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Stefan Buehler*

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ABSTRACT: This paper analyzes the equilibrium outcomes in a network industry under different vertical market structures. In this industry, an upstream monopolist operates a network used as an input to produce horizontally differentiated final products that are imperfect substitutes. Three potential drawbacks of market structure regulation are analyzed: (i) double marginalization, (ii) underinvestment, and (iii) vertical foreclosure. We explore the conditions under which these effects emerge and discuss when the breakup of an integrated network monopolist is adequate.

Keywords: access pricing, investment, vertical foreclosure.

JEL: D43, L43.

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1 Introduction

Many economists believe that introducing competition is the key to achieving the full benefits of privatization in previously monopolized and regulated network industries, such as telecommunications, electricity or railways.[1] The recent wave of "deregulation" in these industries — i.e. the introduction of competition into statutory monopolies — is consistent with this view. The traditional approach towards introducing downstream competition in network industries has been to break up the integrated dominant firm and prohibit the upstream monopolist to reenter the downstream market. Well-known divestures of this type include the breakup of AT&T in the United States in 1984 and the breakup of British Rail in Great Britain in 1994. In a similar vein, the District Court Judge recently ordered the breakup of Microsoft during the ongoing antitrust litigation in the case United States v. Microsoft. A somewhat less radical approach — often adopted in the 1990's by European countries deregulating their national telecommunications markets — allows the upstream monopolist to remain integrated and attempts to create a level playing field for the downstream competitors by regulating the access prices.[2] Yet another approach was adopted in the recent deregulation of the German electricity industry, where market structure regulations have been removed altogether and access charges are freely determined by the industry.

Industrial organization theory suggests that irrespective of the particular approach adopted, the introduction of imperfect downstream competition in network industries with natural monopoly characteristics upstream is subject to the following potential problems:

- *double marginalization*: the introduction of imperfect downstream competition leads to successive markups which imply higher prices for the final good and lower aggregate welfare;[3]

[1]See Newbery (1997) for a recent survey on the state of the debate.

[2]See Laffont and Tirole (1996) for a survey of the problem of one-way interconnection relevant for the problem considered here.

[3]The classic reference is Spengler (1950); Tirole (1988, Chapter 4) and Perry (1989) provide surveys on market outcomes in vertically related industries.

- *underinvestment*: downstream competition tends to reduce the monopolist's incentive to invest in network quality or cost reductions;[4]
- *vertical foreclosure*: when competing with new entrants the monopolist may have incentives to raise downstream rivals' cost by charging excessive wholesale or access prices.[5]

Somewhat surprisingly, regulators and antitrust authorities have rarely addressed these issues when breaking up the vertically integrated monopoly structure, even though the extensive literature on interconnection is either explicitly or implicitly based on the problem of vertical foreclosure.

This paper takes the potential drawbacks of market structure regulation seriously and studies both pricing and investment behavior of a network monopolist under the most common forms of market structure regulation, namely (i) *vertical integration* without downstream competition (ii) *vertical separation*, where the upstream monopolist is fully separated from the imperfectly competitive downstream market, and (iii) *liberalization*, where the upstream monopolist is allowed to operate in the imperfectly competitive downstream market. We consider network industries producing final products that are imperfect substitutes. More specifically, we will assume that the effect of a price increase on own demand dominates the effects on competitors' demands. As a consequence, our analysis is best applied to industries with highly differentiated final products where downstream competition is imperfect and possibly not very intense. In industries with only weakly differentiated products, the drawbacks of regulating market structure discussed in this paper are also present, but they are typically dominated by the positive effects generated by the introduction of fierce downstream competition.

Our main results are the following. *First*, under reasonable assumptions on demand, retail prices are higher under vertical separation and liberalization than under vertical integration. This follows from the fact that under

[4]See Buehler et al. (2000) for an analysis of the monopolist's incentives to invest in infrastructure quality.

[5]See Klass and Salinger (1995) for a survey on the theory of vertical foreclosure and its antitrust implications. Riordan (1998) and Ordover et al. (1990) provide further references and critical reviews of recent contributions.

separation and liberalization, the network monopolist has an incentive to set its access prices higher than the retail prices under integration, because the industry's (partial) separation reduces the perceived price elasticity of the monopolist's demand. *Second*, since the monopolist's incentives to invest in cost reduction are driven by aggregate demand for the intermediate good, marginal cost is higher under separation and liberalization than under integrated monopoly (under the demand assumptions mentioned above). This result reinforces higher prices under deregulation. *Third*, an exogenously imposed change of the vertical market structure from integration to separation or liberalization turns out to be welfare decreasing. *Fourth*, using a simple example with a linear demand system, we demonstrate that the network monopolist does not necessarily wish to foreclose its downstream rivals under liberalization. In fact, the monopolist's incentive to discriminate against his downstream competitors may even increase the competitiveness of the industry relative to vertical separation, in particular when the number of competitors is high.

Hence, if regulatory and antitrust authorities are in fact aiming at lower retail prices and thus higher social welfare, they may find the breakup of a dominant vertically integrated firm undesirable. Of course, carefully crafted (access) price regulations may help to control the monopolist's market power under vertical separation or liberalization, but it is not evident that containing the monopolist's market power is easier or less costly than under integration. It therefore remains to be explained by models of political economy why it seems to be a standard practice to replace vertically integrated monopolists with regulated retail prices by (partially) separated upstream monopolist with regulated access prices.

This paper deviates from previous work in several respects. *First*, the present analysis covers not only vertical integration and separation, but also liberalization as different types of market structure regulation. Earlier papers by Greenhut and Ohta (1976 and 1978), Perry (1978) and Haring and Kaserman (1978) focus on the comparison of vertical integration and separation and essentially show that vertical integration lowers retail prices in the case of homogenous Cournot competition downstream. *Second*, we study Bertrand competition with horizontally differentiated final goods and fairly general demand functions. Recent studies by Vickers (1995) and Lee and Hamilton (1999) investigate the pros and cons of a regulated monopolist's downstream participation in an industry with Cournot competition downstream. *Third*, we study strategic third-degree price discrimination by the network monopolist in each regulatory regime, thereby allowing for vertical foreclosure. Sibley and Weisman (1998) investigate the incentives of an upstream monopolist to foreclose its competitors in the Cournot market downstream and apply their analysis to the telecommunications industry. Mandy and Sappington (2000) point out that the incentive of a regulated upstream monopolist to disadvantage or "sabotage" downstream rivals using non-price strategies crucially depends on the nature of downstream competition, i.e. Cournot v. Bertrand. *Fourth*, throughout the paper, we abstract from access or retail price regulations, both in the benchmark case of vertical integration and the cases of separation and liberalization, thus isolating the effects generated by market structure regulations. Using our results, we discuss the potential role that price regulations might play in the industry.

The remainder of the paper is organized as follows. Section 2 gives the basic setup of the model. It discusses the main assumptions on demand for the final good and outlines the cost structure of the various firms. Section 3 develops the case of vertical integration as a benchmark. Section 4 compares equilibrium prices and investment under vertical separation and integration. Section 5 analyzes the case of liberalization and compares its equilibrium outcome with vertical integration and separation. Section 6 discusses the welfare implications of changes in vertical market structure. Section 7 provides a simple example with a linear demand system. Section 8 concludes.

2 The Basic Setup

We model the production and selling of a differentiated final product provided over a network as an industry with a vertical structure. Suppose that in order to produce the final good (e.g. electricity or internet services), the seller needs access to an intermediate good produced by a monopolist. For simplicity, assume that to provide one unit of the final product (e.g. one kWh or one internet browser), one unit of the homogenous intermediate good (e.g. one kWh of access or one PC operating system) is required. The differentiated final product is sold on n markets with an individual downward-sloping demand $D_i(\mathbf{p})$, $i = 1, ..., n$, where $\mathbf{p} = (p_1, ..., p_n)$ is the vector of retail prices set on the various markets. Aggregate demand for the intermediate good is thus given by $D(\mathbf{p}) \equiv \sum_{i=1}^{n} D_i(\mathbf{p})$. The variable cost $c(e)$ of providing the intermediate good depends on the level of effort e that is exerted by the network operator to reduce this cost; implementing a nonnegative effort is costly, which is reflected in a convex cost function $\psi(e)$. Finally, suppose that there is a fixed cost F of operating the network.

In the various industry configurations, we model the provision of the final good as a simple two-stage game with the following course of events (see Fig. 1).

- *Stage 1:* The network monopolist chooses both the cost-reducing effort e and an access tariff a_i for each of the downstream firms i.
- *Stage 2:* Observing the access tariffs a_i, each downstream firm i sets the retail price p_i for the provision of the final good, taking the retail prices $p_j, j \neq i$, as given.

Observe that in the case of *vertical integration*, the network operator is also owner of the retail firms $i = 1, ..., n$ and thus faces a simple optimization problem. In the case of *vertical separation*, the network operator and the downstream competitors play a sequential game which can be solved using backward induction. In the case of *liberalization*, where the network operator is vertically integrated with one or more downstream firms but faces downstream competitors, a sequential game between the integrated network operator and its downstream competitors is played. The outcomes of these sequential games clearly depend on the market structure and the intensity of downstream competition, in particular on the degree to which the final products are differentiated and whether the vertically integrated network operator can foreclose its downstream competitors by imposing a "price squeeze", i.e. by raising the competitors' access prices and lowering its own retail price. We will pursue these arguments in more detail in the following sections.

Throughout the paper, we require that in the vicinity of the equilibrium, the following basic assumptions are satisfied:

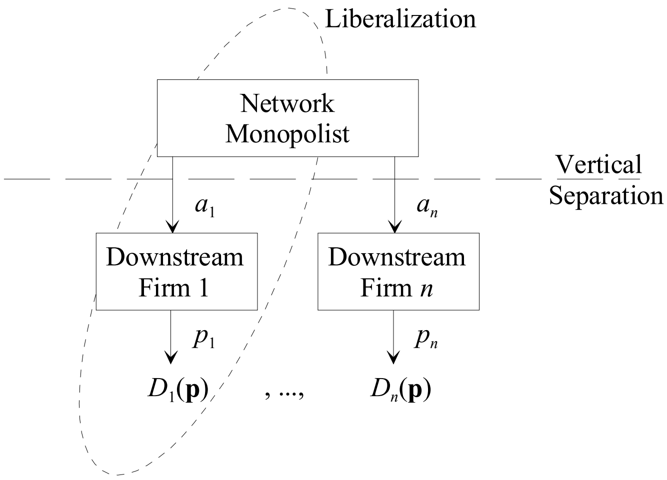

Figure 1: Different types of market structure

[A 1] $\partial D_i(\mathbf{p})/\partial p_i < 0, \partial D_i(\mathbf{p})/\partial p_j \geq 0, i, j = 1, ..., n, i \neq j$; this implies that the final products are substitutes. In addition, we make the standard assumption that demand is not too convex.[6]

[A 2] $\partial D(\mathbf{p})/\partial p_i = \partial D_i(\mathbf{p})/\partial p_i + \sum_{j \neq i} \partial D_j(\mathbf{p})/\partial p_i < 0, i, j = 1, ..., n$; we thus assume that own demand effects dominate effects on competitors' demands; this condition implies that the final products are imperfect substitutes and competition is not very intense, i.e. our analysis is best applied to vertically related industries producing highly differentiated final products.[7]

[A 3] This assumption imposes two important conditions for the case of (partial) vertical separation. They essentially require that the final products remain substitutes from the monopolist's point of view when the industry is vertically separated.

[6] More precisely, "not too convex" means that the condition $\rho_{ii} \geq 1 - \varepsilon_{ii}$ is satisfied, where ε_{ii} is the own price elasticity of demand in market i, and ρ_{ii} is the elasticity of the price elasticity. See the proof of Lemma 2 in the Appendix for further details

[7] Note that if final products are close substitutes, the advantages of introducing downstream competition usually dominate the drawbacks of the industry's (partial) vertical separation.

(i) $\sum_j (\partial D_i(\mathbf{p})/\partial p_j)(\partial p_j/\partial a_i) < 0, i, j = 1, ..., n$; this implies that an increase of the access price for market i leads to a decrease of demand for good i (accounting for all cross-price effects).

(ii) $\sum_{k,j\neq i} (\partial D_j(\mathbf{p})/\partial p_k)(\partial p_k/\partial a_i) > 0, i, j, k = 1, ..., n$; this conditions assures that an increase of the access price for market i leads to an increase of demand for good j (accounting for all cross-price effects).

[A 4] $c'(e) < 0, c''(e) > 0$ (positive, decreasing reduction of cost with higher effort).

[A 5] $\psi'(e) > 0, \psi''(e) > 0$ (positive, increasing cost of providing effort).

We now investigate the equilibrium outcomes under the various types of market structure regulation.

3 Vertical Integration

Suppose that there is a vertically integrated monopolist whose divisions $i = 1, ..., n$ serve all markets with demand $D_i(\mathbf{p})$ for the final good. It is well known that a monopolist serving different demands is at least as well-off under third-degree price discrimination as under uniform pricing, since "at worst" he can always charge a uniform price (Tirole 1988, 137). Only if price discrimination is impossible — e.g. due to regulatory prescriptions requiring uniform retail prices (as is often the case for universal service) or arbitrage possibilities between the different markets — will an integrated monopolist set a uniform linear tariff.[8] Let us therefore assume that the integrated monopolist sets a market price p_i^I for each division $i = 1, ..., n$.[9] Its profit

[8] Throughout the paper we will assume that the monopolist is not able to further discriminate costumers in market i, i.e. it must set a linear retail price.

[9] It is straightforward to show that if the integrated monopolist is restricted to set a uniform retail price $p_i = \bar{p}$ for all markets i, the profit maximizing retail price $\bar{p}^I$ is given by the standard Lerner index, and the optimum effort satisfies $-c'(e_{nd}^I)D(\bar{p}^I) = \psi'(e_{nd}^I)$, where the subscript nd denotes 'no price discrimination'.

maximizing problem is then given by

$$\max_{\mathbf{p},e} \quad \Pi^I(\mathbf{p},e) = \sum_{i=1}^{n} [p_i - c(e)]\, D_i(\mathbf{p}) - \psi(e) - F.$$

The first-order conditions for equilibrium prices p_i^I and equilibrium effort e^I are then given by

$$\frac{p_i^I - c(e^I)}{p_i^I} = \frac{1}{\varepsilon_{ii}(\mathbf{p}^I)} - \frac{\sum_{j\neq i}[p_j^I - c(e^I)]D_j(\mathbf{p}^I)\varepsilon_{ji}(\mathbf{p}^I)}{R_i(\mathbf{p}^I)\varepsilon_{ii}(\mathbf{p}^I)}, \qquad i,j = 1,...,n, \tag{1}$$

and

$$-c'(e^I)D(\mathbf{p}^I) = \psi'(e^I), \tag{2}$$

with

$$\varepsilon_{ii} \equiv -\frac{(\partial D_i/\partial p_i)p_i}{D_i} > 0, \qquad \varepsilon_{ji} \equiv -\frac{(\partial D_j/\partial p_i)p_i}{D_j} < 0$$

denoting the own-price-elasticity of demand in division i, and the cross-price elasticity of demand in division j with respect to the price in division i, respectively.[10] $R_i \equiv p_i D_i$ is the revenue of division i, and $\mathbf{p}^I$ is the vector of equilibrium retail prices. To be sure, (1) is nothing else than the familiar Lerner index for a multiproduct monopoly with separable costs and dependent demands (see e.g. Tirole 1988, 70), where both demands and elasticities are evaluated at the equilibrium retail prices $\mathbf{p}^I$. It is important to note that a vertically integrated monopolist takes into account that the final products offered by its different divisions are substitutes ($\varepsilon_{ji} < 0$) and thus sets higher markups than each of its division would set individually. A preliminary comparative statics result now follows immediately.

Lemma 1 *Suppose the industry is vertically integrated and the monopolist is discriminating its retail prices. Then the cost-reducing effort is decreasing in the retail prices, i.e.* $de^I/dp_i^I < 0, i = 1,...,n$.

Proof. See Appendix. ■

[10] Observe that these elasticities have the conventional signs for imperfect substitutes given in Tirole (1988, 70).

The intuition for this result is straightforward. Aggregate demand for the intermediate good is decreasing in each retail price p_i^I. The cost reductions generated by an effort e^I thus apply to a smaller overall demand the higher each retail price is. Consequently, the upstream monopolist's incentives to exert effort are reduced when retail prices goes up. We shall see that versions of this result emerge under the various market configurations considered in this paper. Let us now turn to the case of vertical separation.

4 Vertical Separation

Under vertical separation, there is an upstream network monopolist and a set of downstream firms $i = 1, ..., n$ forming an oligopoly fully separated from network operation. Given the access charge a_i chosen by the upstream monopolist and the vector of retail prices $\mathbf{p}_{-i}^S = (p_1^S, ..., p_{i-1}^S, p_{i+1}^S, ..., p_n^S)$ set by all other vertically separated downstream firms, firm i chooses its retail price so as to

$$\max_{p_i} \quad \Pi_i(\mathbf{p}, a_i) = [p_i - a_i]\, D_i\left(p_i, \mathbf{p}_{-i}^S\right).$$

The equilibrium retail price p_i^S is thus given by

$$\frac{p_i^S - a_i^S}{p_i^S} = -\frac{D_i(\mathbf{p}^S)}{\partial D_i(\mathbf{p}^S)/\partial p_i \cdot p_i^S} \equiv \frac{1}{\varepsilon_{ii}(\mathbf{p}^S)}, \qquad i = 1, ..., n, \tag{3}$$

where ε_{ii} is again the own-price-elasticity of demand for firm i's services, but now evaluated at $\mathbf{p}^S$ instead of $\mathbf{p}^I$. Given the vector of access prices $\mathbf{a} = (a_1, ..., a_n)$ from the game's first stage, the equilibrium retail prices $p_i^S(\mathbf{a})$ in the second stage are functions of these access prices and characterized by the best-response functions

$$p_i^b(a_i, \mathbf{p}_{-i}^S) = p_i^S, \qquad i = 1, ..., n.$$

If we denote the vector of equilibrium retail prices by $\mathbf{p}^S(\mathbf{a}) = (p_1^S(\mathbf{a}), ..., p_n^S(\mathbf{a}))$, the upstream firm's problem can be written as

$$\max_{\mathbf{a},e} \quad \Pi^U(\mathbf{a}, e) = \sum_{i=1}^{n} [a_i - c(e)]\, D_i(\mathbf{p}^S(\mathbf{a})) - \psi(e) - F,$$

with $\sum_{i=1}^{n} D_i(\mathbf{p}^S(\mathbf{a})) \equiv D(\mathbf{p}^S(\mathbf{a}))$ denoting aggregate demand for the intermediate product. The first-order condition for equilibrium access prices is then given by

$$\frac{a_i^S - c(e^S)}{a_i^S} = -\underbrace{\frac{D_i(\mathbf{p}^S)}{a_i^S \sum_j \frac{\partial D_i(\mathbf{p}^S)}{\partial p_j} \frac{\partial p_j(\mathbf{a}^S)}{\partial a_i}}}_{(+)} - \underbrace{\frac{\sum_{j \neq i} \left[a_j^S - c(e^S)\right] D_j \sum_k \frac{\partial D_j(\mathbf{p}^S)}{\partial p_k} \frac{\partial p_k(\mathbf{a}^S)}{\partial a_i}}{a_i^S \sum_j \frac{\partial D_i(\mathbf{p}^S)}{\partial p_j} \frac{\partial p_j(\mathbf{a}^S)}{\partial a_i}}}_{(+)}, \tag{4}$$

for $i, j, k = 1, ..., n$, where the indicated signs follow from assumption [A 3]. Let us simplify this result using the above definitions of ε_{ii} and ε_{ji}, as well as the elasticities of retail prices with respect to access charge a_i given by

$$m_{ji} \equiv \frac{(\partial p_j / \partial a_i)\, a_i}{p_j} \quad \text{and} \quad m_{ki} \equiv \frac{(\partial p_k / \partial a_i)\, a_i}{p_k}.$$

In addition, let $\tilde{R}_i \equiv a_i D_i$ denote the monopolist's revenue from product i under vertical separation. First-order condition (4) then simplifies to

$$\frac{a_i^S - c\left(e^S\right)}{a_i^S} = E_1(\mathbf{p}^S, \mathbf{a}^S) + E_2(\mathbf{p}^S, \mathbf{a}^S), \tag{5}$$

with

$$E_1(\mathbf{p}^S, \mathbf{a}^S) = \frac{1}{\sum_j \varepsilon_{ij}(\mathbf{p}^S) m_{ji}(\mathbf{a}^S)}$$

denoting the *inverse price elasticity of demand* for a vertically separated upstream monopolist *serving market i only*, and

$$E_2(\mathbf{p}^S, \mathbf{a}^S) = -\frac{\sum_{j \neq i} [a_j^S - c(e^S)] D_j(\mathbf{p}^S) \sum_k \varepsilon_{jk}(\mathbf{p}^S) m_{ki}(\mathbf{a}^S)}{\tilde{R}_i(\mathbf{p}^S) \sum_j \varepsilon_{ij}(\mathbf{p}^S) m_{ji}(\mathbf{a}^S)}$$

denoting the *pricing externalities* to markets $j \neq i$, which are internalized by a monopolist serving all n markets. While the first-order condition for equilibrium effort

$$-c'(e^S) D(\mathbf{p}^S(\mathbf{a}^S)) = \psi'(e^S) \tag{6}$$

has the same form as under integration, equilibrium access prices $\mathbf{a}^S = (a_1^S, ..., a_n^S)$ are now given by a generalized form of the Lerner index for a multimarket monopoly with additively separable costs and dependent demands. First-order condition (5) indicates that since the monopolist is now unable to set retail prices and thus unable to affect demand directly, profit maximization dictates that the monopolist must account for the fact that his price variations in market i are first translated into retail price variations by m_{ji} before they affect demand over ε_{ij}. More specifically, equation (5) shows that the industry's vertical separation changes the pricing incentives of the network monopolist relative to the case of integration (see (1)) in two related ways:

(i) It changes the inverse price elasticity of demand for a monopolist serving market 1 only from $1/\varepsilon_{ii}(\mathbf{p}^I)$ to $E_1(\mathbf{p}^S, \mathbf{a}^S)$. Instead of directly affecting demand via $\varepsilon_{ii}(\mathbf{p}^I)$, an increase of the monopolist's price a_i first affects the pricing decisions of the downstream firms via the elasticities of retail prices m_{ii} and m_{ji}. Only through the associated changes of retail prices does an increase of a_i affect the demand for the final good i. We will show in Lemma 2 that firm i will generally not find it optimal to fully pass on the increase of a_i to its costumers, i.e. $m_{ii} \leq 1$.[11] At the same time, firm i's competitors producing differentiated products welcome the increase of a_i since it allows them to adjust their prices $p_j^S, j \neq i$, upwards. Lemma 2 will show that the elasticities $m_{ji}, j \neq i$, are in fact positive, thereby mitigating the substitution effects generated by the price increase for firm i. As a consequence, from the point of view of a vertically separated upstream monopolist serving market i only, the perceived price elasticity of demand is smaller than under integration, and the corresponding monopoly price will therefore be higher.[12]

(ii) It changes the pricing externalities between markets that a monopolist serving all n markets is internalizing (compare the second term on the right-hand side of (1) with $E_2(\mathbf{p}^S, \mathbf{a}^S)$). As under vertical integration,

[11] Remember that m_{ii} is an elasticity, i.e. it measures the change of p_i in response to a marginal increase of a_i.

[12] Rey and Stiglitz (1995) point out a similar effect when oligopolistic upstream producers implement exclusive territories downstream in order to reduce interbrand competition.

the upstream monopolist accounts for the externalities between the markets i and $j, j \neq i$, when setting its prices. But just as within each market, variations of the access prices now only indirectly affect the demand for the final good. An increase of the access price a_i now generates demand effects — if any — in markets $j \neq i$ only after translation via m_{ji} and m_{ki} into changes of retail prices and then into demand by ε_{ji} and ε_{jk}. Whether vertical separation increases or decreases the pricing externalities between markets appears to be ambiguous in general.

It is well known that in an imperfectly competitive industry, vertical separation introduces a double marginalization provided the prices for the intermediate and the final good are linear. As a consequence, each equilibrium retail price $p_i^S(a_i^S)$ features a *double markup* which increases the retail price under vertical separation relative to the price $p_i^I(c(e))$ under vertical integration.[13] Note, however, that for a given level of marginal cost, there is also a countervailing effect stemming from the introduction of *downstream competition*: The separated downstream firms now compete with each other and are not able to account for the pricing externalities between the different markets, i.e. they set lower retail prices than an integrated monopoly ($\varepsilon_{ji} < 0$) would set.

To compare the market outcomes under vertical integration and separation, we need to study the conditions for which equilibrium retail prices are higher under separation than integration, i.e. $p_i^S(a_i^S(e^S)) > p_i^I(c(e^I)), \forall i$. To simplify, we proceed in two steps. First, we compare the equilibrium retail prices $p_i^S(a_i^S)$ and $p_i^I(c)$ under integration and separation, holding the effort level constant. Second, we study the incentives to exert cost reducing effort in each market configuration.

4.1 Equilibrium Retail Prices for Given Effort

To begin with, suppose that the effort level is fixed at $e \equiv \bar{e}$. A sufficient condition for the retail prices being higher under separation than integration (i.e.

[13] Of course, this double markup may be very small if final goods are close substitutes and downstream competition is thus intense.

$p_i^S(a^S(\bar{e})) > p_i^I(c(\bar{e})))$ is that the access prices $a_i^S(\bar{e})$ under separation are at least as high as the retail prices $p_i^I(c(\bar{e}))$ under integration. This follows from the first-order condition for equilibrium retail pricing under separation, since it implies that $\varepsilon_{ii} > 1, \forall i$. This sufficient condition is recorded as observation 1.

Observation 1 *For the retail prices to be higher under separation than under integration, it is sufficient that the access prices under separation are at least as high as the retail prices under integration, i.e.*

$$a_i^S(\bar{e}) \geq p_i^I(c(\bar{e})) \Rightarrow p_i^S(a^S(\bar{e})) > p_i^I(c(\bar{e})), \forall i.$$

We shall now show that under reasonable assumption on demand, the access charges under vertical separation are in fact at least as high as the retail prices under vertical integration.[14] In order to do so, the following Lemma is helpful.

Lemma 2 *Suppose that there is a unique interior equilibrium in retail prices characterized by the vector* $\mathbf{p}^S$. *Then*

$$0 \leq m_{ji} < m_{ii} \leq 1, \qquad i,j = 1,...,n, i \neq j.$$

Proof. See Appendix. ■

Lemma 2 confirms our initial intuition that in equilibrium, downstream firms only partially pass on changes of access prices to their costumers. Using (1) and (5) and applying Observation 1 as well as Lemma 2, we can now establish our first main result.

Proposition 1 *Suppose that vertical separation does not reduce the pricing externalities between market* i *and* $j, j \neq i$. *In addition, suppose one of the following conditions is satisfied:*
(i) ε_{ii} *is nonincreasing in* $\mathbf{p}$;
(ii) ε_{ii} *is nondecreasing in* $\mathbf{p}$ *and the products are close substitutes.*

[14] Observe that for general demand functions, a direct comparison of $p_i^S(a^S(\bar{e}))$ and $p_i^I(c(\bar{e}))$ using (1) and (3) is impossible.

Then for any given effort level $\bar{e}$, retail prices are higher under vertical separation than under integration, i.e. $p_i^S(a^S(\bar{e})) > p_i^I(c(\bar{e})), \forall i$.

Proof. See Appendix. ■

The intuition of Proposition 1 closely follows the above description of first-order condition (5). Vertical separation eliminates the direct link between the pricing of the upstream monopolist and the demand for the final good and introduces an indirect transmission mechanism. By imposing that vertical separation does not reduce the pricing externalities between markets, i.e. $E_2(\mathbf{p}^S, \mathbf{a}^S)$ is not smaller than the second term in (1),[15] it is sufficient to consider the effects of vertical separation on the perceived price elasticity of demand in each market. Since $\varepsilon_{ij} < 0$ and $m_{ji} \geq 0, \forall j \neq i$, $E_1(\mathbf{p}^S, \mathbf{a}^S)$ is larger than $1/\varepsilon_{ii}(\mathbf{p}^I)$, and hence the access price under separation must be larger than the retail price under integration for given marginal cost. Of course, the level of marginal cost is not exogenous but depends on the endogenous choice of effort. We shall study this choice of effort in the next section.

4.2 Choice of Effort

Let us now analyze the incentives to invest in cost reductions. Consider the first-order conditions (2) and (6) for equilibrium choice of effort. Observe that in both market configurations, the equilibrium effort e^* chosen by the upstream monopolist satisfies a similar condition of the form

$$-c'(e^*)D(\mathbf{p}^*) = \psi'(e^*). \tag{7}$$

[15] This condition is sufficient (but not necessary) to assure that the *lower perceived price elasticity of demand* in market i unequivocally increasing the retail price p_i is not dominated by potentially countervailing effects from reduced *pricing externalities* between markets. Our analysis of a simple example will illustrate that this condition is less severe than it might appear at first sight, since for several demand systems, such as the linear, the CES and the Logit, the cross-price elasticities of downstream prices $m_{ji}, m_{ki}, j, k \neq i$ will turn out to be zero, and the own-price elasticity m_{ii} will be equal to one (see section 7).

If the equilibrium retail prices were the same both under integration and separation, i.e. $\mathbf{p}^* = \mathbf{p}^I = \mathbf{p}^S$, the equilibrium e^* effort would have to be the same in both market configurations. However, since for a given level of effort the equilibrium retail prices are higher under separation (see Proposition 1) and $D(\mathbf{p})$ is decreasing in $\mathbf{p}$, the equilibrium effort e^* must be smaller under separation than under integration. As a consequence, the marginal cost of the upstream monopolist $c(e^S)$ is higher under separation than under integration $c(e^I)$. The next Proposition summarizes our second main result.

Proposition 2 *Suppose the assumptions of Proposition* 1 *hold.*
Then the network's marginal cost is lower under vertical integration than under separation, i.e. $c(e^I) < c(e^S)$.

Here, a similar intuition applies as for Lemma 1 for vertical integration. Given the assumptions of Proposition 1, retail prices are higher under separation than under integration. As a consequence, aggregate demand for the intermediate good is smaller under separation, and hence the incentive to invest in cost reductions is also smaller. Observe that this result reinforces higher retail prices under vertical separation, since the markup of the access price a_i is now based on higher marginal cost.

5 Liberalization

In the case of liberalization the upstream monopolist is also operating in the downstream market. To simplify, assume that the upstream monopolist operates only one firm downstream, namely firm 1 (see Fig. 1). Of course, the pricing rule of the competing downstream firms remains unaltered, but now demand is evaluated at a different set of retail prices $\mathbf{p}^L = (p_1^L, ..., p_n^L)$. The equilibrium retail prices p_i^L of the competing downstream firms thus satisfy the following first-order condition

$$\frac{p_i^L - a_i^L}{p_i^L} = -\frac{D^i\left(\mathbf{p}^L\right)}{\partial D/\partial p_i \cdot p_i^L} \equiv \frac{1}{\varepsilon_{ii}(\mathbf{p}^L)}, \qquad i = 2, ..., n, \tag{8}$$

with $\varepsilon_{ii}(\mathbf{p}^L)$ denoting the own-price-elasticity of demand for firm i's services. The network operator's problem is given by

$$\max_{p_1,\hat{\mathbf{a}},e} \quad \Pi^U(p^1,\hat{\mathbf{a}},e) = [p_1 - c(e)]\, D_1(p_1,\mathbf{p}^L_{-1}(\hat{\mathbf{a}})) \\ + \sum_{i\neq 1} [a_i - c\,(e)]\, D_i(p_1,\mathbf{p}^L_{-1}(\hat{\mathbf{a}})) - \psi\,(e) - F,$$

where $\mathbf{p}^L_{-1}$ is the vector of downstream competitors' retail prices and $\hat{\mathbf{a}} = (a_2, ..., a_n)$ denotes the vector of access prices under liberalization.[16] The first-order condition for the equilibrium retail price in market 1 is then given by

$$\frac{p_1^L - c(e^L)}{p_1^L} = \frac{1}{\varepsilon_{11}(\mathbf{p}^L)} - \frac{\sum_{j\neq 1}[a_j^L - c(e^L)]D_j(\mathbf{p}^L)\varepsilon_{j1}(\mathbf{p}^L)}{R_1(\mathbf{p}^L)\varepsilon_{11}(\mathbf{p}^L)}. \tag{9}$$

Equilibrium access prices satisfy the first-order condition

$$\frac{a_i^L - c\left(e^L\right)}{a_i^L} = E_1(\mathbf{p}^L,\mathbf{a}^L) + \hat{E}_2(\mathbf{p}^L,\mathbf{a}^L) + E_3(\mathbf{p}^L,\mathbf{a}^L) \tag{10}$$

with $i = 2, ..., n, j, k = 1, ..., n$, and

$$E_1(\mathbf{p}^L,\mathbf{a}^L) = \frac{1}{\sum_j \varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)}$$

denoting the *inverse price elasticity of demand* for a monopolist serving market i only,

$$\hat{E}_2(\mathbf{p}^L,\mathbf{a}^L) = -\frac{\sum_{j\neq i, j\neq 1}[a_j^L - c(e^L)]D_j(\mathbf{p}^L)\sum_{k\neq 1}\varepsilon_{jk}(\mathbf{p}^L)m_{ki}(\mathbf{a}^L)}{\tilde{R}_i(\mathbf{p}^L)\sum_{j\neq 1}\varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)}$$

denoting the *pricing externalities* to markets $j \neq i, 1$, and

$$E_3(\mathbf{p}^L,\mathbf{a}^L) = -\frac{\left[p_1^L - c(e^L)\right] D_1(\mathbf{p}^L)\sum_{k\neq 1}\varepsilon_{1k}(\mathbf{p}^L)m_{ki}(\mathbf{a}^L)}{\tilde{R}_i(\mathbf{p}^L)\sum_{j\neq 1}\varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)},$$

[16]Note that thanks to vertical integration, downstream firm 1 now has a first-mover advantage since its price p_1^L is set in the first stage, whereas the downstream competitors set their retail prices $p_i^L, i \neq 1$, in the second stage.

the *pricing externalities* to market 1. Equilibrium effort is given by the standard rule

$$-c'(e^L)D(\mathbf{p}^L) = \psi'(e^L). \tag{11}$$

Note that for vertical separation, two first-order conditions are needed to characterize the upstream monopolist's behavior, whereas three first-order conditions are needed for liberalization. Consider the integrated downstream firm's retail price. Equation (9) indicates that the retail price in market 1 is coordinated with the access prices set in all other markets $j \neq 1$ and therefore internalizes the externalities between markets. The access prices, in turn, are set according to (10) which is very similar to (5), in particular with respect to $E_1(\cdot)$, i.e. the inverse price elasticity of demand in market i. The difference between these two conditions thus mainly concerns the pricing externalities between markets: $E_3(\mathbf{p}^L, \mathbf{a}^L)$ on the right-hand side of (10) accounts for the fact that under liberalization, the monopolist can set the retail price rather than the access price in market 1. Finally, (11) indicates that the monopolist's effort is set according to the same rule as under vertical integration.[17]

To compare this market outcome with vertical integration, we proceed just as for vertical separation. First, we study sufficient conditions for (i) each access price a_i^L being higher than the corresponding retail price p_i^I under integration, and (ii) p_1^L being higher than p_1^I. Second, we study the incentive to exert a cost reducing effort. We then discuss the comparison of liberalization with vertical separation.

5.1 Liberalization v. Integration

To begin with, consider equilibrium retail prices. Using (1), (10) and Proposition 1, it is straightforward to derive our next result.

Proposition 3 *Suppose that liberalization does not reduce the pricing externalities between market i and $j, j \neq i$. In addition, suppose ε_{ii} is nonincreasing in $\mathbf{p}$.*

[17] Of course, all of these terms also need to be evaluated at different access and retail prices compared to vertical separation and integration.

Then for any given effort level $\bar{e}$, retail prices are higher under liberalization than under integration, i.e. $p_i^L > p_i^I, \forall i$.

Proof. See Appendix. ■

Comparison of Proposition 3 and Proposition 1 demonstrates that in order to have retail prices at least as high under liberalization as under vertical integration, the own-price elasticity of demand $\varepsilon_{ii}(\cdot)$ must satisfy a more restrictive condition under liberalization than under separation. In the case of separation, both nonincreasing and nondecreasing elasticities were allowed, whereas in case of liberalization only nonincreasing elasticities are allowed. This result reflects the fact that under liberalization, the upstream monopolist has an incentive to set a relatively low retail price in market 1 in order to divert demand from his downstream competitors to generate higher demand for the good that is produced with lower marginal cost (due to the absence of double marginalization). This incentive is absent under vertical separation, where the monopolist sets its access prices exclusively according to the price elasticities of demand, accounting for the pricing externalities between markets. We shall discuss this issue in the next section in more detail.

Consider now the incentive to exert effort under liberalization. Since the relevant first-order condition (11) has the same form as the first-order conditions under integration and separation, an analogous argument as above can be applied. Given that the assumptions of Proposition 3 holds, equilibrium retail prices are higher under liberalization than under integration for any given effort level $\bar{e}$. Hence, the equilibrium effort under liberalization must be smaller than under integration. Proposition 4 summarizes this result.

Proposition 4 *Suppose the assumptions of Proposition 3 hold.*
Then the network's marginal cost is lower under vertical integration than under liberalization, i.e. $c(e^I) < c(e^L)$.

We now proceed to a more detailed comparison of liberalization with vertical separation.

5.2 Liberalization v. Separation

We have pointed out above that under liberalization, the upstream monopolist has an incentive to divert demand from his downstream competitors to market 1 to generate higher demand for the good that is produced with lower marginal cost. This can be established by setting a relatively low retail price in market 1, or by setting relatively high access prices for all other markets. Evidently, both strategies place the separated downstream rivals at a competitive disadvantage. When studying a particular market outcome, however, the broad notion of "placing competitors at a disadvantage" is not sufficiently precise. One needs to distinguish between discrimination that is truly anticompetitive and discrimination that harms rivals precisely because it is competitive (see Klass and Salinger 1995, 677). The bulk of the recent literature on *vertical foreclosure*[18] therefore argues, starting from the notion of raising rivals' cost (Salop and Scheffman 1983), that an integrated firm acts anticompetitively only when increasing rivals' cost, but not when cutting the cost of its own downstream subsidiaries.

When comparing liberalization and separation, we follow this distinction and say that there is vertical foreclosure if and only if the access charge in market i is higher under liberalization than under separation, i.e. $a_i^L > a_i^S, i = 2, ..., n$. Of course, the level of the retail price p_1^L remains important since it is needed to evaluate demand and the relevant elasticities. Inspection of the first-order conditions (10) and (5) indicates that for small changes of the relevant elasticities with changes in retail prices, the difference in the level of access prices under liberalization and separation is largely determined by the pricing externalities. Unfortunately, a direct comparison of the role that these externalities play in the two market configurations is very complicated with general demand functions.[19] Therefore, we confine ourselves to show that the monopolist's pricing behavior under liberalization will generally be different from that under separation. We will study the different market equilibria using specific functional forms for the demand system in section 7.

[18] See e.g. Riordan (1998), Sibley and Weisman (1998) and Ordover et al. (1990).

[19] Or, as Shapiro (1989, 348) puts it (without considering vertical issues): "With n firms, it is difficult to say much more about differentiated-product pricing equilibria without further assumptions about the demand system".

To see that the monopolist's pricing behavior under liberalization must be different from that under separation, suppose the contrary, i.e. assume that for a given effort level $\bar{e}$, the integrated monopolist sets all access prices $\mathbf{a}^L = \mathbf{a}^S$, as well as $p_1^L = p_1^S$ in market 1. The first-order conditions (8) and (3) then imply that $\mathbf{p}^L = \mathbf{p}^S$. Now consider the first-order conditions (10) and (5) for equilibrium access pricing. Since the elasticities ε_{ij} and m_{ji} are evaluated at the same prices both under liberalization and separation, the inverse of the price elasticities in market i are equal, i.e. $E_1(\mathbf{p}^L, \mathbf{a}^L)\big|_{\mathbf{p}^L=\mathbf{p}^S, \mathbf{a}^L=\mathbf{a}^S} = E_1(\mathbf{p}^S, \mathbf{a}^S)$. Now consider the other terms. Since $p_1^S > a_1^S$, it follows that

$$\hat{E}_2(\mathbf{p}^L, \mathbf{a}^L)\Big|_{\mathbf{p}^L=\mathbf{p}^S, \mathbf{a}^L=\mathbf{a}^S} + E_3(\mathbf{p}^L, \mathbf{a}^L)\big|_{\mathbf{p}^L=\mathbf{p}^S, \mathbf{a}^L=\mathbf{a}^S} > E_2(\mathbf{p}^S, \mathbf{a}^S).$$

This in turn implies that $a_i^L > a_i^S$, hence a contradiction. Our next observation summarizes this result.

Observation 2 *The monopolist's pricing behavior under liberalization is generally different from that under vertical separation.*

Naturally, by itself observation 2 does not predict whether vertical foreclosure does emerge in equilibrium. We will study this issue in more detail in section 7.2.

6 Welfare Effects of Market Structure Changes

So far, we have determined the levels of retail prices and effort under integration, separation and liberalization. Let us now study how aggregate welfare is affected by a change in the industry's vertical structure. To compare aggregate welfare in the different regimes, we apply a useful result provided by Varian (1985). Let us follow the common assumption that aggregate welfare W is measured by the sum of producers' and consumers' surplus and that the demand functions $D_i, i = 1, ..., n$, for the final products are generated by quasi-linear utility. Consider an initial set of prices $\mathbf{p}^0 = (p_1^0, ..., p_n^0)$ and another set of prices $\mathbf{p}^1 = (p_1^1, ..., p_n^1)$. Let $C^0 = c(e(\mathbf{p}^0))\mathbf{D}(\mathbf{p}^0) + F$ and $C^1 = c(e(\mathbf{p}^1))\mathbf{D}(\mathbf{p}^1) + F$ denote the total cost of production associated with $\mathbf{p}^0$ and $\mathbf{p}^1$. Finally, let $\Delta\mathbf{D} = \mathbf{D}(\mathbf{p}^1) - \mathbf{D}(\mathbf{p}^0)$ denote the vector of changes in demand and let $\Delta C = C^1 - C^0$ denote the change in the total cost of production. The change in welfare, ΔW, associated with the transition from $\mathbf{p}^0$ and $\mathbf{p}^1$ then satisfies the following condition[20]

$$\mathbf{p}^0 \Delta \mathbf{D} - \Delta C \geq \Delta W. \tag{12}$$

Using the cost and demand structure outlined above, (12) can also be written as

$$\left[p_i^0 - c(e(\mathbf{p}^0))\right] \sum_i \Delta D_i - \left[c(e(\mathbf{p}^1)) - c(e(\mathbf{p}^0))\right] \sum_i D_i(\mathbf{p}^1) \geq \Delta W. \tag{13}$$

We can use (13) to evaluate the welfare changes implied by changes of vertical market structure. Consider the welfare change associated with the price change from $\mathbf{p}^0$ under integration to $\mathbf{p}^1$ under separation. According to Proposition 2, marginal cost increases with a change from integration to separation, i.e. the second term on the left hand side is negative. Equation (13) therefore indicates that an *increase in output* is a necessary condition for welfare to increase ($\Delta W > 0$). This condition cannot be satisfied, however, since retail prices increase according to Proposition 1, and output must thus decrease (see assumption [A 2]). As a result, a change from vertical integration to separation is welfare decreasing under the assumptions mentioned above. A similar argument holds for the comparison of vertical integration and liberalization, using Proposition 3 and 4 instead of Proposition 1 and 2. Therefore, a change from vertical integration to liberalization is also welfare decreasing under the assumptions mentioned above. The welfare consequences of a change from vertical separation to liberalization, however, are ambiguous for general demand functions.

[20]Proof: See Varian (1985, 872).

7 A Simple Example with Linear Demand

To explore the pricing behavior under the various market configurations in more detail, let us study an example with a linear demand system given by

$$D_i(\mathbf{p}) = \alpha_i - \beta_i p_i + \gamma \sum_{j \neq i} p_j, \qquad i, j = 1, ..., n,$$

with $\alpha_i, \beta_i > 0$ as demand parameters and $\gamma > 0$ denoting the substitutability between products.[21,22] Let us assume for the moment that these parameters satisfy assumptions [A 1] to [A 3].[23] To simplify, assume that $\alpha_i \equiv \alpha$ and $\beta_i \equiv \beta, \forall i$, i.e. we consider symmetric demand functions only. Using this demand system, explicit solutions for both access and retail prices can be obtained. We start by comparing the market outcomes under vertical integration and separation. We then move on to a comparison of vertical separation with liberalization which will allow us to check whether vertical foreclosure as defined above emerges in equilibrium. Note that we abstract from effort considerations during these comparisons.

7.1 Integration v. Separation

Consider the integrated monopolist. Substituting the specific demand functions into the relevant first-order condition (1), imposing symmetry and solving for the retail price yields

$$p_i^I = \frac{\alpha + (\beta - \gamma (n-1)) c}{2 (\beta - \gamma (n-1))}. \tag{14}$$

Compare this with the situation under vertical separation. Here, substituting the specific functional forms into the first-order conditions (3) and (5) and

[21] With $\gamma = 0$ each downstream firm (division, respectively) is a monopolist.

[22] See Häckner (2000) for a recent analysis of the Bertrand equilibrium with differentiated goods assuming such a demand system. However, he does not consider vertical issues.

[23] We will need to make sure that these assumptions are satisfied when simulating the market outcomes with specific parameter values.

solving for the respective prices yields a best-response function

$$p_i^b(a_i) = \frac{\alpha + \beta a_i}{2\beta - \gamma(n-1)}$$

for the retail price, and another one for the access price which we define as $a_i^b(p_i)$.[24] Tedious calculations then show that in equilibrium access and retail prices are given by

$$a_i^S = \frac{\alpha + (\beta - \gamma\,(n-1))\,c}{2\,(\beta - \gamma(n-1))} \tag{15}$$

and

$$p_i^S = \frac{1}{2}\frac{3\alpha\beta + c\beta^2 - \gamma(2\alpha + c\beta)(n-1)}{2\beta^2 + \gamma^2 + \gamma(\gamma n - 3\beta)(n-1)} \tag{16}$$

Inspection of these explicit solutions reveals that the access price under separation is just equal to the retail price under integration, i.e. $a_i^S = p_i^I$. This result emerges because for the simple symmetric demand system considered here, all cross-price elasticities of the downstream prices are zero ($m_{ji}, m_{ki} = 0, \forall j,k \neq i$), and the own-price elasticity turns out to be one ($m_{ii} = 1$). Hence, retail prices are higher under separation which implies that the monopolist's profit is larger under integration for a given level of effort.[25] A network monopolist will thus not voluntarily separate upstream from downstream operations.

Fig. 2 illustrates the equilibrium prices under integration and separation as a function of n, the number of downstream firms, using the following specific numerical values for the demand parameters

$$\alpha = 10; \beta = 1; \gamma = 0.1; c = 0.$$

Note that these parameter values satisfy assumptions [A 1] to [A 3] for $n < 10$.[26]

[24] This best-response function is a complicated polynomial of the demand parameters that we are not detailing here.

[25] Observe that $p_i^I D(\mathbf{p}^I) > a_i^S D(\mathbf{p}^S)$.

[26] To see this, consider each assumption in turn:

[A 1] $\partial D_i(\mathbf{p})/\partial p_i = -1 < 0, \partial D_i(\mathbf{p})/\partial p_j = 0.1 > 0, \partial^2 D_i(\mathbf{p})/\partial p_i^2 = 0.$

[A 2] $\partial D(\mathbf{p})/\partial p_i = -1 + n \cdot (0.1) < 0$ for $n < 10$.

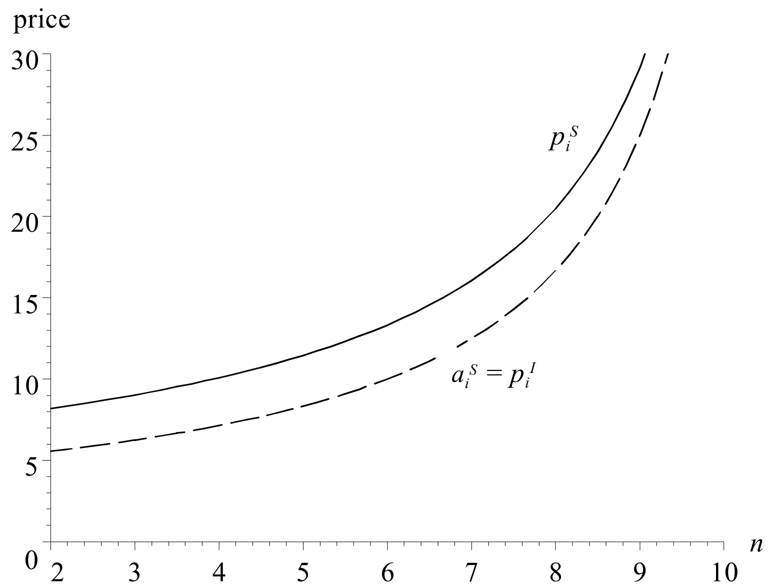

Figure 2: Integration v. Separation ($\alpha = 10; \beta = 1; \gamma = 0.1; c = 0$)

7.2 Separation v. Liberalization

Consider the behavior of the vertically separated downstream firms under liberalization. Substituting the specific demand functions into first-order condition (8), imposing symmetry and solving for the retail price yields

$$p_i(p_1, a_i) = \frac{\alpha + p_1\gamma + \beta a_i}{2\beta - \gamma(n-2)}. \tag{17}$$

Similar transformations of (9) yield the profit maximizing retail price

$$p_1(a_i, p_i) = \frac{1}{2}\frac{\alpha + \gamma(a_i - c + p_i)(n-1) + c\beta}{\beta}$$

for the vertically integrated firm. Finally, as for vertical separation, there is a complicated function $a_i(p_1, p_i)$ for the optimal access price under liber-

[A 3] (i)$\sum_j (\partial D_i(\mathbf{p})/\partial p_j)(\partial p_j/\partial a_i) = \partial D_i(\mathbf{p})/\partial p_i = -1 < 0$;
(ii)$\sum_{k,j\neq i} (\partial D_j(\mathbf{p})/\partial p_k)(\partial p_k/\partial a_i) = \partial D_j(\mathbf{p})/\partial p_i = 0.1 > 0$.

alization. Solving this system of equations yields intricate explicit solutions for the respective prices in terms of the models parameters. To compare the equilibria under separation and liberalization, we graph the respective prices using the same numerical values for the demand parameters as above.

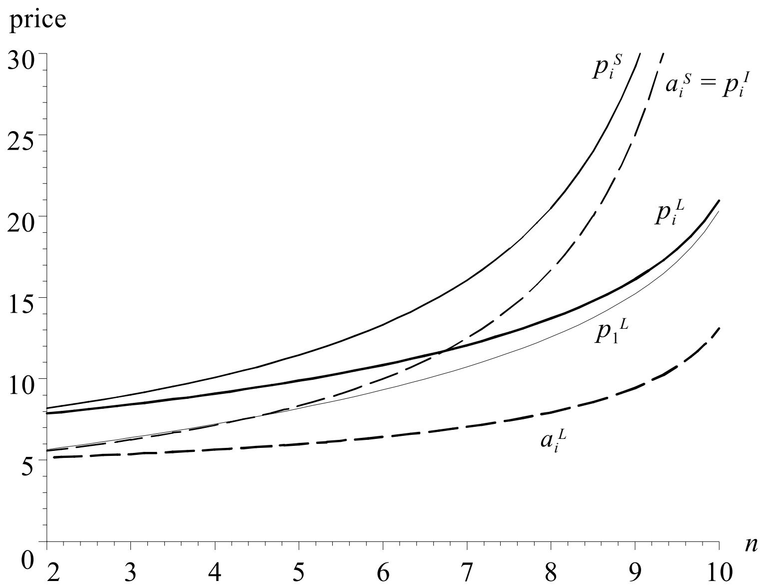

Figure 3: Separation vs. Liberalization ($\alpha = 10; \beta = 1; \gamma = 0.1; c = 0$)

Fig. 3 indicates that with the simple demand system used here, vertical foreclosure does not emerge in equilibrium.[27] While it is true that the vertically integrated upstream monopolist is able to place his downstream competitors at a competitive disadvantage ($p_1^L < p_i^L$), it is not attaining this result by increasing its rivals' access prices relative to separation.[28] It rather reduces the integrated downstream firm's retail price p_1^L strongly enough so that the downstream rivals cannot keep up even though they now face lower access prices. As a result, the retail prices under liberalization remain strictly

[27]Naturally, the prices given in Fig. 2 and 3 depend on the specific parameter values, in particular on the level of substitutability between products given by γ. Simulations with $\gamma < 0.1$, however, yield similar qualitive results even though the price curves are 'flatter'.

[28]The bold dashed curve indicating a_i^L is everywhere below the dahsed curve indicating a_i^S.

lower than those under vertical separation ($p_i^L < p_i^S, \forall i$). This simple example demonstrates that a vertically integrated monopolist may desire to reduce its downstream competitors' costs rather than raising them, even if access prices can be set freely. This result nicely complements Sibley and Weisman (1998) who find that a regulated upstream monopolist may have an incentive to reduce the downstream rivals' cost under Cournot competition.

Interestingly, the retail prices p_i^L under liberalization are even smaller than the retail prices under integration for n large enough, i.e. the effect of introducing competition is strong enough to outweigh the problems associated with the partial vertical separation of the industry when n is large. As a result, changing the vertical structure to liberalization may not only be welfare increasing when starting from vertical separation, but also when starting from vertical integration when there are many competitors. Conversely, breaking up a dominant integrated firm subject to imperfect downstream competition may be difficult to justify.

Consider a simplified version of the Microsoft case for an illustration of the latter statement. Suppose Microsoft is the sole provider of PC operating systems and its browser Internet Explorer (IE) competes in the downstream market with Netscape (NS). In the context of the model discussed above, the industry is thus in a state of liberalization. Note that it is optimal for Microsoft to eliminate a potential double marginalization within its vertically integrated structure, e.g. by selling the operating system for the monopoly price and giving away IE for free. In practice, this is established by bundling the operating system and IE. As a result, there is an intense competitive pressure on NS. In this situation, the breakup of Microsoft and the associated unbundling of the operating system from IE would probably lead to the regulatory imposition of a double markup that not only increases the profitability of providing NS and IE, but also the retail prices. As a result, social welfare would be reduced. From a static welfare point of view, a breakup of Microsoft thus appears to be undesirable.[29]

[29]See Economides (2001) for a recent survey of the Microsoft case.

8 Concluding Remarks

The above analysis suggests that if an integrated network industry's final products are highly differentiated, changing the industry's vertical structure from integration to separation or liberalization is detrimental to social welfare if not supplemented by adequate access or retail price regulation. Consequently, the phasing out of "residual regulation" in deregulated industries targeted by some policy makers seems to be a sensible practice if and only if there is fierce downstream competition and vertical foreclosure can be safely excluded. In addition, the analysis indicates that breaking up a dominant integrated firm subject to imperfect downstream competition — such as Microsoft — is hard to justify on the grounds of static efficiency. Antitrust authorities should therefore attempt to evaluate whether the breakup of a dominating firm would generate higher dynamic efficiency. Overall, the model presented in this paper demonstrates that deregulation and divesture in network industries should be guided by a careful analysis of the pros and cons specific to the network industries' characteristics.

There is ample scope for further research. First, we focussed on cost reducing upstream investment by the network monopolist and did not consider other types of downstream or upstream investment, e.g. investment in network quality or advertisement for the final product. Second, we abstracted from the fact that an integrated dominant firm's incentive to foreclose its downstream competitors by price discrimination will probably depend on its costs relative to non-price discrimination or sabotage. Allowing for different types of vertical foreclosure might prove to be instructive. Finally, the analysis presented here could be adapted to study the effects generated by the entry of downstream competitors with higher efficiency.

9 Appendix

Proof of Lemma 1. Totally differentiating (1) and (2) yields

$$\underbrace{\left[2\frac{\partial D_i}{\partial p_i^I}+[p_i-c(e)]\frac{\partial^2 D_i}{\partial\left(p_i^I\right)^2}+\sum_{j\neq i}[p_j-c(e)]\frac{\partial^2 D_j}{\partial\left(p_i^I\right)^2}\right]}_{<0\text{ (SOC)}}dp_i^I \tag{A1}$$

$$+\underbrace{\left[-c'(e)\frac{\partial D_i}{\partial p_i^I}-\sum_{j\neq i}c'(e)\frac{\partial D_j}{\partial p_i^I}\right]}_{<0\text{ (by assumption [A 2])}}de^I=0$$

and

$$\underbrace{\left[-c'(e)\frac{\partial D_i}{\partial p_i^I}-\sum_{j\neq i}c'(e)\frac{\partial D_j}{\partial p_i^I}\right]}_{<0\text{ (by assumption [A 2])}}dp_i^I+\underbrace{\left[-c''(e)\sum_i D_i-\psi''(e)\right]}_{<0\text{ (SOC)}}de^I=0. \tag{A2}$$

Adding (A1) and (A2) and solving yields $de^I/dp_i^I<0$. ■

Proof of Lemma 2. Recall the following definitions of the retail price elasticities with respect to the access charge a_i:

$$m_{ii}\equiv\frac{\left(\partial p_i/\partial a_i\right)a_i}{p_i};\qquad m_{ji}\equiv\frac{\left(\partial p_j/\partial a_i\right)a_i}{p_j}.$$

We first derive $0<m_{ii}\leq 1$. Then we show that $0\leq m_{ji}<m_{ii}$ to prove Lemma 2.

To begin with, consider m_{ii}. The first-order condition for equilibrium retail pricing under vertical separation is

$$\frac{\partial\Pi_i(\mathbf{p},a_i)}{\partial p_i}=D_i(\mathbf{p})+\left(p_i^S-a_i\right)\frac{\partial D_i\left(\mathbf{p}\right)}{\partial p_i}=0. \tag{A3}$$

Total differentiation then yields

$$\frac{dp_i^S}{da_i}=\frac{\partial D_i/\partial p_i}{2(\partial D_i/\partial p)+\left(p_i^S-a_i\right)\left(\partial^2 D_i/\partial p_i^2\right)}>0.$$

Substituting this result for $\partial p_i/\partial a_i$, we get

$$m_{ii} = \frac{(\partial D_i/\partial p_i)\, a_i}{[2(\partial D_i/\partial p) + (p_i^S - a_i)\,(\partial^2 D_i/\partial p_i^2)]\, p_i}.$$

Transforming yields (using the first-order condition (A3))

$$m_{ii} = \frac{\varepsilon_{ii} + 1}{2\varepsilon_{ii} + \rho_{ii}}$$

with $\varepsilon_{ii} \equiv -\frac{(\partial D_i/\partial p_i)p_i}{D_i} > 0$ and $\rho_{ii} \equiv \frac{(\partial^2 D_i/\partial p_i^2)p_i}{(\partial D_i/\partial p_i)}$, where ρ_{ii} is the elasticity of the demand elasticity ε_{ii}. Now, clearly $m_{ii} \leq 1$ for

$$\varepsilon_{ii} + 1 \leq 2\varepsilon_{ii} + \rho_{ii},$$

or

$$\rho_{ii} \geq 1 - \varepsilon_{ii}, \tag{A4}$$

respectively. (A4) is satisfied in equilibrium if demand is not too convex (i.e. if ρ_{ii} is not too negative). Also, $m_{ii} > 0$ requires

$$2\varepsilon_{ii} + \rho_{ii} > 0,$$

or

$$\rho_{ii} > -2\varepsilon_{ii}, \tag{A5}$$

respectively. Note that (A5) is generally satisfied if (A4) holds, i.e. we have $0 < m_{ii} \leq 1$ for demand not too convex (see [A 1]).

Let us now turn to m_{ji}. Solving the first-order condition (A3) for the price in market j for p_j and writing the retail price as a function of the vector of access charges $\mathbf{a}$ yields

$$p_j^S(\mathbf{a}) = a_j - \frac{D_j(\mathbf{p}(\mathbf{a}))}{\partial D_j(\mathbf{p}(\mathbf{a}))/\partial p_j}. \tag{A6}$$

Differentiating with respect to a_i and simplifying yields (using the first-order condition (A3))

$$\frac{dp_j^S}{da_i} = -\frac{(\partial D_j/\partial p_i)\,(\partial p_i/\partial a_i)}{(\partial D_j/\partial p_j)}.$$

Substituting this result for $\partial p_j/\partial a_i$, we get

$$m_{ji} = -\frac{(\partial D_j/\partial p_i)\,(\partial p_i/\partial a_i)\,a_i}{(\partial D_j/\partial p_j)\,p_i} \geq 0.$$

Transforming yields

$$m_{ji} = -\frac{(\partial D_j/\partial p_i)\,m_{ii}}{(\partial D_j/\partial p_j)} \geq 0 \tag{A7}$$

with $0 < m_{ii} \leq 1$ as shown above. By assumption [A 2], it now follows immediately that $0 \leq m_{ji} < m_{ii} \leq 1$. ■

Proof of Proposition 1. Using Observation 1 as well as the first-order conditions (5) and (1), retail prices are higher under vertical separation than integration if

$$\frac{1}{\sum_j \varepsilon_{ij}(\mathbf{p}^S)m_{ji}(\mathbf{a}^S)} - \frac{\sum_{j\neq i}\left[a_j^S - c(\bar{e})\right]D_j(\mathbf{p}^S)\sum_k \varepsilon_{jk}(\mathbf{p}^S)m_{ki}(\mathbf{a}^S)}{\tilde{R}_i(\mathbf{p}^S)\sum_j \varepsilon_{ij}(\mathbf{p}^S)m_{ji}(\mathbf{a}^S)} \tag{A8}$$
$$\geq$$
$$\frac{1}{\varepsilon_{ii}(\mathbf{p}^I)} - \frac{\sum_{j\neq i}\left(p_j^I - c(\bar{e})\right)D_j(\mathbf{p}^I)\varepsilon_{ji}(\mathbf{p}^I)}{R_i(\mathbf{p}^I)\varepsilon_{ii}(\mathbf{p}^I)}, \forall i, j.$$

Since, by assumption, vertical separation does not reduce the pricing externalities to markets $j \neq i$, we know that

$$-\frac{\sum_{j\neq i}\left[a_j^S - c(\bar{e})\right]D_j(\mathbf{p}^S)\sum_k \varepsilon_{jk}(\mathbf{p}^S)m_{ki}(\mathbf{a}^S)}{\tilde{R}_i(\mathbf{p}^S)\sum_j \varepsilon_{ij}(\mathbf{p}^S)m_{ji}(\mathbf{a}^S)} \tag{A9}$$
$$\geq$$
$$-\frac{\sum_{j\neq i}\left(p_j^I - c(\bar{e})\right)D_j(\mathbf{p}^I)\varepsilon_{ji}(\mathbf{p}^I)}{R_i(\mathbf{p}^I)\varepsilon_{ii}(\mathbf{p}^I)}, \forall i, j.$$

To proof the claim that retail prices are higher under vertical separation than integration, it is therefore sufficient to show that

$$\frac{1}{\sum_j \varepsilon_{ij}(\mathbf{p}^S)m_{ji}(\mathbf{a}^S)} > \frac{1}{\varepsilon_{ii}(\mathbf{p}^I)}, \quad i, j = 1, ..., n \tag{A10}$$

for ε_{ii} nonincreasing and nondecreasing in retail prices.

(i) If ε_{ii} is nonincreasing in the vector of retail prices, the claim follows immediately from $\varepsilon_{ii} > 0$, $\varepsilon_{ij} < 0$ for all $j \neq i$, and Lemma 2.

(ii) If ε_{ii} is nondecreasing in the vector of retail prices, $\varepsilon_{ii} > 0$, $\varepsilon_{ij} < 0$ for all $j \neq i$, and Lemma 2 still work in the right direction but are not sufficient to guarantee that (A10) is satisfied. In addition, we need that the final goods are close substitutes, since then there is only a small difference between $\mathbf{p}^I$ and $\mathbf{p}^S$. Then the claim follows. ■

Proof of Proposition 3. The proof is very similar to the proof of Proposition 1. Using (10), (9) and (1), the retail prices $\mathbf{p}^L$ under liberalization are higher than the retail prices $\mathbf{p}^I$ under integration if

$$\begin{gathered}\frac{1}{\sum_j \varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)} \\ -\frac{\sum_{j\neq i,j\neq 1}[a_j^L - c(\bar{e})]D_j(\mathbf{p}^L)\sum_{k\neq 1}\varepsilon_{jk}(\mathbf{p}^L)m_{ki}(\mathbf{a}^L)}{\tilde{R}_i(\mathbf{p}^L)\sum_{j\neq 1}\varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)} \\ -\frac{\left[p_1^L - c(\bar{e})\right]D_1(\mathbf{p}^L)\sum_{k\neq 1}\varepsilon_{1k}(\mathbf{p}^L)m_{ki}(\mathbf{a}^L)}{\tilde{R}_i(\mathbf{p}^L)\sum_{j\neq 1}\varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)} \\ \geq \\ \frac{1}{\varepsilon_{ii}(\mathbf{p}^I)} - \frac{\sum_{j\neq i}[p_j^I - c(\bar{e})]D_j(\mathbf{p}^I)\varepsilon_{ji}(\mathbf{p}^I)}{R_i(\mathbf{p}^I)\varepsilon_{ii}(\mathbf{p}^I)}\end{gathered} \tag{A11}$$

and

$$\begin{gathered}\frac{1}{\varepsilon_{11}(\mathbf{p}^L)} - \frac{\sum_{j\neq 1}[a_j^L - c(\bar{e})]D_j\varepsilon_{j1}(\mathbf{p}^L)}{R_1\varepsilon_{11}(\mathbf{p}^L)} \\ > \\ \frac{1}{\varepsilon_{11}(\mathbf{p}^I)} - \frac{\sum_{j\neq 1}[a_j^I - c(\bar{e})]D_j\varepsilon_{j1}(\mathbf{p}^I)}{R_1\varepsilon_{11}(\mathbf{p}^I)}\end{gathered} \tag{A12}$$

with $i = 2, ..., n, , j, k = 1, ..., n$. Since, by assumption, liberalization does not reduce the pricing externalities to markets $j \neq i$, we know that

$$-\frac{\sum_{j\neq i,j\neq 1}[a_j^L - c(\bar{e})]D_j(\mathbf{p}^L)\sum_{k\neq 1}\varepsilon_{jk}(\mathbf{p}^L)m_{ki}(\mathbf{a}^L)}{\tilde{R}_i(\mathbf{p}^L)\sum_{j\neq 1}\varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)} \quad \text{(A13)}$$

$$-\frac{\left[p_1^L - c(\bar{e})\right]D_1(\mathbf{p}^L)\sum_{k\neq 1}\varepsilon_{1k}(\mathbf{p}^L)m_{ki}(\mathbf{a}^L)}{\tilde{R}_i(\mathbf{p}^L)\sum_{j\neq 1}\varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)}$$

$$\geq$$

$$-\frac{\sum_{j\neq 1}[a_j^I - c(\bar{e})]D_j(\mathbf{p}^I)\varepsilon_{j1}(\mathbf{p}^I)}{R_1(\mathbf{p}^I)\varepsilon_{11}(\mathbf{p}^I)}.$$

and

$$-\frac{\sum_{j\neq 1}[a_j^L - c(\bar{e})]D_j(\mathbf{p}^L)\varepsilon_{j1}(\mathbf{p}^L)}{R_1(\mathbf{p}^L)\varepsilon_{11}(\mathbf{p}^L)} \geq -\frac{\sum_{j\neq 1}[a_j^I - c(\bar{e})]D_j(\mathbf{p}^I)\varepsilon_{j1}(\mathbf{p}^I)}{R_1(\mathbf{p}^I)\varepsilon_{11}(\mathbf{p}^I)}. \quad \text{(A14)}$$

It is therefore sufficient to show that both

$$\frac{1}{\sum_j \varepsilon_{ij}(\mathbf{p}^L)m_{ji}(\mathbf{a}^L)} \geq \frac{1}{\varepsilon_{ii}(\mathbf{p}^I)}, \quad \forall i,j \quad \text{(A15)}$$

and

$$\frac{1}{\varepsilon_{11}(\mathbf{p}^L)} \geq \frac{1}{\varepsilon_{11}(\mathbf{p}^I)}. \quad \text{(A16)}$$

are satisfied. If ε_{ii} is nonincreasing in the vector of retail prices, the claim follows immediately from $\varepsilon_{ii} > 0$, $\varepsilon_{ij} < 0$ for all $j \neq i$, and Lemma 2. ■

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