^{(i)}(a_i)$. This is depicted graphically in Figure 4 for the case of strategic complements (left panel) and strategic substitutes (right panel).

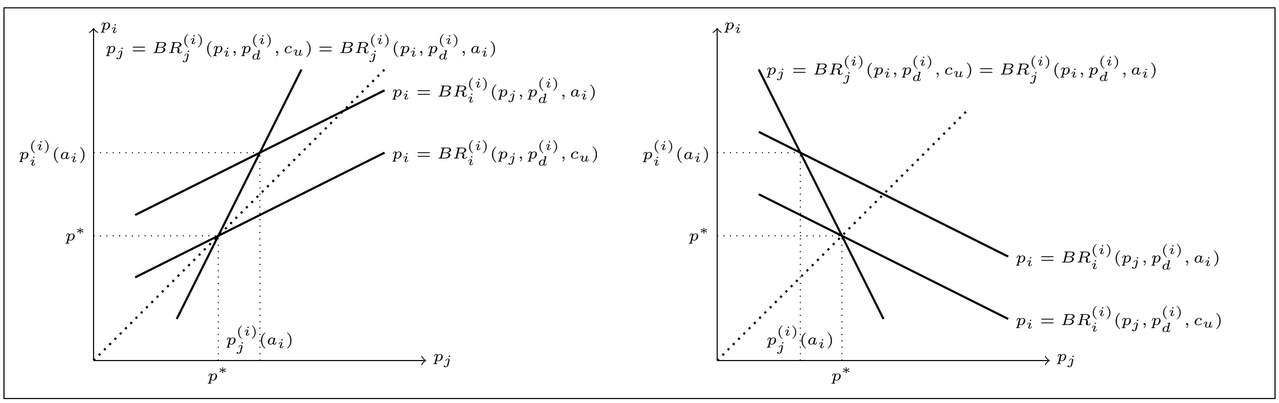

Figure 4: Graphical representation of the proof of Lemma 1

Let us now write down the formal proof. Assume that firm i supplies the upstream market at marginal cost, and firm d sets $p_d^{(i)}(a_i)$ on the downstream market. Let $\bar{p}$ an upper bound for the integrated firms' best-response functions. $p \in [0, \bar{p}] \mapsto BR_i^{(i)}\left(p, p_d^{(i)}(a_i), c_u\right) \in [0, \bar{p}]$ is continuous.[43] By the Brouwer fixed point theorem, this function has a fixed point, which we denote by p^*. When the upstream price is set at marginal cost, integrated firms are identical, therefore, they have the same best-responses, and p^* is a fixed point for $BR_j^{(i)}(., p_d^{(i)}(a_i), c_u)$ as well. As a result, there exists a Nash equilibrium of the two-firm game, in which both

[43]As can be seen by applying the implicit function theorem to equation (1), this function is even continuously differentiable.

firms set p^*. p^* satisfies $p^* = BR_i^{(i)}\left(p^*, p_d^{(i)}(a_i), c_u\right) = BR_j^{(i)}\left(p^*, p_d^{(i)}(a_i), c_u\right)$.

Assume now that integrated firm i increases its upstream price from c_u to a_i. Clearly, firm j's best-response is not affected (see equation (2)). The impact on firm i's best-response is obtained by differentiating equation (1): $\frac{\partial BR_i^{(i)}}{\partial a_i} = -\frac{\partial^2 \tilde{\pi}_i^{(i)}}{\partial p_i \partial a_i} / \frac{\partial^2 \tilde{\pi}_i^{(i)}}{\partial p_i^2} = -\frac{\partial D_d}{\partial p_i} / \frac{\partial^2 \tilde{\pi}_i^{(i)}}{\partial p_i^2}$, which is strictly positive since the second-order condition is satisfied. Therefore, firm i's best-response shifts upwards when a_i increases. In particular, $BR_i^{(i)}(.,.,a_i) > BR_i^{(i)}(.,.,c_u) = BR_j^{(i)}(.,.,a_i)$.

Since $(p_i^{(i)}(a_i), p_j^{(i)}(a_i), p_d^{(i)}(a_i))$ is a downstream equilibrium, we have

$$p_i^{(i)}(a_i) = BR_i^{(i)}\left(BR_j^{(i)}\left(p_i^{(i)}(a_i), p_d^{(i)}(a_i), a_i\right), p_d^{(i)}(a_i), a_i\right).$$

Therefore,

$$p_i^{(i)}(a_i) > BR_i^{(i)}\left(BR_j^{(i)}\left(p_i^{(i)}(a_i), p_d^{(i)}(a_i), c_u\right), p_d^{(i)}(a_i), c_u\right). \tag{6}$$

Define $\Phi(p) = BR_i^{(i)}\left(BR_j^{(i)}\left(p, p_d^{(i)}(a_i), c_u\right), p_d^{(i)}(a_i), c_u\right) - p$, and notice that $\Phi(p^*) = 0$. Φ is continuously differentiable and strictly decreasing, since the slopes of the best-response functions are strictly smaller than 1. Therefore, $\Phi(p) < 0$ if and only if $p > p^*$. Together with inequality (6), this implies that $p_i^{(i)}(a_i) > p^*$.

We conclude the proof by using the stability condition $\left|\frac{\partial BR_j^{(i)}}{\partial p_i}\right| < 1$:

$$\begin{aligned} p_j^{(i)}(a_i) = BR_j^{(i)}\left(p_i^{(i)}(a_i), p_d^{(i)}(a_i), a_i\right) &= BR_j^{(i)}\left(p_i^{(i)}(a_i), p_d^{(i)}(a_i), c_u\right) \\ &= p^* + \int_{p^*}^{p_i^{(i)}(a_i)} \frac{\partial BR_j^{(i)}}{\partial p_i}\left(p_i, p_d^{(i)}(a_i), c_u\right) dp_i < p_i^{(i)}(a_i). \end{aligned}$$

A.2 Proof of Lemma 2

Let integrated firm $i \in \{1,2\}$ be the upstream supplier at price $a_i > c_u$. Its downstream profit is given by:

$$(p_i^{(i)}(a_i) - c_u) D_i(p_i^{(i)}(a_i), p_j^{(i)}(a_i), p_d^{(i)}(a_i)) - c_i\left(D_i(p_i^{(i)}(a_i), p_j^{(i)}(a_i), p_d^{(i)}(a_i))\right). \tag{7}$$

Since $p_i^{(i)}(a_i) > p_j^{(i)}(a_i)$ by Lemma 1, there exists $\hat{p} > p_i^{(i)}(a_i)$ such that $D_i(p_i^{(i)}(a_i), p_j^{(i)}(a_i), p_d^{(i)}(a_i)) = D_i(\hat{p}, p_i^{(i)}(a_i), p_d^{(i)}(a_i))$. Downstream profit (7) is thus strictly smaller than:

$$(\hat{p} - c_u) D_i(\hat{p}, p_i^{(i)}(a_i), p_d^{(i)}(a_i)) - c_i\left(D_i(\hat{p}, p_i^{(i)}(a_i), p_d^{(i)}(a_i))\right).$$

By symmetry between integrated firms, this expression is equal to the downstream profit that rival integrated firm j would earn if it charged the downstream price $\hat{p}$ instead of its actual equilibrium price $p_j^{(i)}(a_i)$. This profit, by revealed preference, is strictly smaller than the actual downstream profit of firm j, which concludes the proof.

A.3 Proof of Proposition 2

Suppose first that both integrated firms offer the same upstream price $a_* \leq a_m$, such that $\pi_i^{(i)}(a_*) = \pi_j^{(i)}(a_*)$. The unintegrated downstream firm chooses indifferently one of them as its upstream supplier, and both integrated firms earn the same profit.

Consider an upward deviation of integrated firm i, be it the upstream supplier or not. Now, by Assumption 1, firm d strictly prefers buying the upstream good from firm j at price a_*, and firm i's profit is unchanged. Consider now a downward deviation: $a_i < a_*$. Firm d strictly prefers to buy from firm i, which then earns $\pi_i^{(i)}(a_i)$. By Assumption 3, since $a_* \leq a_m$, this profit is smaller than $\pi_i^{(i)}(a_*) = \pi_j^{(i)}(a_*)$. That situation is therefore an equilibrium.

Conversely, consider that both integrated firms offer the same upstream price a_*. Suppose first that $a_* > a_m$. The upstream supplier then has a strictly profitable deviation: propose a_m.

If $\pi_i^{(i)}(a_*) < \pi_j^{(i)}(a_*)$, then the upstream supplier would rather set an upstream price above a_* to earn $\pi_j^{(i)}(a_*)$.

If $\pi_i^{(i)}(a_*) > \pi_j^{(i)}(a_*)$, then the integrated firm which does not supply the upstream market would rather set an upstream price slightly smaller than a_* to earn a profit almost equal to $\pi_i^{(i)}(a_*)$.

A.4 Proof of Proposition 3

Consider by contradiction an equilibrium configuration in which $a_i < a_j$ and $a_i \neq a_m$. By Assumption 1, the upstream supplier is firm i. If $a_j > a_m$, it is a strictly profitable deviation for firm i to offer a_m. If $a_j \leq a_m$, firm 1 would rather charge any upstream price in (a_i, a_j), since $\pi_i^{(i)}(.)$ is increasing in this interval by Assumption 3.

Let us now show that a monopoly-like equilibrium Pareto-dominates any matching-like equilibrium, from the viewpoint of integrated firms. We have $\pi_j^{(i)}(a_m) \geq \pi_i^{(i)}(a_m)$ by Proposition 1. Consider a matching-like equilibrium at upstream price a_*. By definition of a_m, $\pi_i^{(i)}(a_m) \geq \pi_i^{(i)}(a_*) = \pi_j^{(i)}(a_*)$. This concludes the proof.

A.5 Proof of Proposition 4

Assume that integrated firm i supplies the upstream market at price a_i, and denote its integrated rival by j. To begin with, it is straightforward to see that we can normalize all upstream and downstream costs to $c = c_u = 0$, by redefining upstream prices as $\frac{a_i - c_u}{1-c-c_u}$ and downstream prices as $\frac{p_k - c - c_u}{1-c-c_u}$.

Then, for all downstream and upstream prices, for $k \in \{1, 2, d\}$, we have $\frac{\partial^2 \tilde{\pi}_k^{(i)}}{\partial p_k^2} = -\frac{2}{3}(1 + \frac{2}{3}\gamma) < 0$. This ensures that the best-response functions are uniquely defined. The stability condition is satisfied, since, for all $k \neq k'$, we have $\left|\frac{\partial BR_k^{(i)}}{\partial p_{k'}}\right| = \frac{\gamma}{6+4\gamma} < 1$. There is a unique downstream equilibrium, which can be computed by solving the set of first-order conditions. The equilibrium quantity served by downstream firm d is positive if and only if $a_i \leq a_{\max}(\gamma) \equiv \frac{6+5\gamma}{6+7\gamma+\gamma^2} > 0$. Assumption 1 is satisfied, since $\pi_d^{(i)}(a_i) = \frac{(1+\gamma)^2(6+\gamma)^2(3+2\gamma)}{4(3+\gamma)^2(6+5\gamma)^2}[a_i - a_{\max}(\gamma)]^2$, thus $\pi_d^{(i)}(.)$ is decreasing for $a_i \leq a_{\max}(\gamma)$.

The profit of the upstream supplier is strictly concave since $\frac{d^2\pi_i^{(i)}}{da_i^2} = -\frac{648+1944\gamma+2205\gamma^2+1158\gamma^3+269\gamma^4+20\gamma^5}{6(18+21\gamma+5\gamma^2)^2} < 0$. Firm i's maximum is reached for $a_i = a_m(\gamma) \equiv \frac{324+594\gamma+360\gamma^2+75\gamma^3}{648+1296\gamma+909\gamma^2+249\gamma^3+20\gamma^4}$. Since $a_m \in (0, a_{\max}(\gamma))$, Assumption 3 is satisfied.

$\pi_i^{(i)}(.)$ and $\pi_j^{(i)}(.)$ are parabolas, they cross each other twice, in $a_i = 0$ and in $a_i = a_*(\gamma) \equiv \frac{9(12+16\gamma+5\gamma^2)}{108+180\gamma+93\gamma^2+13\gamma^3}$. $\pi_i^{(i)}(.)$ is strictly concave and $\pi_j^{(i)}(.)$ is convex since $\frac{d^2\pi_j^{(i)}}{da_i^2} = \frac{(3+2\gamma)\gamma^2(1+\gamma)^2}{2(3+\gamma)^2(6+5\gamma)^2} \geq 0$. Hence, we have:

$$\pi_i^{(i)}(a_i) \geq \pi_j^{(i)}(a_i) \quad \Leftrightarrow \quad a_i \in [0, a_*(\gamma)]. \tag{8}$$

Let us now check whether $a_m(\gamma) \in [0, a_*(\gamma)]$:

$$a_m(\gamma) - a_*(\gamma) = \frac{3(3+\gamma)(6+5\gamma)(-648 - 1296\gamma - 864\gamma^2 - 183\gamma^3 + 5\gamma^4)}{(108 + 180\gamma + 93\gamma^2 + 13\gamma^3)(648 + 1296\gamma + 909\gamma^2 + 249\gamma^3 + 20\gamma^4)}.$$

Analyzing the above function, we establish that there exists $\overline{\gamma} > 0$, such that $a_m(\gamma) \geq a_*(\gamma)$ if, and only if, $\gamma \geq \overline{\gamma}$.

Since $\pi_i^{(i)}(0) = \pi_j^{(i)}(0)$ and $0 \leq a_m(\gamma)$, Proposition 2 implies that the perfect competition outcome is always an equilibrium.

If $\gamma < \overline{\gamma}$, then $0 < a_m(\gamma) < a_*(\gamma)$. By Proposition 1, (8) implies that there is no monopoly-like equilibrium. Moreover $a_*(\gamma) > a_m(\gamma)$ implies by Proposition 2 that there is no other matching-like equilibrium than the perfect competition outcome.

Similarly, if $\gamma \geq \overline{\gamma}$, then $a_m(\gamma) \geq a_*(\gamma)$ and there exist monopoly-like equilibria. This is also a necessary and sufficient condition for the matching-like equilibrium with upstream price a_*.

Finally, to make sure that all these equilibria are indeed equilibria we have to check that, in the downstream competition subgame, the upstream supplier does not want to lower discontinuously its downstream price to drive firm d out of the market. This is proven in our web appendix (Bourreau, Hombert, Pouyet and Schutz, 2010, end of Section I.1).

A.6 Proof of Proposition 6

Let $i \neq j$ in $\{1, 2\}$. We show that the conditions stated in Proposition 6 are sufficient to have $\frac{d\pi_i^{(i)}}{da_i}(c_u) > \frac{d\pi_j^{(i)}}{da_i}(c_u)$. To simplify the exposition, we introduce the following notations. p denotes the equilibrium downstream price set by the three firms when the upstream market is supplied at marginal cost. D denotes the demand addressed to each firm when all downstream prices are equal to p. We also denote by c' and c'' the first and second derivatives of the downstream cost function when the quantity produced is D. Last, we define $\delta \equiv \frac{\partial D_k}{\partial p_k}$, $\tilde{\delta} \equiv \frac{\partial D_k}{\partial p_{k'}}$, $\gamma \equiv \frac{\partial^2 D_k}{\partial p_k^2}$ and $\tilde{\gamma} \equiv \frac{\partial^2 D_k}{\partial p_k \partial p_{k'}}$, where all the derivatives are taken at price vector (p, p, p), and $k \neq k'$ in $\{1, 2, d\}$.[44]

With these notations, when $a_i = c_u$, the first-order conditions on the downstream market can be rewritten as $(p - c_u - c')\delta + D = 0$. The second-order conditions are given by $(2 - \delta c'')\delta + (p - c_u - c')\gamma < 0$, and the stability condition is:

$$\left| \frac{(1 - \delta c'')\tilde{\delta} + (p - c_u - c')\tilde{\gamma}}{(2 - \delta c'')\delta + (p - c_u - c')\gamma} \right| < 1.$$

Notice also that, if downstream prices are strategic complements, then, $(1 - \delta c'')\tilde{\delta} + (p - c_u - c')\tilde{\gamma} \geq 0$. Besides, since the total demand is decreasing, $\delta + 2\delta' \leq 0$.

Differentiating the profit functions with respect to a_i for $a_i = c_u$, we obtain:

$$\begin{aligned} \frac{d\pi_i^{(i)}}{da_i}(c_u) &= (p - c_u - c')\tilde{\delta} \left(\frac{dp_j^{(i)}}{da_i}(c_u) + \frac{dp_d^{(i)}}{da_i}(c_u) \right) + D, \\ \frac{d\pi_j^{(i)}}{da_i}(c_u) &= (p - c_u - c')\tilde{\delta} \left(\frac{dp_i^{(i)}}{da_i}(c_u) + \frac{dp_d^{(i)}}{da_i}(c_u) \right). \end{aligned}$$

Therefore,

$$\frac{d\pi_i^{(i)}}{da_i}(c_u) - \frac{d\pi_j^{(i)}}{da_i}(c_u) = D - (p - c_u - c')\tilde{\delta} \left(\frac{dp_i^{(i)}}{da_i}(c_u) - \frac{dp_j^{(i)}}{da_i}(c_u) \right). \tag{9}$$

[44] Notice that, since the three firms are identical, p, D, c', c'', δ, $\tilde{\delta}$, γ and $\tilde{\gamma}$ are well-defined, and do not depend on k or k'.

As usual, we obtain the expression of $\frac{dp_i^{(i)}}{da_i}(c_u) - \frac{dp_j^{(i)}}{da_i}(c_u)$ by differentiating firms i and j's first-order conditions with respect to a_i. We get:

$$\frac{dp_i^{(i)}}{da_i}(c_u) - \frac{dp_j^{(i)}}{da_i}(c_u) = \frac{\tilde{\delta}}{-\Big((2-\delta c'')\delta + (p-c_u-c')\gamma - ((1-\delta c'')\tilde{\delta} + (p-c_u-c')\tilde{\gamma})\Big)}.$$

Plugging this into equation (9), using the first-order conditions to get rid of the D term, and rearranging terms, we finally obtain:

$$\begin{aligned}\frac{d\pi_i^{(i)}}{da_i}(c_u) - \frac{d\pi_j^{(i)}}{da_i}(c_u) = &\frac{p-c_u-c'}{-\Big((2-\delta c'')\delta + (p-c_u-c')\gamma - ((1-\delta c'')\tilde{\delta} + (p-c_u-c')\tilde{\gamma})\Big)} \\ &\times \Big(-\tilde{\delta}^2 + \delta \Big((2-\delta c'')\delta + (p-c_u-c')\gamma - ((1-\delta c'')\tilde{\delta} + (p-c_u-c')\tilde{\gamma})\Big)\Big).\end{aligned}$$

The stability and second-order conditions imply that the denominator in the right-hand side is positive. Therefore, the above expression is positive if, and only if

$$-\tilde{\delta}^2 + (-\delta)\Big((-\delta)(2-\delta c'') - (p-c_u-c')\gamma + \tilde{\delta}(1-\delta c'') + (p-c_u-c')\tilde{\gamma}\Big) > 0.$$

Since $\delta < 0$, $-\delta > \tilde{\delta} > 0$, $p - c_u - c' > 0$, $c'' > 0$, and $(-\delta)(2-\delta c'') - (p-c_u-c')\gamma > 0$ this is the case if:

- $\tilde{\delta}(1-\delta c'') + (p-c_u-c')\tilde{\gamma} \geq 0$ (namely, if downstream prices are strategic complements at price vector (p,p,p)), and $\gamma \leq 0$,
- or if $\tilde{\gamma} \geq 0$.

A.7 Proof of Proposition 7

First, this is obvious that the unintegrated downstream firm cannot be completely foreclosed in equilibrium, since the unintegrated upstream firm would then prefer to make any acceptable offer above the marginal cost. Similarly, suppose that integrated firm 1 supplies the upstream market at $a_1 > c_u$. Then, by Assumption 1, $\pi_d^{(1)}(a_1) < \pi_d^{(1)}(c_u) = \pi_d^{(u)}(c_u)$. By continuity, there exists $a_u > c_u$, such that $\pi_d^{(u)}(a_u) > \pi_d^{(1)}(a_1)$: a strictly profitable deviation for firm u.

Suppose now that the upstream market is supplied by unintegrated upstream firm u at price $a > c_u$. Let us show that integrated firm 1 can corner the upstream market and enhance its profit by matching firm u's offer, i.e., by proposing $a_1 = a$. Assume that firms 1 and u

propose the same upstream price $a > c_u$, while firm 2 makes no offer.[45] Since $\partial^2\tilde{\pi}_k^{(i)}/\partial p_k p_{k'} \geq 0$ for all $k \neq k' \in \{1, 2, d\}$, the game defined by the payoff functions $(p_k, p_{-k}) \in \mathbb{R}_+^3 \mapsto \tilde{\pi}_k^{(i)}(p_k, p_{-k}, a)$ is smooth supermodular, parameterized by $i \in \{1, u\}$. For all k, $\partial\tilde{\pi}_k^{(u)}/\partial p_k \leq \partial\tilde{\pi}_k^{(1)}/\partial p_k$, therefore, $\tilde{\pi}_k^{(i)}(p_k, p_{-k}, a)$ has increasing differences in (p_k, i) with the order relation $u < 1$. Besides, the downstream equilibrium is, by assumption, unique. Supermodularity theory (see Vives 2001, Theorem 2.3) tells us that the equilibrium of that game is increasing in i, i.e., $p_k^{(u)}(a) \leq p_k^{(1)}(a)$ for $k = 1, 2, d$. Moreover, the inequality is strict for $k = 1$. Indeed, since $\tilde{\pi}_1^{(i)}(p_1, p_{-1}, a)$ has strictly increasing differences in (p_1, i), we can write the following inequalities:

$$0 = \frac{\partial\tilde{\pi}_1^{(u)}}{\partial p_1}(p_1^{(u)}(a), p_2^{(u)}(a), p_d^{(u)}(a), a) \leq \frac{\partial\tilde{\pi}_1^{(u)}}{\partial p_1}(p_1^{(u)}(a), p_2^{(1)}(a), p_d^{(1)}(a), a)$$
$$< \frac{\partial\tilde{\pi}_1^{(1)}}{\partial p_1}(p_1^{(u)}(a), p_2^{(1)}(a), p_d^{(1)}(a), a).$$

A revealed preference along the line of the proof of Lemma 2 implies that firm d strictly prefers to purchase from firm 1 than from firm u.

By the same revealed preference argument, firm 1's downstream profit is larger when it supplies the upstream market than when firm u does. In addition, it gets strictly positive upstream profit. Therefore, matching firm u's offer is a strictly profitable deviation, which concludes the proof.

A.8 Proof of Proposition 8

The proof that the upstream market cannot be supplied above marginal cost in equilibrium proceeds as in the proof of Proposition 7. To streamline the analysis, we only provide the main steps. To begin with, notice that, if a firm wants to corner the upstream market, it just needs to slightly undercut its rival. Indeed, because of Assumption 4, unintegrated downstream firms cannot commit to purchasing from a more expensive supplier. Consider that the upstream market is supplied by firm 1 at price $a_1 > c_u$. Then, firm u can set $a_u = a_1 - \varepsilon$, and corner the upstream market. Conversely, if firm u supplies the upstream market at price $a_u > c_u$, then firm 1 sets $a_i = a_u - \varepsilon$, since, as in the proof of Proposition 7, this enables it to capture the upstream profits, and to relax downstream competition. Therefore, the upstream market cannot be supplied above marginal cost.

[45] The new notations are similar to the previous ones: $\tilde{\pi}_k^{(u)}(., ., a)$ denotes the profit of firm k when the upstream market is supplied by firm u at price a, while $p_k^{(u)}(a)$ denotes its downstream price at downstream equilibrium.

Let us now demonstrate that the perfect competition outcome is the only equilibrium. Assume that firms 1 and u set $a_1 = a_u = c_u$. Obviously, firm u does not want to undercut. Firm 1 does not want to undercut either, since it would then make upstream losses. Besides, we claim that all final prices would decrease, which gives even less incentives to undercut. To see this, assume that firm 1 undercuts by setting $\hat{a} < c_u$, and notice that the game defined by payoff functions $(p_k, p_{-k}) \in [0, +\infty)^3 \mapsto \tilde{\pi}_k^{(i)}(p_k, p_{-k}, a)$ is smooth supermodular, parameterized by $a \in \{\hat{a}, c_u\}$. For all k, $\partial\tilde{\pi}_k^{(i)}(.,., c_u)/\partial p_k \geq \partial\tilde{\pi}_k^{(i)}(.,.,\hat{a})/\partial p_k$, therefore, $\tilde{\pi}_k^{(i)}(p_k, p_{-k}, a)$ has increasing differences in (p_k, a). Besides, the downstream equilibrium is, by assumption, unique. Supermodularity theory (see Vives 2001, Theorem 2.3) tells us that the equilibrium of this game is increasing in a. Therefore, $p_k^{(i)}(c_u) \geq p_k^{(i)}(\hat{a})$ for all k. Therefore, the perfect competition outcome is an equilibrium.

Last, let us check that the upstream market cannot be supplied below cost in equilibrium. First, if firm u supplies the upstream market below c_u, it has a strictly profitable deviation: set $a_u = c_u$. Conversely, if firm 1 supplies the upstream market at $a_1 < c_u$, then, we claim that it can also strictly increase its payoff by setting c_u. To make this point, we need to distinguish two cases, depending on whether $a_u \lesseqgtr c_u$. First, if $a_u \geq c_u$, then, firm 1's payoff increases, since the integrated firm gets rid of its upstream losses, and, using again the supermodularity argument developed in the previous paragraph, all downstream prices increase. If, on the other hand, $a_u < c_u$, then, firm u becomes the upstream supplier. Again, firm 1 gets rid of its upstream losses, and, using this time the supermodularity argument from the proof of Proposition 7, all prices increase. This concludes the proof.

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