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BOTTLENECK ACCESS WITH STRUCTURAL REGULATION AND ENDOGENOUS COMPETITION

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Bottleneck Access with Structural Regulation and Endogenous Competition*

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Abstract

In a simple model of network industry, where an upstream monopolist provides an essential input for downstream service supply, we analyze the competitive settings arising in the downstream market under alternative regulatory frameworks; we combine structural (i.e. vertical integration, functional/ownership separation) and conduct (discriminatory and nondiscriminatory access) regulatory remedies. Downstream firms are characterized by different levels of cost efficiency in the provision of the service. We show that the degree of heterogeneity in firms' cost efficiency is critical to the determination of the amount of competition that emerges in the downstream market, and of the efficiency of the industry. We show that *i*) when downstream firms are significantly heterogenous, discriminatory access fees may be socially desirable and *ii*) vertical integration is always socially preferable.

Keywords: Vertical Integration, Functional Separation, Ownership Separation, Regulation, Discriminatory Access Fees.

JEL classification: L13, L22, L44

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1 Introduction

This paper studies the impact of structural regulation (namely, vertical integration vs legal/ownership separation) and open access provisions on the efficiency of network industries when the downstream market structure in endogenously determined by the network operator.

These issues are particularly relevant in traditional public utilities, such as railways or energy supply, which in many developed economies have undergone radical liberalization processes during the last three decades. The actual performance of such reforms has proven somewhat controversial; as a matter of fact, despite developments in technology have eroded some of the natural monopoly aspects of traditional public utilities, the network infrastructure used to distribute most utility products and services has remained largely monopolistic. Competition has been introduced in service provision by granting open access to the use of the network infrastructure to new operators. Open access is a regulatory arrangement that allows any competitor meeting certain conditions (such as financial or technical requirements) to use the network infrastructure at fair (often regulated) prices, and on transparent and non-discriminatory terms.

One of the most controversial issues regarding regulation of network industries is whether the regulatory framework should prevent the firm controlling the infrastructure to be, at the same time, active in service provision; this form of "structural" regulation, known as vertical unbundling, impacts directly on the vertical structure of the industry and it is aimed at limiting the monopoly power of the network operator. Alternatively, the regulator may intervene on firms behavior by regulating, for example, retail/wholesale prices and/or profits - the so called "conduct" regulation (Vickers, 1995). This latter approach is generally more difficult to implement due to the several imperfections characterizing regulatory intervention (e.g., asymmetric information, political agency). Such imperfections prevent regulators from limiting effectively the market power of infrastructure operators and represent the major explanation for the aforementioned controversial effects obtained by liberalization programs.

Vertical unbundling creates a neutral competitive framework where downstream firms compete on equal footing; this makes this form of structural intervention desirable despite the inefficiencies it may generate due to the associated double marginalization or to unexploited vertical economies. Structural regulation may occur with different intensities; vertical separation represents, in fact, an extreme form of structural regulation. A less extreme intervention is legal or functional separation, whereby the vertically integrated operator establishes operationally separate business entities in control of the infrastructure and the provision of services, without any change in ownership. Functional separation is seen as a way to ensure fair competition in markets dominated by one firm without incurring the costs of breaking-up the vertically integrated operator.

Railways are an interesting sector to discuss. Some countries (e.g., the UK, Sweden) have forced vertical (and horizontal) unbundling of infrastructure and operations in the last twenty years. Other countries have preferred to keep an integrated incumbent while opening competition in operations. The EU *railways packages* fostered competition in operations, initially in freight segment and then in passenger segment, and forced all EU countries to introduce at least functional separation between infrastructure management and operation of the incumbent aiming at improving transparency of costs and subsidies. Other countries

outside the EU have also pushed forward reforms involving some forms of vertical ownership unbundling (see Di Pierantonio and Pelkmans, 2004; Drew and Nash, 2011; European Commission, 2011). However, despite their popularity, the existing empirical analysis have not reached a consensus about the optimality of these reforms.[1]

We model a framework characterized by an incumbent firm that, in control of a bottleneck facility, faces the threat of entry by two service firms at the retail level. The two potential rivals are assumed to have heterogeneous cost structures and to be more efficient than the incumbent in the provision of the services. They need access to the infrastructure in order to operate; they observe the access fee set by the upstream firm and decide whether to enter or not. We use this simple partial equilibrium model to assess the social optimality of alternative forms of regulatory intervention; in particular, we restrict our attention to the analysis of structural regulation (vertical integration vs legal/ownership unbundling) and basic conduct regulation (access discrimination vs non discriminatory access). In our model, access terms are set by the upstream firm. We do not explicitly consider strict conduct regulation (i.e. the terms of access are set by a welfare maximizing regulator) for a simple reason; in a model with perfect and symmetric information, the case with conduct regulation is of little theoretical interest since social welfare would necessarily be larger than in the case of un-regulated access fee. On the top of this, as argued above, optimal conduct regulation is not very realistic too, due to a series of imperfections which prevent the regulatory process to achieve the optimality.

The main feature of our model is that the degree of downstream competition is endogenously determined. In fact, rival firms' decision to enter (or to exit) is influenced by the access conditions set by the upstream firm; in other words, the upstream incumbent acts as a market leader: through the choice of the access charge, it determines the degree of downstream competition that arises at the equilibrium. We show that different degrees of downstream competition arise depending on firms technological characteristics. In particular, we show that if potential entrants production costs are sufficiently heterogeneous, it may be socially desirable to allow the infrastructure firm to set discriminatory access fees. This is an interesting result that goes against the aforementioned non-discrimination prescription commonly imposed by open access rules. We demonstrate that if access discrimination is allowed, more intense downstream competition may emerge at the equilibrium and this may go to the benefit of consumers. Finally, we show that social welfare is maximized when the upstream network operator is vertically integrated.

Access to a bottleneck facility is a traditional issue in industrial organization.[2] To our best knowledge, the considered literature has not carefully investigated the trade off faced by the vertically integrated incumbent in the determination of the access terms; on the one side, the network owner benefits from excluding rivals from downstream operations in order to protect its market power. On the other hand, when competitors are more efficient, it may benefit from stronger competition on the downstream market by outsourcing production to the more efficient rivals.[3] In this perspective, we show that in a context

[1] In analyzing railways cost structures of a panel of countries, Mizutani and Uranishi (2013) find that vertical integration is associated to lower costs for high train density, and to higher costs for low train density, where train density is the ratio between the number of trains and the length of the track and it measures the use of railway facility.

[2] For overviews, see Armstrong et al. (1994), Laffont and Tirole (1993), and Rey and Tirole (2007).

[3] Similar arguments have been also put forward, in a different setting, in Schmidtchen and Bier (2005).

characterized by endogenous market structure, access discrimination may become a useful tool to reconcile alternative targets.

Our paper contributes also to the literature on structural regulation; in our modeling we follow a relatively recent literature addressing the policy-relevant issue of alternative unbundling forms (i.e., legal or ownership). In Cremer and De Donder (2013), the idea of a fully-owned downstream subsidiary maximizing its own profits has been introduced; the authors compare legal unbundling to ownership separation in an unregulated framework. They find that ownership separation yields higher total output and welfare. A different result is obtained in Höffler and Kranz (2011a). The authors analyze a context with access regulation but where the regulator cannot prevent the incumbent from hindering downstream firms in some other ways (i.e. sabotage); they show that legal unbundling ensures higher output and welfare than ownership separation. This analysis is then extended in Höffler and Kranz (2011b) where a not fully independent network manager is considered (the so called imperfect legal unbundling).

The paper is organized as follows: Section 2 introduces the theoretical setting; Sections 3 and 4 analyze the cases of vertical bundling and unbundling, respectively; Section 5 draws concluding remarks.

2 The Model

The industry is characterized by an upstream natural monopoly producing a good which is used as input by downstream firms; the good is essential to the production of downstream firms. This structure is typical in network industries, where the intermediate good is access to the infrastructure; access provision is a natural monopoly because of high fixed and sunk costs. Each unit of downstream service requires one unit of access; we represent the cost to provide access services as follows:

$$\Gamma(k, K, q) = kQ + K, \tag{1}$$

where: k is the marginal cost of providing access to downstream operators, Q is the total amount of units supplied by downstream operators and K are infrastructure fixed costs. For the sake of simplicity we normalize to zero the upstream marginal cost k. Fixed costs K play no role in our analysis, thus will be ignored henceforth.[4]

Without loss of generality, we analyze the case of only one downstream market relying on the essential infrastructure.[5] Downstream firms are characterized by different production costs; formally, we assume that the cost structure of the generic downstream operator j is:

$$H(\theta_j, C, q_j) = \theta_j\, q_j + C, \tag{2}$$

[4]Alternatively, we may assume that fixed costs are lower than the incumbent's operative profit, or that they are covered by taxpayers.

[5]Often, in network industries, there are several downstream markets that need access to the same infrastructure; for example in the railway industry, downstream services include local transport of passengers, high-speed services, transport of freights. In our simple setting, assuming different downstream markets would not change our main results, given that we do not consider any constraint to the network capacity.

where: θ_j and and q_j are the marginal operating costs and the amount of service supplied by firm j, respectively; C is the downstream fixed cost that, for the sake of simplicity, we normalize to zero. In order to access the upstream essential infrastructure, new operators and, if required by the regulatory framework, the incumbent have also to pay a per unit access charge, determined by the infrastructure manager.[6]

All throughout the paper we consider a stylized downstream market made of at most three active firms: the downstream incumbent I, and two potential entrants, L and H respectively. We assume that new operators have some cost advantage with respect to the incumbent; this assumption is taken both on practical and theoretical grounds. In fact, one of the scopes of network industries liberalization processes is to stimulate entry of more efficient firms in the operation stage; from a theoretical viewpoint, since the aim of this paper is to analyze how structural and (mild) conduct regulation impact on the incumbent's access strategy and, consequently, on markets' efficiency, it is natural to look at these issues in the presence of more efficient potential entrants, that is when entry is highly socially desirable.[7]

Formally, we normalize the incumbent's marginal cost of production to one, $\theta_I = 1$; as regard firm L and firm H, the low-cost and the high-cost entrant respectively, we make the following assumption:

Assumption 1 *Firms H and L are more efficient than the incumbent and they have heterogeneous technologies:* $\theta_L \leq \theta_H < \theta_I = 1$.

Finally, we assume that all firms are profit-maximizers, and that downstream competition occurs *à la* Cournot.[8]

Downstream market demand is assumed to be linear; for technical reasons, all throughout the paper, we assume that downstream market is large enough to allow for competition to emerge at the equilibrium; formally, we make the following assumption:

Assumption 2 *Downstream market is* $P = A - Q$*, where* $A \geq 7$ *represents the maximum dimension of the market.*

We analyze several frameworks characterized by different mix of structural and conduct regulatory remedies. As far as conduct regulation is concerned, we consider two alternative scenarios: non-discriminatory access, whereby the regulatory framework mandates the incumbent to charge the same access fee, denoted by a, to all downstream firms, and discriminatory access where the network firm is allowed to charge different fees to different downstream firms. As far as structural regulation is concerned, we distinguish between bundling and unbundling of infrastructure management and service operation. In the latter setting, also referred to as vertical separation, the incumbent is forced to split its upstream and downstream branches in two separate and independent firms. Furthermore, on the basis of the practical experience

[6] Alternative structures of the access fee can be considered, such as non linear access charge. Notably, in the model we discuss the case with access discrimination where the incumbent firm sets different access charges to different downstream operators; in this case, firms pay different per-unit fees depending on their cost and quantity produced, a feature which in many respects resembles the outcome of non linear fees.

[7] A typical example of network industry characterized by more efficient downstream entrant firms is Italian railways; here, the incumbent firm faces higher labour costs, because of specific agreements with trade unions, that are not mandatory for rival firms.

[8] Similar results can be obtained assuming price competition and capacity investments in the operation phase. We assume Cournot competition for the sake of simplicity.

observed in many countries, we consider two alternative regimes of vertical separation: i) legal separation, when separation does not affect ownership, which is still in the hands of a single entity, and ii) ownership separation, whereby the infrastructure and the operating firms are also owned by different entities. With legal separation the firm originating by the former vertically integrated incumbent can be a subsidiary of a single economic group, though constraints on cross-subsidization between the two parent companies can be imposed by the regulatory framework. For the sake of simplicity, in our analysis, we consider, as Cremer and De Donder (2013), that under legal unbundling the incumbent upstream firm takes into consideration the impact of its choices on the downstream subsidiary, while the latter just maximizes its downstream profit.[9]

When the incumbent is integrated downstream, it sets the access fee (or the access fees when discrimination is allowed) in order to maximize its total profits (upstream and downstream). Under legal separation, the incumbent downstream subsidiary has to pay an access fee to the upstream firm, as its rivals do; the upstream incumbent determines the access fee(s), also taking into account the effect on the profit of its downstream subsidiary. With ownership separation, the infrastructure manager is completely separated by downstream firms and the access charge(s) is (are) set to maximize upstream profits.

3 Vertical integration

Under vertical integration, the incumbent manages the infrastructure and, at the same time, it is allowed to operate the downstream service on its own. Any new firm willing to enter the downstream segment of the market has to pay an access fee to the incumbent; in the first part of this section, we consider the case of mild conduct regulation, i.e. the network firm fixes the access fee to maximize its profit, but it cannot discriminate among entrants. Then, in Section 3.2, we lift the nondiscrimination requirement.

3.1 Nondiscriminatory access fees

The incumbent knows that firms L and H are willing to enter and their technological characteristics, θ_j, j =H,L. Before the two rivals take their entry decision, firm I sets the profit maximizing (non-discriminatory) access fee.[10]

This amounts to say that the incumbent may use the access fee to affect the entry decision of the two firms; for example, a sufficiently high access charge may induce firm H, the least efficient entrant, to stay out. In other words, the downstream market structure is endogenously determined by the incumbent; more specifically three possible downstream market configurations may emerge at the equilibrium:

1. triopoly, in which all three firms are active downstream (ILH - incumbent, low-cost rival and high-cost rival);

2. duopoly, in which only two firms are active downstream (IL or IH or LH);

[9] Our case also corresponds to the "reverse unbundling" analyzed by Höffler and Kranz (2011b); this light form of regulation is a good approximation of what observed in the regulation of US telecommunications.

[10] Note that we do not need to assume that the incumbent observes firms' marginal costs of production. We simply need that it knows the distribution of θs.

3. monopoly, in which only one firm is active downstream (I or L or H).

Note that in several potential market configurations, the incumbent is not active in the service provision; in these cases, the equilibrium displays what we define as "endogenous vertical separation". This may happen because the incumbent, being the two rivals more efficient, may find it profitable to exit the downstream market and to "delegate" the provision of services to the new entrants.[11]

This argument has an interesting consequence. It is easy to check that it is never optimal for the upstream incumbent to set an access fee that excludes the most efficient firm. In fact, due to its high level of efficiency, firm L generates large surplus; therefore, the incumbent always finds it profitable to delegate at least part of its production to firm L and then to extract the generated surplus via the access charge. Consequently, the duopoly IH or the monopolies I or H never occur at the equilibrium.

Finally, the set of potential market configurations can be reduced even more: as already mentioned above, we are restricting our attention to a downstream market of sufficient size to allow some degree of competition to emerge; therefore, also monopoly L never occurs at the equilibrium. Putting all these observations together, the only three (nontrivial) potential market configurations, out of the initial nine, that may actually emerge at the equilibrium are the triopoly ILH and the duopolies IL and LH.

We find the equilibrium following a two-step procedure; as first, we determine the so called implementable downstream market structures, that is under which conditions regarding the two entrants production costs, θ_L an θ_H, the nontrivial potential market configurations can be implemented at the equilibrium. In the second step, we assess which market structure, among the implementable ones, actually emerges at the equilibrium. Note that the equilibrium market structure is the one selected by the upstream incumbent: by setting the access charge, the incumbent *de facto* chooses its preferred downstream market structure among the implementable ones.

3.1.1 Implementable downstream market structures

As discussed above, the potential market configurations that may emerge at the equilibrium are ILH, IL and LH.

Let us first consider the triopoly ILH. The incumbent sets the access charge in the first stage and then downstream competition takes place. Proceeding by backward induction, let us start from the competition stage: given the access fee, a, firms set outputs to maximize their profits. Formally, the maximization problem of the vertically integrated incumbent competing downstream with firms L and H is:

$$\max_{q_I} \quad a\left(q_L + q_H\right) + \left(P - 1\right) q_I, \tag{3}$$

while the maximization problem of the entrant firm j =L,H is:

$$\max_{q_j} \quad \left(P - a - \theta_j\right) q_j, \tag{4}$$

[11] The incumbent strategy of delegating service provision to more efficient rivals and then to tax their profits away via the access charge is not new in the literature; see De Fraja and Manenti (2003), for an application to telecommunications, or Schmidtchen and Bier (2005).

where $P = A - \sum q_i$, i =I,L,H, is the demand function. From these maximization problems, the second-stage best-reply functions are:

$$q_I(q_L, q_H) = \frac{A - 1 - q_L - q_H}{2}, \tag{5}$$

$$q_L(a, q_I, q_H) = \frac{A - a - \theta_L - q_I - q_H}{2}, \tag{6}$$

$$q_H(a, q_I, q_H) = \frac{A - a - \theta_H - q_I - q_L}{2}. \tag{7}$$

On the basis of conditions (5)-(7), entry conditions (i.e., non-negative quantity) and production levels can be determined. Solving the system (5)-(7), the second-stage equilibrium quantities (given the access fee) are given by:

$$q_I^{V_{ILH}}(a) = \frac{A + 2a - 3 + \theta_L + \theta_H}{4}, \tag{8}$$

$$q_L^{V_{ILH}}(a) = \frac{A - 2a + 1 - 3\theta_L + \theta_H}{4}, \tag{9}$$

$$q_H^{V_{ILH}}(a) = \frac{A - 2a + 1 + \theta_L - 3\theta_H}{4}, \tag{10}$$

where the superscript V_{ILH} indicates that we are in a triopolistic market structure with vertical integration.

The access fee is a marginal cost for entrant firms; both $q_L^{V_{ILH}}$ and $q_H^{V_{ILH}}$ decrease with a and it can be seen immediately that for a sufficiently high access fee both L and H may be induced not to produce, i.e., to stay out of the market. For later purposes, it is useful to define $\bar{a}_j^{V_{ILH}}$ as the level of access that keeps firm j = L,H out of the market:

$$\bar{a}_L^{V_{ILH}} = \frac{A + 1 - 3\theta_L + \theta_H}{2},$$
$$\bar{a}_H^{V_{ILH}} = \frac{A + 1 + \theta_L - 3\theta_H}{2}.$$

Of course, $\bar{a}_L^{V_{ILH}} > \bar{a}_H^{V_{ILH}}$: in order to keep firm L, the most efficient entrant, out of the market, the access fee must be set at a higher level than the one to deter entry of the high cost rival.

At the first stage of the game, the incumbent - anticipating second-stage reactions - determines the access fee. Thus, plugging expressions (5)-(7) into expression (3), and solving the incumbent first order condition w.r.t. a, the optimal access fee is

$$a^{V_{ILH}} = \frac{A}{2} - \frac{1 + \theta_L + \theta_H}{6}. \tag{11}$$

Substituting (11) in (8)-(10), it is possible to derive the optimal quantity and the profits of the firms. The formal expressions of firms profits in the various vertical and horizontal industry structures analyzed in the paper are given in the Table 1.

Simple algebra is enough to show that the equilibrium output of the most efficient is strictly positive, while the outputs of the downstream incumbent and the less efficient rival are positive only under specific technological conditions. From the non-negativity conditions on the incumbent's and the less-efficient-

rival's quantities, it is possible to derive the condition under which the triopoly ILH is an implementable market structure:

Lemma 1 *Under vertical integration with nondiscriminatory access, triopoly is an implementable downstream market equilibrium if and only if* $\theta_L \geq 2\theta_H - 1$.

Proof. Firm L is always active. The downstream incumbent's equilibrium profit is non-negative if and only if $\theta_L \geq 5 - 3A - \theta_H$; since A satisfies Assumption 2, then for any admissible value of θ_L and θ_H, firm I is always active in the service sector. Finally, independently of A, firm's H equilibrium profit is non-negative if and only if $\theta_L \geq 2\theta_H - 1$. ■

This Lemma is quite intuitive: it simply states that both rivals actively participate to the downstream market if their production costs do not differ too much (i.e. if θ_L is not too small compared with θ_H). If this happens, then firm I sets an access charge at a level which allows entry of both rival firms. If, on the contrary, firm L is much more efficient than firm H, then the high-cost entrant (reacting to the access fee fixed by the incumbent) may decide to stay out of the downstream market. The incumbent always operates on the downstream market, given that demand is assumed sufficiently large.

Let us now consider the duopoly IL; such a market structure can emerge as an equilibrium if only the incumbent and the most efficient firm find it optimal to produce downstream. Under this specification, firm I and firm L second-stage equilibrium quantities, given the access fee, are:

$$q_I^{V_{IL}}(a) = \frac{A + a - 2 + \theta_L}{3}, \tag{12}$$

$$q_L^{V_{IL}}(a) = \frac{A - 2a + 1 - 2\theta_L}{3}. \tag{13}$$

where the superscript V_{IL} indicates that we are in the scenario with vertical bundling and with only firm I and firm L active downstream. Anticipating such output levels, the upstream incumbent sets the access fee in order to maximize its profit; it can be shown that the optimal access fee set by the incumbent in this case is $a^{V_{IL}} = (5A - 1 - 4\theta_L)/10$. This fee is always below the level that prevents the low-cost firm to produce,[12] hence for any admissible value of the parameters, firm L is active downstream. Consequently, in order for the duopoly IL to be implementable we need to check that the following conditions are satisfied: *i*) the incumbent is effectively willing to operate in the downstream market and *ii*) given the equilibrium access fee $a^{V_{IL}}$ and the levels of output produced by firm I and firm L, the high-cost firm is not willing to enter. The following result holds:

Lemma 2 *Under vertical integration, duopoly IL is an implementable downstream market equilibrium if and only if* $\theta_L \leq (5\theta_H - 2)/3$.

Proof. We have already seen that firm L is always active. The downstream incumbent's equilibrium profit is non-negative if and only if $\theta_L \geq 7 - 5A$, hence given Assumption 2, firm I is active in the

[12] Using expression (13), it is immediate to see that $q_L^{V_{IL}}(a) \leq 0$ if $a \geq \bar{a}_L^{V_{IL}}$, where $\bar{a}_L^{V_{IL}} = (A+1-2\theta_L)/2$, with $\bar{a}_L^{V_{IL}} > a^{V_{IL}}$.

service sector. Finally, we need to check that the high-cost firm does not enter the market. We do so by substituting the equilibrium output levels of the incumbent and the low-cost firm, respectively given in expressions (12) and (13), and the access fee $a^{V_{IL}}$ back into the best-reply function of the high-cost firm given in expression (7); it is possible to see that firm's H output and profit levels are non-positive if and only if $\theta_L \leq (5\theta_H - 2)/3$. ■

Lemma 2 simply states that when firm L is sufficiently efficient, the incumbent firm is able to set an access fee high enough to foreclose firm H and, at the same time, to maximize the access payments obtained by firm L.[13]

Finally, the last nontrivial market structure that may emerge downstream is the duopoly LH, whereby the incumbent leaves the market to the two entrant firms; we name this market structure as "endogenous vertical separation" since market conditions are such that the incumbent, autonomously and not constrained by any regulatory remedy, prefers not to be active in the service production. In the duopoly LH, the second-stage Cournot outcomes of active firms are:

$$q_L^{V_{LH}}(a) = \frac{A - a - 2\theta_L + \theta_H}{3}, \tag{14}$$

$$q_H^{V_{LH}}(a) = \frac{A - a + \theta_L - 2.\theta_H}{3} \tag{15}$$

Anticipating such an equilibrium, the upstream incumbent chooses a to maximize its profit which, in case of endogenous vertical separation, reduces to $a(q_L^{V_{LH}}(a)+q_H^{V_{LH}}(a))$. A duopoly LH can be implemented if and only if the high-cost firm is willing to enter the market; the following Lemma holds:

Lemma 3 *Under vertical integration and nondiscriminatory access, duopoly LH is always an implementable downstream market equilibrium.*

Proof. Under duopoly LH, the access fee that maximizes firm I's profits is $a^{V_{LH}} = (2A - \theta_L - \theta_H)/4$. This fee is always below the level that keeps the low-cost firm out of the market, $\bar{a}_L^{V_{LH}}$; to see this, use expression (14) and solve $q_L^{V_{LH}}(a) = 0$ for the access price to get $\bar{a}_L^{V_{LH}} = A - 2\theta_L + \theta_H$: since $a^{V_{LH}} < \bar{a}_L^{V_{LH}}$ for any admissible value of θ_L and θ_H, then firm L is always active downstream. Firm H equilibrium profit is non-negative if and only if $\theta_L \geq 7\theta_H - 2A$; hence, given Assumption 2, firm H is active in the service sector. The incumbent never enters the downstream market by individual rationality: if I has decided to stay out in the first stage, it is rational to stay out also in the second stage (the Cournot game). ■

The three lemmas are summarized in Figure 1, where a graphical representation of the implementable market structures in the (θ_H, θ_L) space is provided; note that by $\theta_L < \theta_H$, the space of relevant cost parameters is below the 45° line. While duopoly LH can always be implemented (Lemma 3), the triopoly

[13] Note that if condition $\theta_L \leq (5\theta_H - 2)/3$ is violated (i.e., the low-cost firm is not so efficient), firm H finds it profitable to to enter the downstream market, thus deviating from $q_H^{V_{IL}} = 0$. However, despite this deviation is possible, duopoly IL can still be implemented: the upstream incumbent can foreclose the high-cost firm by choosing an access fee larger than $\bar{a}_H^{V_{IL}}(q_I, q_L) = A - q_I - q_L - \theta_H$, the level that makes $q_H^{V_{IL}} = 0$. Of course, such a strategy would imply lower profit for the incumbent (and for the rival firm too).

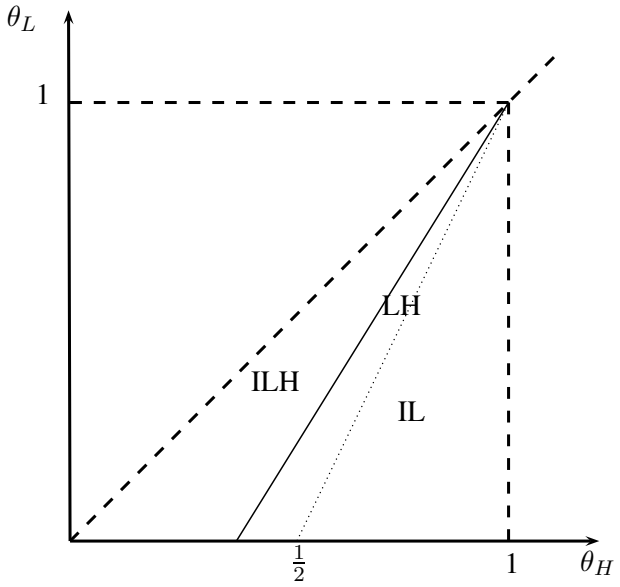

Figure 1: Implementable downstream market structures under bundling

ILH is implementable only for values of rivals' marginal costs above the dotted line (Lemma 1) and the (unconstrained) duopoly IL can be implemented only for values of the θs below the straight line (Lemma 2). Note that for technological parameters falling in the region between the two lines, both the triopoly and the duopoly IL can be implemented.

3.1.2 Optimal Downstream Market Structures

Once defined the implementable markets structures, we are now in the position to determine which one of them is actually chosen by the vertically integrated incumbent; the decision is taken looking at the structure conducive to higher profits.

Proposition 1 *Under vertical integration and non-discriminatory access, the incumbent firm sets the access fee to implement: triopoly if and only if* $\theta_L \geq \underline{\theta}(\theta_H)$*, where* $\underline{\theta}(\theta_H) = (5+2\sqrt{15})\theta_H/7 - 2(\sqrt{15}-1)/7$*; duopoly IL otherwise.*

Proof. In order to prove the proposition we must compare the incumbent's profit in the three implementable market structures (see Table 1). Comparison ILH *vs* IL: the difference between incumbent's profit under triopoly and under duopoly IL is non-negative if and only if $\theta_L \geq \underline{\theta}(\theta_H)$. Comparison ILH *vs* LH: given Assumption 2, the difference between incumbent's profit under triopoly and under duopoly LH is always non-negative; hence, in the relevant parameters' range, firm I always prefers ILH to LH. Being always dominated by ILH, LH is never the market structure preferred by the incumbent. ■

Figure 2 sums up the findings of Proposition 1, where the straight line represents the threshold $\theta_L = \underline{\theta}(\theta_H)$. The figure shows that the market structure maximizing the incumbent's profit is triopoly (resp. duopoly IL) for costs vector above (resp. below) the line $\theta_L = \underline{\theta}(\theta_H)$ which crosses the horizonal axis at $\tilde{\theta} = \frac{2\cdot(\sqrt{15}-1)}{5+2\cdot\sqrt{15}} (\approx 0.45)$. The following corollary follows from Figure 2:

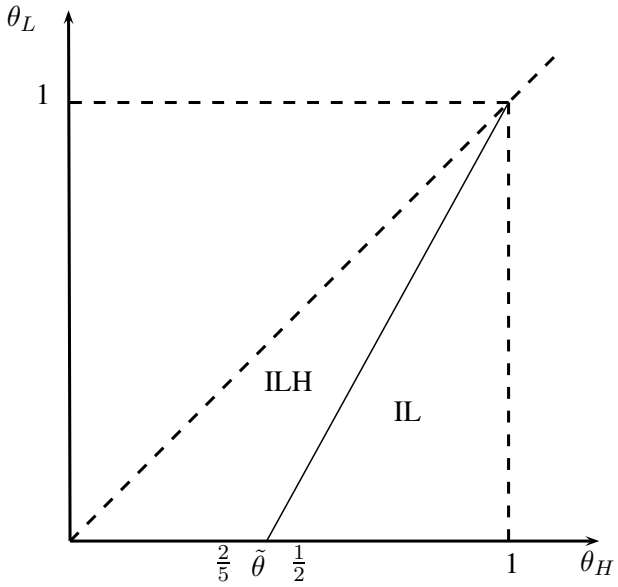

Figure 2: Equilibrium downstream market structures with vertical integration

Corollary 1 *When firms H and L production costs are sufficiently heterogeneous, the vertically integrated incumbent sets the access charge to foreclose the least efficient firm. When rivals' costs of production are not too different, the incumbent implements triopoly. Endogenous vertical separation is never optimal for the incumbent.*

This result can be easily interpreted. The incumbent firm faces a dilemma; on the one side, since rival firms are more efficient, it would like to allow both firms to enter the market by setting a relatively low access charge; this option would maximize downstream competition, reduce double marginalization and increase service production. On the other side, firm I would like to exploit as much as possible the higher efficiency of firm L by setting a relatively high access charge; the counter effect of this option would be that firm H, if not sufficiently efficient, would be kept out of the market.

When the two rivals have similar levels of technological efficiency, the first option is the preferred one: in this case the "opportunity cost" of giving access also to the less efficient firm and to let firm H to operate is more than compensated by a lower degree of double marginalization. Alternatively, when firm L is far more efficient than firm H, the incumbent prefers to set the access fee in such a way that this latter is driven out of the market: in this case, when only the highly efficient firm L is active, access revenues are at their maximum level and this more than compensates the negative effect of a larger double marginalization due to less downstream competition.

3.2 Discriminatory access

In the previous section, the incumbent was prevented by the regulatory framework to discriminate between the low- and the high-cost new entrant. The discussion of the results revealed that the no-discrimination provision generates a trade off for the network firm; things may change if such provision is removed. It is therefore interesting to extend the analysis to the case of a completely unregulated framework in which

the incumbent can impose differentiated access fees to entrant firms. Following the same procedure as above, we first characterize the implementable downstream market structures, and then we assess the structure that, depending on technological parameters, is optimally chosen by the upstream incumbent at the equilibrium.

Since the solution strategy is the same as before, we focus on main findings for the sake of brevity. Under access fee discrimination, the incumbent sets two fees, a_H for the high cost rival and a_L for the low cost rival. Entry and production decisions are determined maximizing the downstream firms' profits, given a_L and a_H; the best-reply functions are similar to the previous case, see expressions (5)-(7), with the only difference that now the two rivals' best reply functions depend on a_H and a_L. Again, the possible market structures that may emerge at the equilibrium are the triopoly ILH and the two duopolies IL and LH.

As far as the duopoly IL is concerned, the analysis is simple; in fact, we have already analyzed this market structure in the previous section when we assumed non-discriminatory access charge. Whether the incumbent discriminates or not is indeed irrelevant when only the low-cost firm is active on the market. Hence, Lemma 2 applies to the discriminatory case as well.

As far as the triopoly ILH and the duopoly LH are concerned, we prove the following lemma:

Lemma 4 *Under vertical integration and discriminatory access: i) triopoly is an implementable downstream market equilibrium if and only if $\theta_L \geq 5\theta_H - 4$, and ii) duopoly LH is always an implementable downstream market equilibrium.*

Proof. Consider the triopoly ILH; given the access fees a_L and a_H, the Cournot outcomes in the triopoly equilibrium are:

$$q_I^{V_{d,ILH}}(a_L, a_H) = \frac{A + a_L + a_H - 3 + \theta_L + \theta_H}{4}, \tag{16}$$

$$q_L^{V_{d,ILH}}(a_L, a_H) = \frac{A - 3a_L + a_H + 1 - 3\theta_L + \theta_H}{4}, \tag{17}$$

$$q_H^{V_{d,ILH}}(a_L, a_H) = \frac{A + a_H - 3a_L + 1 + \theta_L - 3\theta_H}{4}, \tag{18}$$

where the superscript $V_{d,ILH}$ indicates that we are in a triopolistic market structure with vertical integration and discriminatory access.

The access fees are determined in the first stage by the incumbent in order to maximize its profits, and are given by:

$$a_i^{V_{d,ILH}} = \frac{A}{2} - \frac{2 + 5\theta_i - \theta_j}{12}, \qquad i, j = L, H. \tag{19}$$

Output levels and firms profits are obtained substituting (19) in (16)-(18). The most efficient firm is always active. The incumbent's equilibrium profit is non-negative if and only if $\theta_L \geq 5 - 3A - \theta_H$; hence, given Assumption 2, for any admissible value of θ_H and θ_L the incumbent is active in the service sector. Finally, independent of A, the high-cost firm's equilibrium profit is non-negative if and only if $\theta_L \geq 5\theta_H - 4$. This proves part *i*) of the lemma.

Consider now the duopoly LH; this market structure is a subgame equilibrium if and only if the

incumbent does not enter the service market while both rival firms do enter it. Under this specification, the second-stage equilibrium quantities of operating firms - depending on the access fees a_H and a_L - are:

$$q_i^{V_{d,LH}}(a_i, a_j) = \frac{A - 2a_i + a_j - 2\theta_i + \theta_j}{3}, \qquad i, j = I, L. \tag{20}$$

Anticipating such an equilibrium and considering that the incumbent does not enter the downstream market, the optimal access fees determined by the upstream incumbent at the first stage are $a_i^{V_{d,LH}} = (A - \theta_i)/2$, for $i = L, H$.

The most efficient firm always operates on the market. The least efficient firm's equilibrium profit is non-negative if and only if $\theta_L \geq 2\theta_H - A$, which is always satisfied given Assumption 2. The incumbent never enters the downstream market by individual rationality. ■

Once defined the implementable market structures, we can proceed to the determination of the equilibrium of the game. The upstream incumbent chooses the downstream market structure conducive to higher profits.

Proposition 2 *Under vertical integration and discriminatory access, the upstream incumbent sets the access fees to implement triopoly if and only if $\theta_L \geq 5\theta_H - 4$, otherwise it implements duopoly IL.*

Proof. In order to prove the proposition we need to compare the incumbent's profit in the various implementable market structures (see Table 1). Comparison ILH *vs* IL: the difference between incumbent's profit under triopoly and under duopoly IL is always positive. However, triopoly can be implemented only if $\theta_L \geq 5\theta_H - 4$. Comparison ILH *vs* LH: given Assumption 2, the incumbent's profit under triopoly are strictly larger than under duopoly LH. Comparison IL *vs* LH: a sufficient condition for incumbent's profit in duopoly IL to be larger than under duopoly LH is that $A \geq (11 + 3\sqrt{2})/5 (\approx 3.04)$, which is verified under Assumption 2 and the proposition follows. ■

Figure 3 provides a graphical representation of our findings. Whenever the triopoly can be implemented, which occurs in the region above the line, triopoly is also the market structure selected by the incumbent at the equilibrium. For θs in the region below the line, duopoly IL can be implemented and this is also the structure that emerges at the equilibrium.

3.2.1 No discriminatory *vs* discriminatory access

A comparison of the equilibrium market structures with and without access discrimination (see Propositions 1 and 2) yields to the following corollary:

Corollary 2 *Under vertical integration, discriminatory access widens the scope for triopoly ILH.*

This is an interesting result which can be easily explained by recalling our previous arguments. As discussed above, the incumbent welcomes the presence of the two competitors: since they are more efficient, it can benefit from their technological superiority by letting them to produce the service and then by

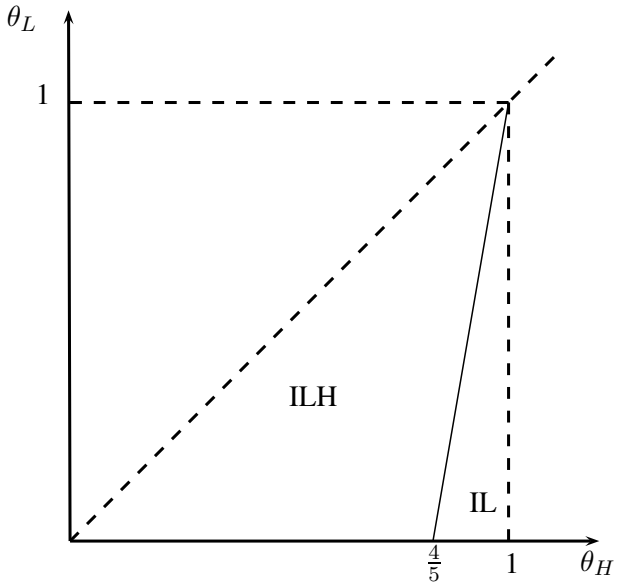

Figure 3: Equilibrium downstream market structures under bundling and discrimination

taxing their profits away through the access charge. Without discrimination, the incumbent faces a trade off between the need to stimulate downstream competition (to reduce double marginalization) on the one side, and the willingness to charge a larger access fee to extract the low-cost firm profits on the other. With access price discrimination, this trade off disappears; by charging customized access fees, the incumbent is able to stimulate the highest possible level of competition and to extract the highest amount of profits from the two rivals at the same time.

It is interesting to compare the two alternative conduct regulatory frameworks from the social welfare perspective. In general, with access discrimination the incumbent is in a better position to extract profits from the downstream rivals; this goes to the detriment of rivals' ability to compete in the service market and it may go against social welfare. On the other side, when the incumbent is allowed to discriminate among the two rivals, more competition tends to emerge at the equilibrium: whenever it can be implemented, ILH is the equilibrium downstream market structure (see Corollary 2). This fact, not only allows the incumbent to obtain larger profits, but it may also yield a larger consumers surplus and, hence a higher social welfare. The following two propositions compare social welfare (measured as the sum of consumers' and producers' surpluses) and consumers surplus with and without access discrimination.

Proposition 3 *Access discrimination increases social welfare whenever the lift of the no discrimination remedy strengthens downstream market competition. Formally, access discrimination reduces social welfare for* $\theta_L \geq \underline{\theta}(\theta_H)$*, it does not affect social welfare for* $\theta_L \leq 5\theta_H - 4$ *while it increases social welfare for* $\theta_L \in (5\theta_H - 4, \underline{\theta}(\theta_H))$*.*

Proof. In order to prove this proposition, we must compute social welfare, measured as the sum of consumers' and producers' surpluses. Given the linear demand schedule, consumers' surplus simply reduces to $Q^2/2$ where Q, the total amount of downstream production, depends on the market structure which emerges at the equilibrium; firms' profits in the various scenarios are given in Table 1. From Proposition 1 we know that with vertical integration and nondiscriminatory access, the equilibrium market structure is

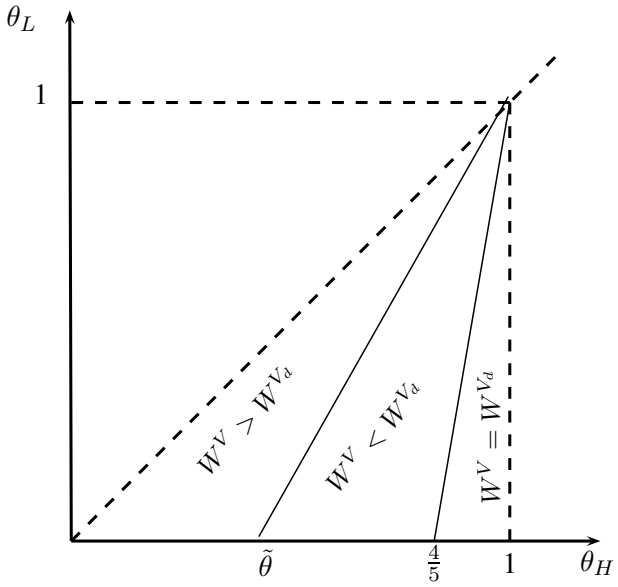

Figure 4: Non discriminatory access *vs* discriminatory access

triopoly if $\theta_L \geq \underline{\theta}(\theta_H)$ and duopoly IL otherwise. Hence, after some algebraic manipulations, social welfare is the following piecewise function:

$$W^V = \begin{cases} \frac{3}{8}A^2 - \frac{7}{12}A + \frac{59}{72} - (\theta_H + \theta_L)\left(\frac{19}{36} + \frac{A}{12}\right) + \frac{47}{72}\left({\theta_H}^2 + {\theta_L}^2\right) - \frac{25}{36}\theta_L\theta_H & \text{for} \quad \theta_L \geq \underline{\theta}(\theta_H); \\ \frac{3}{8}A^2 - \frac{A}{10}\theta_L - \frac{13}{20}A + \frac{19}{50}{\theta_L}^2 - \frac{33}{50}\theta_L + \frac{131}{200} & \text{otherwise.} \end{cases}$$

From Proposition 2 we know that with vertical integration and discriminatory access, the equilibrium market structure is triopoly if $\theta_L \geq 5\theta_H - 4$ and duopoly IL otherwise. Hence, the social welfare in this case is the following:

$$W^{V_d} = \begin{cases} \frac{3}{8}A^2 - \frac{7}{12}A + \frac{59}{72} - (\theta_H + \theta_L)\left(\frac{19}{36} + \frac{A}{12}\right) + \frac{29}{72}\left({\theta_H}^2 + {\theta_L}^2\right) - \frac{7}{36}\theta_L\theta_H & \text{for} \quad \theta_L \geq 5\theta_H - 4; \\ \frac{3}{8}A^2 - \frac{A}{10}\theta_L - \frac{13}{20}A + \frac{19}{50}{\theta_L}^2 - \frac{33}{50}\theta_L + \frac{131}{200} & \text{otherwise.} \end{cases}$$

where the superscript V and V_d indicate the welfare levels with vertical integration without access discrimination and with discrimination, respectively. The proposition follows from the comparison between W^{V_d} and W^V. ■

Figure 4 provides a graphical representation of Proposition 3. Interestingly, access discrimination may be socially desirable; this occurs when $\theta_L \in (5\theta_H - 4, \underline{\theta}(\theta_H))$ that is when access discrimination is conducive to more competition. A comparison of the two regimes from the perspective of the consumers surplus allows us to qualify these arguments.

Proposition 4 *Under vertical integration, access discrimination never reduces consumers' surplus. In particular, consumer surplus increases whenever lifting the no discrimination remedy strengthens downstream market competition.*

This proposition can be explained as follows. When firm H and firm L are characterized by sufficiently heterogenous cost parameters, with access discrimination the incumbent finds it optimal to set the access

charges in a way that both firms are active in the downstream market. On the contrary, without discrimination, firm I sets an access charge that drives the high cost firm out of the market. Therefore, in this scenario, with access discrimination consumers benefit from enhanced competition.

Putting these two propositions together, it is clear that when triopoly is the equilibrium market structure both with and without discrimination (formally, this occurs when $\theta_L \geq \underline{\theta}(\theta_H)$), social welfare with access discrimination is lower due to lower industry profits and not to lower consumers' surplus. In particular, when the incumbent sets customized access fees, firms produce different quantities but total industry output is the same as without discrimination, so are price and consumers' surplus.

4 Vertical separation

Let us now consider a regulatory framework that imposes separation of the former incumbent's business; this approach, known as "structural" regulation, is aimed at creating two distinct firms, one in control of the upstream infrastructure, and one that operates downstream.

Advocates of structural regulation push in favor of vertical unbundling seen as a way to create a level playing field that facilitates entry and where more intense competition may emerge. We consider two possible forms of structural regulation: ownership separation, where the two new firms are controlled by independent entities, and legal or functional separation, whereby the vertically integrated operator establishes operationally separate business entities in control of the infrastructure and the provision of service, without any change in ownership. Legal unbundling may involve some limitations to cross-subsidies among entities managing the infrastructure and the service operation. In both cases, we solve the model with and without conduct regulation imposing the upstream incumbent to charge non-discriminatory access fees.

Under our assumptions, the downstream game is unaffected by the choice of functional or ownership separation; in both cases the firms (including the incumbent's offspring) maximize their profits.[14] The equilibrium quantities are determined as in Section 3. Whether we have functional or ownership separation matters in the first stage of the game, when access fees are determined. In Section 4.1, we consider the case of ownership separation; then in Section 4.2 we analyze the case of functional separation.

4.1 Ownership separation

We follow the same procedure as above and we start by presenting the implementable market structures with ownership separation; we then proceed by finding the market structure which is actually selected by the upstream incumbent and which emerges at the equilibrium.

As first, we consider the case of conduct regulation imposing nondiscriminatory access fees. As far as the implementable market structures are concerned, it is immediate to verify that a duopoly IL where the downstream, and highly inefficient, incumbent and the low-cost firm are active in the service sector is never implementable: given that the upstream incumbent does not discriminate the terms of access, it is

[14] Assuming a different behavior of incumbent upstream and downstream firms in the case of legal separation may affect this result.

not possible to set an access fee that forecloses H and that at the same time allows the now independent and highly inefficient firm I to stay in the downstream market. It is also interesting to note that duopoly LH is implementable for any possible pair of the cost parameters; the explanation is simple and intuitive: since the upstream and the downstream incumbent firms are now two separated and independent entities, the upstream incumbent can always implement a duopoly LH by setting a sufficiently high access fee to foreclose the downstream incumbent.

The following Lemma defines the implementable market structures with ownership separation and nondiscriminatory access fee:[15]

Lemma 5 *Under vertical ownership separation and non-discriminatory access, duopoly IL cannot be an implementable market structure. Triopoly ILH and duopoly LH are always implementable market structures (LH is implementable provided that the upstream incumbent distorts the access fee upward to foreclose downstream firm I from the market).*

The upstream incumbent chooses the access fee to implement the market structure that maximizes its profit. Table 1 reports the level of profits that the upstream incumbent is able to obtain with ownership separation in the two downstream implementable market structures, ILH and LH;[16] a simple algebraic comparison is enough to prove the following proposition.

Proposition 5 *Under ownership separation and nondiscriminatory access, the upstream incumbent always sets the access fee to implement triopoly.*

This Proposition confirms the conventional wisdom that vertical separation stimulates downstream competition; with separation, the upstream incumbent does not have any direct stake in the operation business and, hence, it has full interest in stimulating downstream competition and production in order to maximize access payments.

We now turn to consider the alternative case in which discriminatory access fees are allowed. This scenario is very simple; as far as the implementable market structures are concerned, it is immediate to verify that all the admissible markets structures can be implemented by the upstream incumbent when it is allowed to set different access fees. The upstream incumbent chooses the access fees, i.e., the downstream market structure, to maximize its profit. As with ownership separation, the incumbent finds it optimal to stimulate downstream competition as much as possible.

Proposition 6 *Under vertical ownership separation and discriminatory access, the upstream incumbent always sets the access fees to implement triopoly.*

Hence, either with or without non-discriminatory access, with ownership separation, ILH is always the equilibrium market structure. Obviously, firms' outputs, profits and welfare are not the same in the two

[15]This Lemma has been obtained using the equilibrium Cournot outputs and following a procedure identical to the one applied in the previous section. The proofs of this and of the following lemmas are available upon request from the authors.

[16]It should be noted that when the downstream market structure is duopoly LH, I's profits are not affected by structural regulation: in the duopoly LH, the incumbent is already not active in the downstream market and a regulatory remedy mandating separation is totally ineffective.

regimes. In particular, it is of interest to compare the welfare levels under ownership separation with and without access price discrimination; from the comparison, we have the following result:

Proposition 7 *Under vertical ownership separation, discriminatory access i) reduces social welfare and ii) it does not affect consumers' surplus.*

Proof. In order to prove part *i*) of the proposition, we must compute social welfare, measured as the sum of consumers' and producers surplus. With ownership separation, social welfare with and without access price discrimination are the following:

$$\begin{aligned} W^{O} &= \frac{\frac{39}{2}A^2 - 13A - (\frac{115}{3} + 13A)(\theta_H + \theta_L) + \frac{269}{6}{\theta_H}^2 - \frac{115}{3}\theta_H\theta_L + \frac{269}{6}{\theta_L}^2 + \frac{269}{6}}{64}, \\ W^{O_d} &= \frac{\frac{39}{2}A^2 - 13A - (17 - 13A)(\theta_H + \theta_L) - 17\theta_H\theta_L + \frac{47}{2}{\theta_H}^2 + \frac{47}{2}{\theta_L}^2 + \frac{47}{2}}{64}. \end{aligned}$$

where the superscripts O and O_d indicate the welfare with ownership separation but without access discrimination and with discrimination respectively. Simple algebra reveals that $W^O - W^{O_d} = (1-\theta_H)^2 + (1-\theta_L)(\theta_H - \theta_L) > 0$.

As the consumers surplus is concerned, both with and without access discrimination its equilibrium level is $(3A - 1 - \theta_H - \theta_L)^2/238$. ■

According to Proposition 7, with ownership separation access discrimination is always detrimental to social welfare. This result highlights an interesting difference with the case of vertical integration. In Proposition 3, we have shown that with vertical integration, access discrimination may, in some circumstances, improve social welfare; the intuition was that with access discrimination more downstream competition may eventually occur at the equilibrium. This is no longer the case with ownership separation; with unbundling, in fact, triopoly is always the equilibrium market structure, both with and without access discrimination; whether the upstream incumbent discriminates or not matters in its ability to appropriate more effectively of rivals' profits. With discriminatory access the incumbent increases its profits at the rivals' expense with respect the no discrimination regime.

As we observed under vertical integration, also with ownership unbundling, the introduction of access discrimination does not alter the equilibrium market output, thus consumers' surplus with or without discriminatory access stays the same.

4.2 Legal separation

We conclude by analyzing the case of legal separation. In this scenario, the incumbent is still separated in two independent and autonomous entities but the two firms are under the same ownership. Following Höffler and Kranz (2011b,a) and Cremer and De Donder (2013), we model this scenario assuming that the subsidiary of the incumbent operating the service maximizes its (downstream) profit without taking into consideration the effects of its choices on the upstream incumbent profit.[17] Formally, while nothing changes

[17] Given that upstream and downstream incumbent firms are under the same ownership, one might consider more reasonable to model a downstream incumbent which takes into account the effects of its choices on the upstream firm's profit. In this

with respect the downstream subsidiary which, as with ownership separation, maximizes its profits, the ownership structure of the industry matters in the determination of the access charge; given that upstream and downstream businesses are still under the same ownership, despite being operationally independent, it is natural to assume that the upstream firm sets the access charge (or the access charges in case of discrimination) by internalizing the effects that its choice has on subsidiary's profits (i.e. the group's profits).

As before we solve the model with and without conduct regulation imposing non-discriminatory access fees. As stressed above, the downstream game is the same as with ownership separation; hence, the implementable market structures are identical to this case. In particular, also with legal separation, the duopoly IL is never implementable under access non-discrimination: any access fee which allows the (highly inefficient) downstream incumbent to operate is incompatible with whatever access fee that keeps the least efficient rival out of the market. On the top of this, it is immediate to see that from the point of view of the equilibrium market structure selected by the upstream incumbent, legal unbundling does not involve any major structural change with respect to ownership unbundling. Hence, Propositions 5 and 6 are valid also with legal separation.[18]

We are left with the discussion of the welfare effect of access discrimination; it is therefore interesting to contrast the social welfare and the consumers surplus with and without access discrimination. The following result holds:

Proposition 8 *Under vertical legal unbundling, access discrimination increases both social welfare and consumers' surplus.*

Proof. With legal separation, social welfare with and without access price discrimination are the following:

$$\begin{aligned} W^{L_d} &= \frac{3\,A^2 - 6\,A - 8(\theta_H - \theta_L) + 4\,{\theta_H}^2 + 4\,{\theta_L}^2 + 11}{8}, \\ W^{L} &= \frac{\frac{315}{2}\,A^2 - 157\,A - (271 + 79A)(\theta_H + \theta_L) + \frac{659}{2}\,{\theta_H}^2 - 309\,\theta_H\theta_L + \frac{659}{2}\,{\theta_L}^2 + \frac{699}{2}}{484}. \end{aligned}$$

where the superscripts L_d and L indicate the welfare levels under legal separation, with and without access

case, legal separation would determine the same outcomes as vertical integration. In the real world, legal separation is unlikely to determine exactly the same results than vertical integration because of differences introduced by potential divergences in managerial objectives, and above all because of institutional constraints limiting cross-subsidies between downstream and upstream firms belonging to the incumbent group. Our assumption can be considered a shortcut of such limitations.

[18] Formally, without access discrimination, the difference between the upstream incumbent profit in the triopoly ILH and in the duopoly LH is $\frac{5}{132}A^2 + \left(\frac{4}{33}(\theta_H + \theta_L) - \frac{7}{22}\right) A + \frac{19}{264}\left(\theta_L + \theta_H\right)^2 + \frac{25}{44} - \frac{9}{22}(\theta_H + \theta_L)$, which is a parabola in A pointing downward; through algebraic manipulations it is possible to see that $A > (56 - \sqrt{66})/(16 - \sqrt{66})$ $(\approx 5,8)$ is a sufficient condition for upstream profit under triopoly ILH to be larger than under duopoly LH. With access discrimination, both triopoly ILH and the two duopolies IL and LH are implementable; the difference between upstream profits under triopoly ILH and under duopoly IL is $(1 - \theta_H)^2/4$, while the difference between upstream profits under triopoly ILH and under duopoly LH is $(A - 3 + \theta_H + \theta_L)^2/12$, which are both positive, confirming that also with access discrimination triopoly ILH is the preferred structure by the legally independent upstream manager.

discrimination respectively. The difference $W^{L_d} - W^L$ is:

$$\frac{6}{121}A^2 + \left(\frac{79}{484}(\theta_H + \theta_L) - \frac{103}{242}\right)A - \frac{175}{968}({\theta_H}^2 + {\theta_H}^2) - \frac{213}{484}(\theta_H + \theta_L) + \frac{79}{121} + \frac{309}{484}\theta_H\theta_L,$$

which is a parabola in A pointing downwards. A sufficient condition for $W^{L_d} - W^L$ to be positive is $A > 79/12$ ($\approx 6,58$), which is always satisfied given Assumption 2.

As far as the consumers surplus is concerned, its levels with and without access discrimination are the following:

$$CS^{L_d} = \frac{(A-1)^2}{8} \qquad CS^L = \frac{(9A - 7 - \theta_h - \theta_l)^2}{968}.$$

It is immediate to check that with $CS^{L_d} > CS^L$ for any admissible parameters' value. ■

With legal separation, the ability of the upstream incumbent to set individual access fees has a positive impact on social welfare; this result is interesting as it goes exactly in the opposite direction of Proposition 7 obtained with ownership separation. The reason for this apparently unexpected result is however intuitive: with legal separation, the upstream incumbent sets the access fee by keeping into account the effects generated by its decision on the downstream subsidiary (while with ownership separation the two firms are two completely separated entities). As a consequence, when access discrimination is allowed, the upstream incumbent is induced to charge the subsidiary a low access fee in order to make it more competitive vis a vis its rivals; a more competitive downstream incumbent translates into higher profits for the subsidiary but also into a lower equilibrium price and a higher social surplus and welfare.

4.3 Bundling or not? Welfare analysis

It is now interesting to assess the various structural policies (i.e., vertical separation, legal and ownership separation) in terms of social welfare and consumers' surplus. The following Proposition, the last of the paper, summarizes the main result:

Proposition 9 *Social welfare is maximized with vertical integration. Moreover, (discriminating) legal separation dominates in terms of social welfare (nondiscriminating) ownership separation.*

Proof. From Proposition 8 we know that with legal separation access discrimination is socially desirable; on the contrary, with ownership separation, access discrimination deteriorates social welfare (see Proposition 7). A first welfare comparison can be done contrasting ownership separation without discrimination and legal separation with discrimination; the difference $W^{L_d} - W^O$ is equal to:

$$\frac{9}{128}A^2 + \left(\frac{13}{64}(\theta_H + \theta_L) - \frac{35}{64}\right)A - \frac{77}{384}({\theta_H}^2 + {\theta_L}^2) - \frac{77}{192}(\theta_H + \theta_L) + \frac{115}{192}\theta_H\theta_L + \frac{259}{384}.$$

This is a parabola in A pointing upwards and a sufficient condition for this parabola to be positive is $A > (35 - 13(\theta_H + \theta_L) + 4\sqrt{25({\theta_H}^2 + {\theta_L}^2) - 28(\theta_H + \theta_L) - 22\theta_H\theta_L + 28})/9$, a condition which is always satisfied under Assumption 2; this proves the second part of the proposition.

To prove the first part of the proposition we need to compare the social welfare when the incumbent is vertically integrated with legal separation and access discrimination; from Proposition 3, we know that with integration, *i*) no discrimination is desirable for $\theta_L > \underline{\theta}(\theta_H)$, *ii*) access discrimination is desirable for $\theta_L \in (5\theta_H - 4, \underline{\theta}(\theta_H))$, and *iii*) it is irrelevant otherwise. Hence, in order to compare the welfare levels under legal separation/discrimination and under vertical integration, we need to run three different comparisons: as for point *i*), we compute the difference between W^V, evaluated when $\theta_L > \underline{\theta}(\theta_H)$, and W^{L_d}; formally:

$$\left(\frac{1}{6} - \frac{1}{12}(\theta_H + \theta_L)\right) A + \frac{17}{36}(\theta_H + \theta_L) - \frac{25}{36}\theta_H\theta_L + \frac{11}{72}({\theta_H}^2 + {\theta_L}^2) - \frac{5}{9}.$$

This expression is positive for $A > (40 + 50\theta_H\theta_L - 34(\theta_H + \theta_L) - 11({\theta_H}^2 + {\theta_L}^2))/(6(2 - (\theta_L + \theta_H)))$: a sufficient condition for this inequality to hold is $A > 10/3$. Proceeding to point *ii*), we need to evaluate the difference between W^V, evaluated when $\theta_L \in (5\theta_H - 4, \underline{\theta}(\theta_H))$, and W^{L_d}; formally: $(2 - (\theta_H + \theta_L))(7\theta_H - 20 + 7\theta_H + 6A)/72$ which, again is positive for $A > 10/3$. Finally, we need to compare social welfare with vertical integration when $\theta_L < 5\theta_H - 4$ (and in this case it is irrelevant whether I discriminates or not) with W^{L_d}; the difference is equal to $-\frac{3}{25}{\theta_L}^2 + \left(\frac{17}{50} - \frac{A}{10}\right)\theta_L - \frac{18}{25} + \frac{A}{10} + \frac{1}{2}\theta_H(1 - \theta_H)$. This is a parabola in θ_L pointing downwards, which takes positive values for $\theta_L < (17 - 5A + 5\sqrt{A^2 - 23 - 2A + 24\theta_H(2 - \theta_H)})/17$. This last inequality is always satisfied when $\theta_L < 5\theta_H - 4$. ■

Proposition 9 suggests several interesting considerations which deserve to be discussed. Quite surprisingly, it shows that even in a model without vertical economies, social welfare is at its maximum with vertical bundling that is when the incumbent is active in all the production stages; even more surprisingly, we have shown that when the potential rivals are sufficiently heterogeneous in terms of cost efficiency, it may also be desirable to allow the vertically integrated firm to discriminate the terms of access.

There are at least two explanations of this result: on the one side, with vertical integration, the effects of double marginalization on prices and welfare are lower than with separation; on the other side, the ability of the integrated incumbent to discriminate allows the firm to stimulate downstream competition as much as possible. On the contrary, and for the opposite reasons, ownership separation without discrimination is the industrial/regulatory scenario which is conducive to the lowest welfare. Notably, the combination between conduct regulation requiring open and non-discriminatory access and vertical separation of the incumbent's businesses is a common requirement in the European regulatory frameworks governing the liberalization processes in network industries.

5 Conclusions

In a simple model of network industry, where an upstream monopolist provides an essential input for downstream service supply, we analyze the competitive settings arising in the downstream market under alternative regulatory frameworks characterized by open access to the network infrastructure.

Downstream firms are characterized by different levels of cost efficiency in the provision of the service. We show that whenever access fees cannot be directly regulated, the degree of heterogeneity in firms' cost efficiency is crucial to determine the amount of competition that emerges in the downstream market, and the welfare ranking between vertical integration (of incumbent's infrastructure-management and operation) and vertical (functional or ownership) separation. An interesting implication of our analysis is that liberalization policies need to consider the joint role of structural and (mild) conduct remedies. In particular, while no discriminatory clauses may be socially desirable under ownership unbundling, this is not the case under legal unbundling. We pointed out that *i*) if downstream firms have significantly different levels of cost efficiency, discriminatory access fees may be socially desirable and *ii*) vertical integration is always socially desirable.

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Table 1: Firms' profits in the various implementable markets' structures

	Market structure	Firm			
		Incumbent		**Firm L**	**Firm H**
Bundling with no discrimination	ILH	$\frac{A}{4}(A-2)+\frac{7}{12}+\frac{1}{12}(\theta_H+\theta_L)(\theta_H+\theta_L-4)$		$\frac{1}{9}(1-2\theta_L+\theta_H)^2$	$\frac{1}{9}(1+\theta_L-2\theta_H)^2$
	IL	$\frac{A}{4}(A-2)+\frac{9}{20}+\frac{1}{5}\theta_L(\theta_L-2)$		$\frac{4}{25}(1-\theta_L)^2$	
	LH	$\frac{1}{24}(2A-\theta_L-\theta_H)^2$		$\frac{1}{144}(2A-7\theta_L+5\theta_H)^2$	$\frac{1}{144}(2A-7\theta_H+5\theta_L)^2$
Bundling with discrimination	ILH	$\frac{A}{4}(A-2)+\frac{7}{12}-\frac{1}{3}(\theta_H+\theta_L-\theta_L\theta_H)+\frac{5}{24}(\theta_H-\theta_L)^2$		$\frac{1}{144}(4-5\theta_L+\theta_H)^2$	$\frac{1}{144}(4-5\theta_H+\theta_L)^2$
	IL	$\frac{A}{4}(A-2)+\frac{9}{20}+\frac{1}{5}\theta_L(\theta_L-2)$		$\frac{4}{25}(1-\theta_L)^2$	
	LH	$\frac{A}{6}(A-\theta_L-\theta_H)+\frac{1}{6}(\theta_H^2+\theta_L^2)-\frac{1}{6}\theta_H\theta_L$		$\frac{1}{36}(A-2\theta_L+\theta_H)^2$	$\frac{1}{36}(A-2\theta_H+\theta_L)^2$
Legal separation with no discrimination		Incumbent upstream	Incumbent downstream		
	ILH	$\frac{1}{242}(5A+1-3\theta_H-3\theta_L)(9A-7-\theta_H-\theta_L)$	$\frac{1}{484}(3A-17+7\theta_H+7\theta_L)^2$	$\frac{1}{484}(3A+5+7\theta_H-15\theta_L)^2$	$\frac{1}{484}(3A+5+7\theta_L-15\theta_H)^2$
	IL	impossible			
	LH	equivalent to duopoly LH with bundling			
Legal separation with discrimination		Incumbent upstream	Incumbent downstream		
	ILH	$\frac{A}{2}(2-\theta_H-\theta_L)-\frac{1}{2}\theta_H\theta_L-\frac{3}{2}+\theta_L+\theta_L$	$\frac{1}{4}(A-3+\theta_H+\theta_L)^2$	$\frac{1}{4}(1-\theta_L)^2$	$\frac{1}{4}(1-\theta_H)^2$
	IL	$\frac{1}{2}(1-\theta_L)(A-1)$	$\frac{1}{4}(A-2+\theta_L)^2$	$\frac{1}{4}(1-\theta_L)^2$	
	LH	equivalent to LH with bundling			
Ownership separation with no discrimination		Upstream	Downstream		
	ILH	$\frac{1}{48}(3A-1-\theta_H-\theta_L)^2$	$\frac{1}{576}(3A-17+7\theta_H+7\theta_L)^2$	$\frac{1}{576}(3A+7+7\theta_H-17\theta_L)^2$	$\frac{1}{576}(3A+7+7\theta_L-17\theta_H)^2$
	IL	impossible			
	LH	equivalent to duopoly LH with bundling			
Ownership separation with discrimination		Incumbent upstream	Incumbent downstream		
	ILH	$\frac{A}{16}(3A-2-2\theta_H-2\theta_L)-\frac{1}{8}(\theta_L+\theta_H-2\theta_H\theta_L)+\frac{3}{16}((\theta_H-\theta_L)^2+1)$	$\frac{1}{64}(A-3+\theta_L+\theta_H)^2$	$\frac{1}{64}(A+1-3\theta_L+\theta_H)^2$	$\frac{1}{64}(A+1-3\theta_H+\theta_L)^2$
	IL	$\frac{A}{6}(A-1-\theta_L)+\frac{1}{6}(1-\theta_L+\theta_L^2)$	$\frac{1}{36}(A-2+\theta_L)^2$	$\frac{1}{36}(A+1-2\theta_L)^2$	
	LH	equivalent to LH with bundling			