# Legal unbundling: A "golden mean" between vertical integration and vertical separation?

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**Abstract**

We study an industry with one upstream monopolist supplying an essential input at a regulated price to several downstream firms. Legal unbundling means that a downstream firm owns the upstream firm but this upstream firm is legally independent and maximizes its own profits (instead of maximizing the group profits). Although we allow for non-tariff discrimination by the upstream firm, we show that under rather general conditions legal unbundling yields higher quantities in the downstream market than vertical separation and integration. Incentives to invest in cost reduction of the upstream firm are also highest under legal unbundling. The output results are robust to the case where unbundling is "imperfect" in the sense that the upstream firm still attaches some weight to downstream profits, where and to the case where the downstream firm owns only parts of the upstream firm.

Keywords: Network industries, regulation, sabotage

JEL-Classification: L11, L42, L43, L51

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# 1 Introduction

In many industries vertically integrated firms are not only active on the final product market but they also supply essential inputs to potential downstream competitors. Prominent examples are the software industry (where, e.g. Microsoft offers "compatibility" to Windows and at the same time competes in the applications market) or network industries (like telecommunications, energy, or rail). An important and heavily researched policy question is: should vertical integration be allowed? Standard arguments in favor of this are that integration at least partially overcomes the double marginalization problem and might provide better investment incentives for the upstream operations. The main counter-argument and therefore main motivation for vertical separation is that integration can lead to discriminatory behavior against downstream competitors, and therefore reduces downstream competition.

We analyze a third alternative: Legal unbundling. Legal unbundling means that an integrated firm which controls an essential facility and is also active in the input and output markets, is required to operate the essential facility in a legally independent entity, but may still fully or partially own this entity. In Europe, legal unbundling is the standard requirement for the energy industry[3], and similar forms of "partial separation" are common in the telecommunications industry in Europe and the US.[4] The idea is that the independence of the upstream unit shall prevent discrimination. The judgement on whether this is successful is, however, mixed. Although in many network industries the price for the essential input (the "access") is usually regulated, and non-discrimination with respect to tariffs is relatively easy to impose,[5] non-tariff discrimination is in important problem with

[3]For the electricity market see Directive 2003/54/EC, Articles 10 (1) and 15 (1), for the gas market see Directive 2003/55/EC, Articles 9 (1) and 13 (1).

[4]For the US see Section 272 of the Telecommunications Act of 1996; for the European Union see Directive 2002/21/EC, Article 13 (1b).

[5]Although this also can be an issue, e.g. if non-linear tariffs are used. They might be tailored such that only the subsidiary of the integrated company can realize low prices. Exactly for this reason, regulators are sceptical about such tariffs. See e.g. European Commission, Energy Sector Inquiry, Competition reporton enery sector inquiry, part 1, p. 59. One example was the access to the Deutsche Telekom network required to offer narrowband internet access (a product called T-Online-Connect-Interconnect), where Deutsche Telekom offered quantity rebates which

integrated firms; and also legally unbundled firms might engage in some form of "sabotage" in form of undue delays in delivery of the service, overly complex contractual requirements, requiring unreasonably high bank guarantees and the like.[6]

In this paper we show that under rather general conditions legal unbundling can be viewed as superior to both, vertical integration and vertical separation. Legal unbundling yields higher quantities and higher incentives to invest in reducing the upstream firm's cost, compared to the other two alternatives.

We consider a model with one upstream monopolist ($F_0$), a potentially integrated affiliated downstream firm ($F_1$), the "incumbent", and $n-1$ potential downstream competitors. The upstream firm produces an essential input at constant marginal cost which the downstream firms need in a fixed proportion (1:1) to produce the final output. We impose no other restriction on the downstream firms' technologies, in particular, some or all competitors might be more or less efficient than the incumbent $F_1$. We do not restrict the strategic variables of downstream firms. Decisions could, for example, be about quantities, non-linear price schedules, investments or entry decisions. We assume that $F_1$ moves first in downstream competition. We require this assumption to derive the general results, but it seems not crucial in many cases, as we illustrate via a similar result for simultaneous quantity competition.

$F_0$ can invest in reducing the marginal cost of production. It must sell the input at a regulated price (above marginal costs) to all downstream firms. Although price discrimination is not possible, $F_0$ can "sabotage" the downstream firms, i.e. can impose additional cost individually on each downstream firm.

Four different vertical structures are compared: First, integration of $F_0$ and $F_1$; second, separation (i.e. all firms are independent); third, legal unbundling, ($F_0$ is legally independent and maximizes its own profits but is owned by $F_1$). Just

were only realized by its own subsidiary "T-Online". The regulatory authority ruled this to be discriminatory. See the German regulator's annual report "Tätigkeitsbericht 1998/99", p. 67.

[6] See e.g. European Commission, Energy Sector Inquiry, Competition report on energy sector inquiry, part 1, p.164, or, for the Telecommunications sector a submission of the VATM (Association of competitors of Deutsche Telekom) to the European Commission, "Markteintrittsbarrieren im deutschen Telekommunikationsmarkt", September 2001.

for sake of comparison, we also analyze the less realistic reverse case where the downstream part is legally unbundled.

Our main results are the following. Legal unbundling leads to (weakly) higher levels of output and of (weakly) higher levels of investment than separation and vertical integration. That unbundling leads to higher quantities than vertical integration is not very surprising. Because of the price regulation $F_0$ wants to maximize total output under legal unbundling and therefore has less incentives for harmful sabotage than under vertical integration. Maybe more surprising is that under our general conditions for downstream competition legal unbundling always leads to weakly higher output than vertical separation. Although reduction of double marginalization is one factor, there is the additional effect that under legal unbundling the downstream incumbent wants to increase the output of its competitors to increase upstream profits from selling the input good.

The quantity effect also drives the higher investment incentives under legal unbundling. When a higher quantity is sold there are obviously higher gains from cost reduction. On the other hand the investment result is not completely trivial, since investment also changes the output quantity and these changes may be bigger under vertical integration than under legal unbundling.

The assumption that under legal unbundling $F_0$ only maximizes its own profits while being completely owned by $F_1$ is quite strong and we therefore perform two robustness checks. First, we consider the case of "imperfect" legal unbundling where $F_0$ takes to some extends its parent company's profits into account. Such imperfection could be limited, however, if $F_0$ has an additional minority shareholder who has interest to ensure profit maximization by $F_0$'s management. We analyze therefore also the case where the incumbent only has partial ownership of the upstream firm. Our output results survive these robustness checks: increasing $F_0$'s independence always (weakly) increases output and as long as independence is achieved output also (weakly) increases in $F_1$'s ownership share in $F_0$. We will also exemplify that the effect of $F_1$'s ownership share can be ambiguous when $F_0$ does not act independently.

Although in many settings higher output implies higher consumer surplus and

higher welfare, such implications can not be made in our general model. We therefore present the example of price competition with homogeneous goods in the downstream market including a detailed welfare analysis. For this example, welfare is highest under legal unbundling.

Despite its great policy relevance in the European Union, there is little literature on legal unbundling. One important exception is Cremer *et al.* (2006). They address a very similar question and the idea how to model legal unbundling is also closely related. There are, however, important differences. First, they assume that the downstream firm is legally unbundled, i.e. that the network owner maximizes joint profits while the downstream firm maximizes only the own profits. This is our case of "reverse" unbundling. Furthermore, they model investment as the upstream firm's choice of the network size, which in equilibrium determines the total level of output in stage two. Finally, they do not allow for sabotage.

Apart from this, our paper is related to two rich strands of literature. Generally, to the literature on vertical integration, where an overview is provided e.g. in Perry (1989). A paper addressing vertical issues similar to the ones we analyze is Vickers (1995). More recent papers have addressed investment incentives for different vertical structures, see Buehler *et al.* (2004). In their paper an upstream firm can invest in increasing the quality of the final product which shifts demand outwards. However, the restrict attention to a chain of monopolies. The second line of literature focuses on the issue of sabotage. Mandy (2000) offers an overview of a series of articles (like Economides (1998) or Beard *et al.* (2001)) and their different specific assumptions, yielding quite different results an policy implications. Most recently, Mandy and Sappington (2007) compared cost increasing to quality decreasing sabotage. We add to this literature first by deriving our main results in a more general setup (we make no restriction on the downstream firms' cost function, the technology of sabotage, or the downstream competition; we also consider more general regulatory schemes than linear access pricing) and by addressing the issue of legal unbundling as an alternative to the extremes of separation and integration.

The remainder of the paper is organized as follows. Section two presents the

model. Section three derives the general results. Section four discusses Bertrand competition with linear demand as an example. Section five discusses the results, possible limitations, and policy implications. Section six concludes.

# 2 Basic model

**Structure and Regulation** There is a monopolistic upstream firm $F_0$ that produces a good at constant marginal costs $c_0$, which is used as input good for $n$ competing downstream firms, $F_1, ..., F_n$. Each downstream firm needs a constant and identical amount of the input good to create an output good. For simplicity, we normalize input quantities such that each firm needs exactly one unit of the input good to create one unit of an output good.

**Non-tariff Discrimination** We assume $F_0$ is a regulated natural monopoly, e.g. the owner of an essential transmission network in electricity or telecommunication markets. The regulator fixes a per-unit access price $a > c_0$ that $F_0$ must charge from both downstream firms. The regulator can enforce these prices but cannot prevent $F_0$ from hindering some or all downstream firms in some other way. $F_0$ chooses an action $h \in H$ that specifies some sabotage strategy against downstream firms. Sabotage can increase access costs for downstream firms or reduce demand by creating inconveniences for customers. Sabotage can be specifically targeted at some firm, e.g. some $h$ may slightly hamper $F_2$, others may hamper $F_1$, other $h$ may hamper no firm. We assume that the choice of $h$ has no direct impact on the profit of $F_0$, although perhaps indirectly if it changes the total quantity sold.

**Timing** First, $F_0$ choose $h$, i.e. decides how to hinder the downstream firms. In an extended model $F_0$ also decides on an investment level $I$ that can decrease its marginal costs. Then, downstream firms engage in downstream competition. The strategic variable of downstream firm $i$ is denoted by $x_i$ and $x = (x_1, ..., x_n)$ denotes the vector of downstream strategies. The action $x_i$ can either be a price, a quantity, or something more complicated like a non-linear tariffs, or product characteristics.

We will assume that $F_1$, the incumbent's downstream operations, moves first and that $F_2, ..., F_n$ can observe this. Whether the other downstream firms move simultaneously or sequentially does not matter for our model.

**Downstream Market and Payoffs**

Downstream strategies together with sabotage determine downstream firm's output $q_i(x,h)$, their market prices $p_i(x,h)$ and their total costs $C_i(x,h|a)$. Total output quantity is given by $Q(h,x) = \sum_{i=1}^{n} q_i(x,h)$.[7]. $F_0$'s profits are given by

$$\pi_0(x,h|a) = (a - c_0)Q(x,h) - K + S$$

The constant $K$ represents fixed costs and the constant $S$ possible state subsidies. Profits of downstream firm $i$ are given by

$$\pi_i(x,h|a) = p_i(x,h)q_i(x,h) - C_i(x,h|a) \text{ for } i = 1, ..., n$$

We will derive our output results without making any further restrictions on functional forms.

**Vertical structures** We compare the following four vertical structures.

$v$ : Vertical integration. $F_0$ and $F_1$ both maximize their joint profit

$$\pi_{01} = \pi_1 + \pi_0$$

$s$ : Complete separation or ownership unbundling. All firms maximize their own profits $\pi_i$.

$u$ : Legal unbundling: $F_0$ maximizes its own profits whereas $F_1$ maximizes their joint profits $\pi_{01}$.

$r$ : Reverse legal unbundling: For comparison reasons we also consider this case where $F_0$ maximizes joint profits $\pi_{01}$ and $F_1$ maximizes its own profits $\pi_1$.

The entering downstream firms $i = 2, ..., n$ maximize their own profits under all vertical structures.

Legal unbundling requires that the network part, or more generally, the part

[7] If firms' play mixed strategies these variables denote expected values. In that case, we assume that all firms are risk-neutral.

of the company controlling the essential facility, has to be separated into a legally independent entity. However, the EU legislation explicitly states that legal unbundling does not imply that the integrated firm has to sell the network operations. Thus, assuming 100% ownership of the network operations by the integrated firm (i.e. the downstream operations) is possible and current practice in many European countries (e.g. in the energy industries in France and Germany).

What is more involved is to assume that legal unbundling leads the network operator to focus solely on the own profits and to disregard effects on the group profits. At least direct instruction are explicitly excluded by the legislation (Directive 2003/54/EC, Article 10 and 15) or arm's length relations prescribed (US Telecommunications Act 1996, Section 272 (b) [5]). Nevertheless, legal unbundling might be imperfect in the separation of interests. We will therefore later allow for such correlated interests between $F_0$ and $F_1$.

**Regularity condition** There may be multiple equilibria under each vertical structure. Instead of comparing equilibrium sets we facilitate the analysis by imposing the following regularity condition.

*Let $B_i$ denote a set of best replies of firm $i \in \{1, 2, ..., n\}$ and let $\psi$ be a function which selects a best reply $b_i \in B_i$. This function $\psi$ shall only depend on the set of best-replies $B_i$ but not on any other exogenous variable, i.e. $\psi = \psi(B_i)$.*

The condition implies that if we have multiple equilibria, and the set of equilibria is the same in two different vertical structures then the same equilibrium will be selected under both structures.

**Remark** Under the condition above entrants equilibrium decisions only depend on $h$ and the decision of the incumbent $x_1$. This means given $h$ firm 1 can choose between different decision profiles $x = (x_1, x_2(x_1, h), ..., x_n(x_1, h))$. These profiles must come from a set $X(h)$ which only depends on $h$ but not on the vertical structure. This observation will prove useful in deriving the general results.

# 3 General results

## 3.1 Quantities and profits for exogenously given $c_0$

Assume that no cost reducing investments are possible. We want to investigate the effect of legal unbundling on market quantities. Since the upstream firm's profits are just equal to the quantity of access multiplied by the fixed access charge $a$ net of marginal costs $c_0$, and since the quantity of access depends linearly on the final market quantities, higher quantities in the final market have a one to one implication on the profit of firm $F_0$.

**Proposition 1** *If $F_1$ moves first, total output and profits of $F_0$ under legal unbundling are weakly higher than under vertical integration and full separation and reverse legal unbundling.*

Unless otherwise stated, all proofs can be found in the appendix. It is not surprising that vertical integration leads to (weakly) lower quantities than legal unbundling. The reason is simply that with legal unbundling $F_0$ uses a sabotage strategy that maximizes total output $Q^u$. This is because with the fixed access price $a > c_0$ maximization of profits $\pi_0$ coincides with output maximization. Under legal unbundling $F_0$ can guarantee the same output than under vertical integration by simply using the same sabotage strategy.

What is more surprising is that legal unbundling also yields a weakly higher quantity than separation. Given the way we modelled legal unbundling, the intuition for this result is, however, straightforward. In both cases – legal unbundling and vertical separation – the upstream firm $F_0$ has identical interests, i.e. to maximize its profit which is identical to maximizing total output. Output is higher under legal unbundling than under separation, because under legal unbundling $F_1$ also has an interest to increase $F_0$'s profits, i.e. total output. This incentive to increase output is broader than only the effect that under legal unbundling $F_1$'s internal input price falls from $a$ to $c_0$ (reduction of double marginalization). $F_1$ may also use strategies that are especially targeted to increase outputs from downstream competitors, as we illustrate in the price competition example in Section

4.

From the consumers' perspective, legal unbundling is therefore likely to be superior to the other two vertical structures. In particular, if the downstream products are homogenous (like e.g. voice calls, electricity, or gas) and if firms charge linear tariffs, it is immediate that higher quantities yield also a higher consumer surplus.

**Corollary 1** *If output goods are perfect substitutes and downstream firms use linear tariffs, consumer surplus is weakly highest under legal unbundling.*

**Proof.** Immediate. ■

Legal unbundling can also be preferred by taxpayers, since $F_0$ makes higher profits than under the other vertical structures: if subsidies would be required to ensure production by firm $F_0$, such subsidies would be lowest under legal unbundling.

**Corollary 2** *The minimal state subsidy, that guarantees that $F_0$ makes no losses, is lowest under legal unbundling.*

However, without assumptions on how discrimination works and how downstream competition works, results on total welfare are not possible. We will later provide a full welfare analysis for the case of Bertrand competition.

We assumed that firm $F_1$ moves first. This is not a necessary requirement for the results of Proposition 1 to hold. For instance, if we assume Cournot competition downstream and a specific sabotage technology, the results also hold: Consider a sabotage technology that linearly increases costs, i.e. $h = \{h_1, ..., h_n\}$ such that the cost of firm $i$ become $C_i(h) = (a + h_i) q_i + C_i(q_i)$. Then Proposition 1 holds also for this simultaneous move game.

**Proposition 2** *Consider the special case of the linear sabotage technology. Assume downstream firms compete by setting simultaneously quantities (Cournot competition). Then total output is weakly highest under legal unbundling.*

Note that the result also hold under differentiated goods. Proposition 2 indicates that under appropriate regularity conditions the output results seem to be robust with respect to relaxing the first mover characteristic used in the proof of Proposition 1.

In order to make our results comparable to Cremer *et al.* (2006), what is left to discuss is the case of "reverse unbundling". Recall that reverse legal unbundling means $F_0$ maximizes $\pi_{01}$ whereas $F_1$ has an independent management and maximizes $\pi_1$. In practice, this would imply that e.g. a integrated electricity company would have to form a legally independent sales unit which is owned by the network operations (or by the whole group, including generation facilities). The important point is that with reverse legal unbundling the essentially facility would not be separated in an independent unit, which contradicts legal practice.

Reverse unbundling is not only unrealistic, it also leads to lower quantities in equilibrium compared to vertical separation and, by Proposition 1, also to lower quantities than legal unbundling.

**Proposition 3** *Total output under reverse legal unbundling is weakly lower than under separation.*

## 3.2 Imperfect Legal Unbundling and Partial Ownership

The assumption that under legal unbundling $F_0$ only maximizes its own profits while being completely owned by $F_1$ is quite strong. Even if both entities have different personnel and direct interference by the mother company is not allowed (which is a legal requirement for the telecommunications industry in the US according to Section 272 of the Telecommunications act, and also a requirement in the European energy industry, see footnote 2) this might not suffice to guarantee independence.

We therefore perform a robustness check along two lines. We consider the case of "imperfect" legal unbundling where $F_0$ takes to some extends its parent company's profits into account.

One way to reduce such imperfections in unbundling and ensuring that management of $F_0$ focuses on maximization of own profits $\pi_0$ is to allow outside in-

vestors to hold a share in $F_0$. Such an investor would participate only in $\pi_0$ and under usual corporate governance rules would have instruments to force the management to not to shift profits to $F_1$.

We discuss both elements, partial ownership of $F_0$ by $F_1$ and imperfect legal unbundling in the following formalization. We assume that under imperfect legal unbundling $F_0$ maximizes[8]

$$u_0 := \pi_0 + \rho\pi_1 \text{ with with } 0 \leq \rho \leq 1$$

where $\rho$ is measure that is inversely related to the degree of independence of $F_0$. Under partial ownership we assume that $F_1$ acts in order to maximize

$$u_1 := \pi_1 + \sigma\pi_0 \text{ with } 0 \leq \sigma \leq 1$$

The parameter $\sigma$ can be interpreted as the ownership share of $F_1$ in the upstream $F_0$.

If we allow for all combinations of $\rho$ and $\sigma$ we have a general set-up that encompasses as special cases vertical separation: $\sigma = 0$, $\rho = 0$, legal unbundling: $\sigma = 0, \rho = 1$, reverse legal unbundling: $\sigma = 0, \rho = 1$ and vertical integration: $\sigma = 1, \rho = 1$. This is illustrated in figure 1:

The arrows indicate comparative statics results for total output with respect to $\sigma$ and $\rho$, which are formalized in the propositions below. For instance, if one moves from the bottom right corner to the left (i.e assume that $\rho = 0$, implying that the downstream management cares only about the own profits), this reduces the share $F_1$ holds in $F_0$; such a movement decreases the total quantity, i.e. allowing $F_1$ to hold even a small share in $F_0$ still yields a larger quantity than full vertical separation.

**Proposition 4** *Assume $\rho = 0$ then total output is weakly increasing in $\sigma$.*

[8] Alternatively one may consider the case where firm 0 maximizes: $\pi_0 + \widetilde{\rho} u_1 = \pi_0 + \widetilde{\rho}(\pi_1 + \sigma\pi_0)$ with $0 \leq \widetilde{\rho} \leq 1$

This is equivalent, however, to maximizing $\pi_0 + \frac{\widetilde{\rho}}{1+\widetilde{\rho}\sigma}\pi_1$. By setting $\rho = \frac{\widetilde{\rho}}{1+\widetilde{\rho}\sigma}$ we see that this is just a special case of the formulation we made in the text, restricted to the cases $0 \leq \rho \leq \frac{1}{1+\sigma}$.

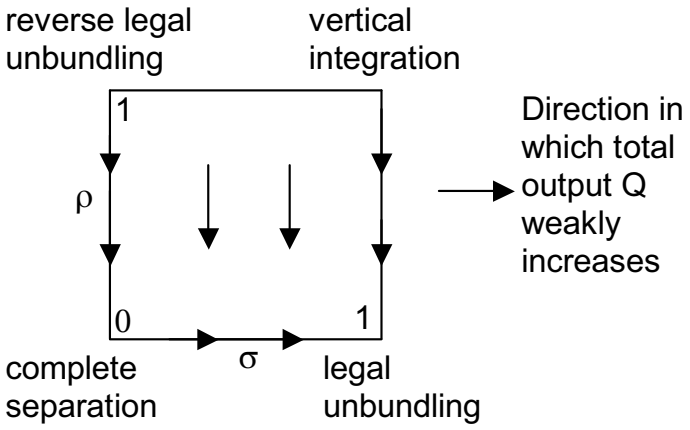


Figure 1: Illustration of the 4 special cases as functions of $\sigma$ and $\rho$ and comparative statics of total output Q.

Alternatively, consider any move downwards in Figure 1: this always increases total quantity, i.e. independent of how big the stake $F_1$ holds in $F_0$ imperfect legal unbundling is still better than full integration.

**Proposition 5** *For every mode of downstream competition and every $\sigma$, total output is weakly decreasing in $\rho$.*

The two results do also imply that perfect legal unbundling with full ownership ($\sigma = 1, \rho = 0$) leads to a weakly higher output than every other combination of $\sigma$ and $\rho$. Thus whenever higher total output is linked to higher welfare it would indeed be desirable to achieve such perfect legal unbundling with full ownership.

The results of Proposition 4 and 5 are quite intuitive. Output increases when $F_0$ becomes more independent, since for lower $\rho$ $F_0$ attaches lesser weight on $F_1$'s profit and relatively greater weight on output maximization. Similarly, when $F_1$'s ownership share $\sigma$ increases, $F_1$ attaches greater weight on output maximization, which should lead to an increase in total output. However, this latter effect can be shown to be true in general only for the case of complete independence, i.e. for $\rho = 0$. It is intuitive that it also hold for larger values of $\rho$, but it is possible to construct counterexamples. Assume there are two downstream firms with constant

marginal costs $c_1 = 0.4$ and $c_2 = 0.3$ who compete by setting simultaneously quantities (Cournot).[9] The inverse demand is given by $p = 1 - q_1 - q_2$. The access price is $a = 0.25$ and $F_0$ produces at zero marginal costs $c_0 = 0$. $F_0$ can hamper downstream firm $i$ by increasing marginal costs to an arbitrary level $c_i + h_i$. Figure 2 illustrates the resulting total output for all combinations of $\rho$ and $\sigma$.

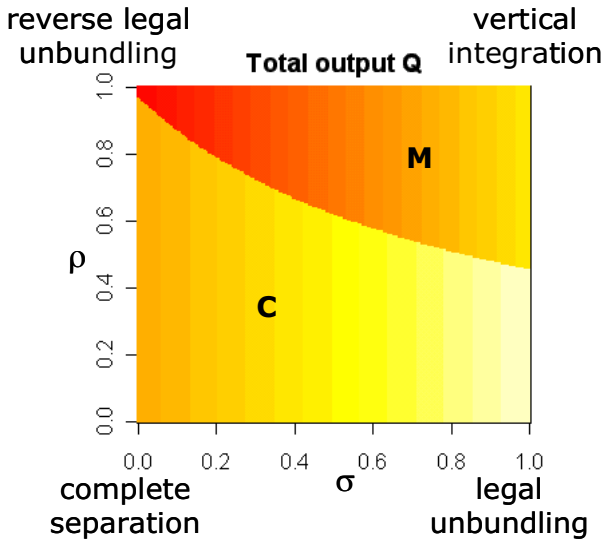


Figure 2: Total output in Cournot example. Brighter colors correspond to higher total output.

There are two classes of equilibria corresponding to the areas $C$ and $M$ in figure 2. Either there is no sabotage and both downstream firms compete (area C) or we have a downstream monopoly of $F_1$ while firm 2 will be strongly sabotaged and therefore produces 0 (area M). As is intuitively clear the monopoly outcome arises only for sufficiently high $\rho$. Within the sets of monopoly outcomes and competitive outcomes total output is always increasing in $F_1$'s ownership share $\sigma$. But for high levels of $\rho$ a reduction in $\sigma$ may lead from a monopoly outcome to a competitive outcome with higher total output. The intuition for this finding is that the monopoly outcome is more attractive for $F_0$ when $F_1$'s ownership share

[9] There exist also examples for the case where firm 1 moves first.

$\sigma$ is high, since for higher $\sigma$ losses due to double marginalization are less severe. If $\rho$ is low this effect does not arise because then $F_0$ mainly cares about high output quality and therefore prefers the competitive solution.

This example highlights two aspects. First, if we move horizontally from the C-region to the M-region, total quantity counter-intuitively decreases with increasing $\sigma$. Thus, we can not in general exclude that complete separation (i.e. $\sigma = 0$) yields lower output levels for all values of $\rho > 0$. Second, within each region, the basic intuition applies that higher $\sigma$ increases output for all values of $\rho$.

## 3.3 Investments in reducing marginal costs $c_0$

Assume $F_0$ can decrease the original marginal costs $c_0$ by some amount $\delta < c_0$. Such marginal cost reduction requires to make an investment with costs $I(\delta)$ that are increasing in $\delta$. We show that $F_0$ invests weakly more into marginal cost reduction under legal unbundling than under both vertical separation and vertical integration (i.e. we return to the case where $\rho = 0$ and $\sigma = 0$).

Let us first establish the following helpful lemma, which just proves for our general case the intuitive idea that with decreasing production cost for the upstream firm $F_0$, its output will increase and therefore also overall output in the downstream market increases.

**Lemma 1** *Total output under legal unbundling is weakly decreasing in $F_0$'s marginal cost $c_0$.*

Provided with this intuitive result, we can show that investment incentives are highest with legal unbundling.

**Proposition 6** *If $F_1$ moves first, investment under legal unbundling are weakly higher than under vertical separation and vertical integration.*

The quantity effect also drives the higher investment incentives under legal unbundling. When a higher quantity is sold there are obviously higher gains from cost reduction. Although intuitive, this result is not totally trivial. Clearly,

investments change the output quantity; the extent to which they affect total output, however, could depend on the vertical industry structure. For instance, it could be the case that changes in quantities are larger under vertical integration than under legal unbundling. This proposition shows, however, that investment incentives are nevertheless always weakly bigger under legal unbundling.

# 4 Bertrand example: price competition with general falling demand

## 4.1 Exogenously given level of upstream cost $c_0$

In the preceding sections we have shown that legal unbundling yields superior results in terms of quantities produced and incentives to invest. Usually, this will also lead to higher social surplus and higher consumer surplus, since we usually will be facing underproduction (due to double marginalization and market power problems) and insufficient low investments (due to the fact that the upstream firm can appropriate only a part of the returns of its investment – they have to be shared with downstream firms and consumers). Nevertheless, within the very general formulation of the model used so far, it might be possible to construct counter-examples, i.e. situation in which legal unbundling might yield overproduction or overinvestment, or welfare losses due to wrong allocation of production. A full welfare analysis is possible only with more restriction on the model. Here we present a full welfare analysis for the case of price competition in homogenous goods (Bertrand competition) with two downstream firms.

**Assumptions** There are two downstream firms, selling perfect substitutes. Total demand is given by a downward sloping demand function $Q(p)$, $Q'(p) < 0$. We maintain the assumption that the incumbent $F_1$ moves first. Furthermore, we assume constant marginal cost of the downstream firms, with a cost disadvantage for the incumbent. Furthermore, sabotage is assumed to be linear; thus, cost

functions are

$$C_1(q_1) = (c_1 + a + h_1)\, q_1,$$
$$C_2(q_2) = (c_2 + a + h_2)\, q_2,$$

where $c_1 > c_2$. Considering a cost disadvantage is of interest since a standard argument for regulated market opening is to allow more efficient firms to enter the downstream market.

To exclude uninteresting cases, assume that the integrated incumbent (i.e. a combined entity of $F_0$ and $F_1$), it were also a downstream monopolist would like to serve the market. Let $p_{01}^m$ be the monopoly price of the integrated incumbent. Profitability of an integrated monopoly thus requires $p_{01}^m > c_1 + c_0$.

We also assume that the access price $a$ is not Pareto-dominated by some lower access price. This means that it is not the case that total welfare would be (weakly) higher and at the same time all firms would be (weakly) better off by some lower access price. This condition would for example be violated under separation when an access price is so high that no downstream firm can profitable produce at any price that yields positive demand.

Since we consider a Bertrand game with asymmetric marginal cost, multiple equilibria can arise. We therefore focus attention on equilibria in which firms do not play weakly dominated strategies.

Finally, for the question on how the market is split between the two firms in case they choose identical prices, we make the following assumptions. If the price is above $F_2$'s marginal costs, i.e. $p > c_2 + a$, we assume that $F_2$ gets the whole market (for the never occurring case that $p_1 = p_2 < c_2 + a$ assume $F_1$ gets the whole market). This captures the idea that if prices were discrete (e.g. denoted in cents) then $F_2$ as second mover would prefer to minimally undercut the price if $p > c_2 + a$ and prefer not to sell any output if $p < c_2 + a$.

If the price is equal to $F_2$'s marginal cost, i.e. $p = c_2 + a$, then $F_1$ can decide whether $F_1$ gets the whole market, $F_2$ gets the whole market, or the market is split equally, i.e. $q_1 = q_2 = \frac{1}{2}Q$. This captures the idea that if prices were discrete $F_1$ could either set a price slightly above $F_2$'s marginal cost in which case $F_2$ gets the

whole market, exactly split the market at $F_2$'s marginal cost, or slightly undercut $F_2$'s marginal cost to get the whole market.

**Vertical separation** This is the typical Bertrand case, except for the fact that $F_1$ moves first. We find the following result:

**Lemma 2** *Under separation in every equilibrium $F_2$ gets the whole market. The infimum market price of all equilibria where no firm plays a weakly dominated strategy is given $p = a + c_1$.*

The price $p = a + c_1$ which equals the high cost firms' marginal cost is the typical Bertrand outcome. Nevertheless there are additional equilibria. As under simultaneous moves there are equilibria with prices between $a + c_2$ and $a + c_1$, but those are equilibria where $F_1$ plays a weakly dominated strategy. If there is only a small doubt that $F_2$ will not undercut $F_1$, $F_1$ will never set a price below its own marginal cost $a + c_1$. Since $F_1$ moves first and always makes zero profits there are also equilibria with prices above $a+c_1$, i.e. a price of $a+c_1$ is not the only outcome but the welfare optimal outcome when we neglect weakly dominated strategies.

**Legal unbundling** If $F_1$ owns $F_0$ but $F_0$ wants to maximizes its own profits, $F_0$ again wants to maximize total output and therefore will not make use of sabotage. Contrary to vertical separation, now also the downstream firm $F_1$ has an incentive to maximize total output, since $F_0$'s profits will accrue to $F_1$ under legal unbundling. It would therefore be willing to give up own sales in the downstream market, it this increases upstream profits sufficiently. This intuition is taken to the extreme with Bertrand competition, as stated in the following Lemma.

**Lemma 3** *Under legal unbundling $F_0$ sets $h_2 = 0$. $F_1$ and 2 both set prices $c_2 + a$ and $F_2$ gets the whole market.*

Note that even though the price set by $F_1$, $p_1 = a + c_2$, can below $F_1$'s true marginal costs $c_0 + c_1$ — in contrast to what we found vertical separation — it is not a weakly dominated strategy for $F_1$ to set such a price. This is because if $F_1$ would set a higher price, $F_2$ would react with a higher price and total output and therefore the profit of the integrated firm $\pi_0 + \pi_1$ would be reduced.

**Vertical integration** With vertical integration, there are two candidates for an equilibrium. Either the upstream firm uses sabotage in order to drive $F_2$ out of the market (the "monopolistic" outcome); alternatively, $F_0$ might not want to sabotage $F_2$ and $F_2$ instead of $F_1$. The latter will be more likely, the larger the cost disadvantage of the own downstream operations is. With very inefficient own downstream operations, even the integrated firm might find it optimal to use $F_2$ as its "sales channel" and live only on the upstream profits. In this case, clearly, sabotage would not make sense.

**Lemma 4** *If $F_0$ and $F_1$ are integrated. There are two candidates for equilibrium:*
*(i) Case m: Set $h_2 = \infty$ and let $F_1$ serve the whole market at the monopoly price of the integrated firm $p_{10}^m$.*
*(ii) Case u: The same as under legal unbundling. Set $h_2 = 0$ and $p_1 = p_2 = c_2 + a$ and let $F_2$ get the whole market at its marginal cost.*

In the first case profits of the integrated firm are given by

$$\pi_{01}^m = (p_{01}^m - c_0 - c_1)\, Q\,(p_{01}^m)$$

In the second case profits are given by

$$\pi_{01}^u = (a - c_0)Q(c_2 + a)$$

We find $\frac{\partial\left(\pi_{01}^m - \pi_{01}^u\right)}{\partial c_1} < 0$ and $\frac{\partial\left(\pi_{01}^m - \pi_{01}^u\right)}{\partial c_2} > 0$, i.e. the monopoly output is more likely to occur when marginal costs of $F_1$ are low and marginal costs of $F_2$ are high.

**Reverse unbundling** Again let us assume that $F_1$ does not play a weakly dominated strategy and will therefore not set a price below $a + c_1$. Then no equilibrium with a price below $a + c_1$ exists. Thus $F_0$ always weakly prefers that $F_1$ gets the market. The market price maximizing joint profit is given by $p_{10}^m$. For $p > p_{10}^m$ joint profits are weakly decreasing in the price.

In the case $a + c_1 < p_{10}^m$ $F_0$ will handicap $F_2$ such that $a + c_2 + h_2 = p_{10}^m$. The total market goes to $F_1$ at price $p_{10}^m$. Thus we always have the bad of the two possible outcomes under vertical integration.

In the case $a + c_1 \geq p_{10}^m$ $F_1$ will not handicap $F_2$ more than $c_1 - c_2$. Market price will be $p = a + c_1$, either $F_1$ or $F_2$ gets the complete market. In the first case the trembling hand equilibrium leads to the same outcome than owner-ship unbundling.

**Comparison of the four cases** Equipped with the solutions for the four cases it is easy to see that in the Bertrand case for general falling demand functions legal unbundling is strictly superior to all other vertical structures (except for the competitive case of vertical integration, which yields an outcome identical to legal unbundling). Total output and consumer surplus are inversely related to the market price and therefore highest under legal unbundling. Profit of $F_0$ is increasing in total output and hence also highest under legal unbundling. Production is efficient since $F_2$ produces everything. Then total welfare is increasing in total output as long as market prices are weakly above marginal cost of production $c_0 + c_2$, which is always the case. Thus we can state the following proposition:

**Proposition 7** *Under legal unbundling prices are strictly lower, and total output, profit of $F_0$, i.e. $\pi_0$, consumer surplus and total welfare strictly higher than under vertical separation, reverse legal unbundling and the monopoly case of vertical integration. (In the competitive case of vertical integration we have identical outcomes than under legal unbundling).*

**Proof.** Immediate from comparing the outcome of the four cases. ■

One reason for welfare losses is that we assumed imperfect upstream regulation, i.e. the access price $a$ is above the marginal cost of producing access, $a > c_0$. It is therefore interesting to investigate what would happen if regulation improves in the sense that $a$ approaches the true cost of access $c_0$. Only for legal unbundling the outcome will approach the first best, i.e. the final market price will equal $p^{FB} = c_0 + c_2$. For separation as well as for integration, the market outcome remains inefficient even for $a = c_0$. With separation, the market price converges to $p = c_0 + c_1 > p^{FB}$, due to the assumption $c_1 > c_2$. And for vertical integration we find that for $a \to c_0$ always the monopoly case arises since income from selling input goods $(a - c_0)Q$ converges to zero.

**Proposition 8** *With perfect upstream regulation, $a \to c_0$, legal unbundling obtains the first best while the other vertical structures do not converge to the first best.*

**Proof.** Immediate. ■

## 4.2 Investment into marginal cost reduction

So far we assumed in the Bertrand example that marginal costs $c_0$ are exogenously given. Let us consider now the case that $F_0$ can reduce marginal costs by some amount $\delta < c_0$ where cost reduction requires investments of $I(\delta)$, with $I'(\delta) > 0$ and $I''(\delta) > 0$.

Let $I^u, I^v, I^s$ denote the investment levels chosen by $F_0$ under the different vertical structures. We compare these investment levels to the levels a social planner would choose under the restriction that the price of access is $a$ and that downstream competition is not regulated (this reflects the idea that a regulator believes that $a$ is set correctly, i.e we neglect the inefficiencies stemming from imperfect upstream regulation and the lack of downstream regulation). We denote by $I_o^u = I(\delta_o^u)$ this (second best) socially optimal investment level under legal unbundling. Let $I_s^s$ and $I_o^v$ are similarly defined for separation and vertical integration.

Under legal unbundling and vertical separation, $F_0$ has efficient investment incentives in the sense that it chooses the same investment as the social planner (given the restriction mentioned).

**Proposition 9** *Under both legal unbundling and vertical separation $F_0$ will select the socially optimal level of investment, i.e. $I^u = I_o^u$ and $I^s = I_o^s$. Investment incentives under vertical integration are not generally efficient, i.e. $I^v = I_o^v$ does not always hold.*

The reason for this is that, given the unregulated downstream interaction, the first order condition for the social planner with respect to the investment decision is to equate the downstream quantity (which is equal to the marginal

gain from reducing $c_0$) to the marginal cost of cost reduction, i.e. $I'(\delta_o^u) = Q^u$ and $I'(\delta_o^s) = Q^s$. This is identical to the upstream firm's incentive to invest in cost reduction if it is independent, i.e. it considers only the upstream profits which equal the product of per unit profits times quantity. With vertical integration, however, the investment incentives are more complex since the integrated firm takes into consideration the effect of changes of $c_0$ on its optimal downstream price $p_{01}^m$. It is therefore possible to construct examples where considerations with respect to price changes and effects on infra-marginal profits lead to lower investment incentives under vertical integration, compared to the social optimal.

These results are counter-intuitive at first sight. Usually, the intuition is that vertical integration should provide the best investment incentives, since it internalizes transaction costs (e.g. hold-up problems) and avoids double marginalization. The former effect is not captured in our set-up, the latter is dominated in the Bertrand set-up by the effect just described. We therefore doubt that these results carry over to more general setups, e.g. with differentiated products. From Buehler *et al.* (2004) we know that for quality improving investment results can be indeed different.

# 5 More general regulatory pricing schemes

Maybe readers may worry that a linear access price by a regulator is too restrictive. A linear access price has two important features, however. First, the profit of $F_0$ only depends on the total quantity $Q$ but not on allocation of total production among the downstream firms. This seems to be a very sensible feature of an access price scheme, since otherwise the regulator would cause $F_0$ to prefer selling to some specific firms (e.g. to the smaller or to the bigger one when access prices are used that are non-linear $q_i$). Also a non-linear access price scheme may cause one firm to pay a higher average access price than the other firm, which may be difficult to justify if one firm decides to sue the regulatory agency before court. The second aspect of our linear price scheme with $a > c_0$, is that $F_0$'s profits increase in its output quantity. Usually it will be good thing to give $F_0$ incentives

to increase total output since the danger of having a too high total output is quite low, considering costs of downstream production and problems of double marginalization. Typically we will have a problem of inefficiently low output.

It turns out that these two features are all we need for the general results on output quantity and investment levels. We can therefore consider a bigger class of regulatory schemes that fulfill these two features. Let $\alpha$ denote such a general regulatory scheme. The regulatory scheme $\alpha$ determines how much money $F_0$ receives when selling a total output $Q$, denoted by a revenue function $R(Q|\alpha)$. We require that $F_0$'s revenues $R$ only depend on total output $Q$, but not directly on the vector of indiviudal outputs $(q_1, ..., q_n)$. Furthermore the scheme $\alpha$ specifies how much downstream firms have to pay when actions $x$ are chosen (which imply quantities $q_i$). Thus profits are given by

$$\pi_0(x, h|\alpha) = R(Q(x, h)|\alpha) - c_0 Q(x, h) - K + S$$

$$\pi_i(x, h|\alpha) = p_i(x, h)q_i(x, h) - C_i(x, h|\alpha) \text{ for } i = 1, ..., n$$

We only consider those schemes were $F_0$'s profits are strictly increasing in $Q$. This means we require i.e. for all $Q', Q$ with $Q' > Q$ that $R(Q') - c_0 Q' > R(Q) - c_0 Q$. This implies means that whenever $F_0$ makes higher profits $\pi_0$ we also know that total output must be higher.

Note that those general schemes do not require that all revenues $R(Q|\alpha)$ of $F_0$ have to be paid by the downstream firms. Part of revenues may also come from a subsidy by the state. For example, the state may charge downstream firms an access price of $c_0$, and pay the upstream firm an additional subsidy per unit sold. Such a scheme has two benefits. First, the per unit subsidy can give $F_0$ strong incentives to maximize total output, which may be a good way to reduce potential incentives for sabotage when $F_0$ is not completely independent (the case of $\rho > 0$). At the same time, output in downstream markets is increased because the bottleneck input is priced at its true marginal costs.

This per-unit-subsidy may also slowly fade out if $F_0$ sells enough quantity, i.e. $R'(Q)$ could converge from above towards $c_0$ as $Q$ increases. Such a fade-

out may be a good idea to yield high output, but at the same time avoid the danger of inefficiently high total output. Inefficiently high output is avoided when downstream firms have to pay $c_0$ and $R'(Q)$ is only slightly above $c_0$ such that $R'(Q)$ is below the sum of marginal cost of upstream and cheapest downstream production. In this case it cannot be profitable for any coalition of firms to sell final products at a price below the sum of upstream and downstream marginal costs (a scheme which may be profitable if the state would pay high subsidies on goods sold).

For these more general regulatory schemes which provide scope for additional desirable features, all the results proven in Section 3 and 4 still hold.

**Proposition 10** *Consider regulatory schemes for which (i) $\pi_0$ depends only on $Q$, and (ii) $\pi_0$ strictly increases in $Q$. The following results hold also for this larger class of regulatory schemes: Proposition 1, 3, 4, 5, 6 and Lemma 1 and2.*

The prove of the results for the larger class of regulatory schemes can be found in Appendix B. Thus, we find that also for the larger class of regulatory schemes, legal unbundling can be seen as a golden mean between separation and vertical integration as it still delivers higher quantities and better investment incentives. Also the robustness features with respect to imperfect legal unbundling and partial ownership carry over fully to this context.

# 6 Discussion

The analysis so far has shown that under rather general assumption legal unbundling seems to exhibit desirable properties. These theoretical findings stand in stark contrast to judgments of some regulatory authorities on legal unbundling. For the European Union, Nelly Kroes, Commissioner for competition policy, expressed her view on experiences with legal unbundling in the European energy industry in an informal statement frankly as follows:

> Speaking very personally, I see only one way forward if we are to restore credibility and faith in the market. Europe has had enough of

> "Chinese walls" and quasiindependence. There has to be a structural solution that once and for all separates infrastructure from supply and generation. In other words: ownership unbundling.[10]

More officially, in its "Sector Inquiry" the European Commission stated:

> Economic evidence shows that ownership unbundling is the most effective means to ensure choice for energy users and encourage investment. This is because separate network companies are not influenced by overlapping supply/generation interests as regards investment decisions.[11]

This statement is somewhat irritating, since it can surely not mean that investment decisions of an independent network company are not influenced by what happens in the downstream market. What is meant, and probably at the heart of the perceived disappointing experience with legal unbundling, is that is did not succeed in establishing non-discriminatory access to the essential facility. Though regulated tariffs are in place, the Commission cites a series of non-tariff discrimination efforts (see footnote 4).

However, in our model we allowed exactly for these non-tariff discrimination and still obtained the positive results for legal unbundling. We see three reasons why the theoretical analysis and the practical experience may yield different perspectives.

First, also from a theoretical point it is obvious that if some forms of tariff-like discrimination is possible, legal unbundling is not a good institutional choice. At some instances, tariff-like discrimination may play a role, in particular, where non-linear tariffs are used an tailored in such a way, that only the own downstream operation benefit from quantity discounts (see footnote 3). It is a matter of practical experience whether regulators feel sufficiently equipped to avoid such

[10] Speech Nelly Kroes, A new energy policy for a new era, Conference on European Energy Strategy – the Geopolitical Challenges, Lisbon, 30th October 2006.

[11] EU Commission, An Energy Policy for Europe, p. 7, Brussels, 10.1.2007, COM(2007) 1 final.

discriminatory behavior. Our view is that – by and large – tariff-like discrimination is not a big problem.

A second problem is that the network part is not really independent, i.e. in our model, $F_0$ does not only maximize its own profits. We believe that this is also the major point for the European Commission making it feel uneasy about legal unbundling. Clearly, if legal unbundling would de facto be the same as vertical integration, our results would not apply. However, apart from the question that in general it is not clear whether vertical integration or separation is welfare superior, our analysis suggests that probably as long as there is a little effect of legal unbundling, legal unbundling is superior to vertical separation and vertical integration (although we cannot be sure that this result holds for all levels of $\rho$ in the model).

What seems very important to us is that allowing outside investors to hold a minority share (i.e. partial ownership in our model) is likely to be an effective mechanism to ensure that the network company's management does not shift all profits to the downstream company or the holding company. Consider a large institutional investor, like a pension fund, holding 10% in the network company. This would ensure legal rights to control and enforce profit maximization for the network company, and institutional investors would probably able and willing to execute their rights to safeguard the returns on their 10% stake. Thus, we believe that a legal unbundling, combined with a partial ownership unbundling could be a beneficial solution. Legislation could e.g. allow ownership of the network company by a holding company also active in the related up- and downstream markets, but only up to a maximum of, say, 90%.

Finally, there might be political economy reasons why there is a bad perception of legal unbundling. We have shown that legal unbundling does also yield the highest profits for the upstream company. It is likely that in many situations the mirror image of this is that the competitors' profits are lower. For instance, in the linear demand version of the Bertrand model, profits of the downstream competitor are higher under separation compared to legal unbundling. It is probably not surprising that former integrated incumbents favor legal unbundling over separa-

tion due to negative effects on their profits, while for competitors the preference ordering is reversed. However, our analysis highlights the simple insight that high profits for the former incumbent are not, as such, welfare deteriorating, or need to reduce consumer surplus (in our analysis, the opposite applies).

Finally, let us remark that we have left out a couple of generally important issues. For instance, we have not discussed "vertical economies", i.e. possible efficiency gains from vertical integration from a technological or transaction cost point of view. The evidence for their existence is not crystal clear, however, a couple of authors find some, more or less economically significant, vertical economies (e.g. Fraquelli *et al.* (2005), Kwoka (2002), or Kaserman and Mayo (1991)). It is likely that such economies of vertical integration can not be fully realized under legal unbundling, though to a larger extent than with compete separation (e.g. the hold-up problem is likely to be reduced, since at least $F_1$ would, in an investment decision, take into account the surplus accruing to $F_0$). We have investigated cost reducing investment, which might be of importance in particular in the energy industry. However, in other industries, quality improving investments by the upstream company might also play an important role. For such investments, it is less clear that legal unbundling would generally establish better investment incentives. Actually, we doubt this, given the mixed (theoretical) results by Buehler *et al.* (2006) and the finding by Buehler *et al.* (2004) that even the effect on final quantity of quantity increasing investments is not generally clear (although they share the intuition that it should increase output).

# 7 Conclusion

In this paper we have demonstrated that from a theoretical point, legal unbundling can be seen as a "golden mean" between complete separation and full vertical integration. If legal unbundling can ensure that the network company controlling the essential facility maximizes only the own profits, legal unbundling ensures higher quantities and better investment incentives, which usually will also lead to higher social surplus.

If a full separation of interest between the network company and the downstream operations can not be ensured, the theoretical results are less clear cut: on theoretical grounds it can no longer be exclude that full separation can lead to higher quantities than legal unbundling. However, in many plausible cases legal unbundling will imply higher quantities even if the interests are to some extent aligned.

A combination of legal unbundling with the obligation to take on minority shareholders for the undbundled network company appears to be a pragmatic compromise that ensures independence of the network company and which at the same time can exploit at least some of the benefits of (perfect) legal unbundling.

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# Appendix A: Proofs

We prove Propositions 1, 3, 4, 5, 6 and Lemma 1 and 2 directly for the more general regulatory schemes introduced in section 5. The original propositions are a special case of this set-up where revenues of $F_0$ are given by $R = (a - c_0)Q$.

Proof of Proposition 1: Proposition 1 is a direct implication of Propositions 4 and 5.■

Proof of Proposition 2: (Cournot) It is easy to show that quantity under legal unbundling is weakly higher than under vertical integration, i.e. $Q^u \geq Q^v$. Under legal unbundling $F_0$ sets $h^u$ such as to maximize total output $Q^u$ and an output of $Q^u = Q^v$ can always be guaranteed by using the same sabotage strategy under legal unbundling as under vertical integration, i.e. by setting $h^u = h^v$. This is because downstream firms have the same payoff functions under legal undbundling and vertical integration and we have therefore the same downstream outcome when $h$ is the same.

We will show now that output under weakly unbundling is also weakly higher than under separation, i.e. $Q^u \geq Q^s$. $F_0$ can guarantee an output of $Q^u = Q^s$ by setting $h_1^u = h_1^s + (a - c_0)$ and hampering all other entrants in the same way as under vertical separation, i.e. setting $h_i^u = h_i^s$ for all $i$=2,...,n. With such hampering $F_1$ maximizes under legal unbundling

$$\pi_1^s(q) + (a - c)q_2.$$

where $\pi_1^s(q)$ denotes $F_1$'s profit function under vertical separation. The added term $(a - c)q_2$ has no influence on $F_1$'s best reply function and therefore both firms have the same best reply functions than under vertical separation, leading to the same equilibrium outcome.■

Proof of Proposition 3: Proposition 3 is a direct implication of Propositions 4 and 5.■

Proof of Proposition 4: (effect of $\sigma$) Consider two ownership shares $\sigma^a$ and $\sigma^b$ with $\sigma^a < \sigma^b$. Let $h^a$ and $h^b$ be the optimal choice of $F_0$ under $\sigma^a$ and $\sigma^b$, respectively. Let $x^a$ ($x^b$) be the optimal choice of $F_1$ given $\sigma^a$ and $h^a$ ($\sigma^b$ and $h^b$), and let $x^{ba}$ be the optimal choice of $F_1$ given $\sigma^b$ and $h^a$.
Optimal choice by $F_0$ implies

$$\pi_0(x^b, h^b) \geq \pi_0(x^{ba}, h^a)$$

Optimal choice by $F_1$ implies

$$\pi_1(x^a, h^a) + \sigma^a \pi_0(x^a, h^a) \geq \pi_1(x^{ba}, h^a) + \sigma^a \pi_0(x^{ba}, h^a)$$
$$\pi_1(x^{ba}, h^a) + \sigma^b \pi_0(x^{ba}, h^a) \geq \pi_1(x^a, h^a) + \sigma^b \pi_0(x^a, h^a)$$

Adding these two inequalities and dividing by $(\sigma^b - \sigma^a)$ yields together with the first inequality:

$$\pi_0(x^b, h^b) \geq \pi_0(x^{ba}, h^a) \geq \pi_0(x^a, h^a)$$

Since profits of $F_0$ are weakly increasing in quantity this yields the result $Q(x^b, h^b) \geq Q(x^{ba}, h^a) \geq Q(x^a, h^a)$.■

Proof of Proposition 5 (effect of $\rho$): Consider $\rho^a$ and $\rho^b$ with $\rho^a < \rho^b$. Let $h^a$ and $h^b$ those handicaps that maximize $F_0$'s profits under $\rho^a$ and $\rho^b$, respectively. Let $\pi_i(h) = \pi_i(x(h), h)$. By optimal choice we must have

$$\rho^a \pi_1(h^a) + \pi_0(h^a) \geq \rho^a \pi_1(h^b) + \pi_0(h^b)$$
$$\rho^b \pi_1(h^b) + \pi_0(h^b) \geq \rho^b \pi_1(h^a) + \pi_0(h^a).$$

Note that $\pi_0(h^a) \geq \pi_0(h^b)$ implies that $Q(h^a) \geq Q(h^b)$ since profit of $F_0$ is weakly increasing in total output. If $\rho^a = 0$ the result thus follows directly from the first inequality. If $\rho^a > 0$ divide the first inequality by $\rho^a$, the second inequality by $\rho^b$. To get $(\frac{1}{\rho^a} - \frac{1}{\rho^b})\pi_0(h^a) \geq (\frac{1}{\rho^a} - \frac{1}{\rho^b})\pi_0(h^b)$ and therefore $Q(h^a) \geq Q(h^b)$.■

Proof of Lemma 1: The proof resembles the proof that $Q^u \geq Q^s$ from above. Let $c_0^a$ and $c_0^b$ be two marginal costs with $c_0^a > c_0^b$. Let $h^a$ $F_0$'s optimal $h$ if marginal costs are $c_a$. Under legal unbundling $F_0$ wants to maximize total output $Q$. We

show that $F_0$ can guarantee $Q^b \geq Q^a$ by setting $h^b = h^a$. Optimal choice by $F_1$ implies

$$\pi_1(x^a, h^a) + R\left(Q(x^a, h^a)\right) - c_0^a Q(x^a, h^a) \geq \pi_1(x^b, h^a) + R\left(Q(x^b, h^a)\right) - c_0^a Q(x^b, h^a)$$
$$\pi_1(x^b, h^a) + R\left(Q(x^b, h^a)\right) - c_0^b Q(x^b, h^a) \geq \pi_1(x^a, h^a) + R\left(Q(x^a, h^a)\right) - c_0^b Q(x^a, h^a)$$

Adding up the two inequalities yields $(c_0^a - c_0^b)Q(x^b, h^a) \geq (c_0^a - c_0^b)Q(x^a, h^a)$ and therefore $Q(x^b, h^a) \geq Q(x^a, h^a)$.■

Proof of Proposition 6: Let $I_a$ and $I_b$ be two investment levels with $I_a < I_b$ and let $c_0^a$ and $c_0^b$ with $c_0^a > c_0^b$ be the resulting marginal costs. Let $\Delta_{ab}^u := \pi_0^b(h_b^u, x_b^u) - \pi_0^a(h_a^u, x_a^u)$, $\Delta_{ab}^s := \pi_0^b(h_b^s, x_b^s) - \pi_0^a(h_a^s, x_a^s)$ and $\Delta_{ab}^v := \pi_{01}^b(h_b^v, x_b^v) - \pi_{01}^a(h_a^v, x_a^v)$ denote the changes in $F_0$'s objective function when marginal costs change from $c_a$ to $c_b$ (excluding the change in investment costs $I_b - I_a$) under the different vertical structures.

We will first derive a lower bound on $\Delta_{ab}^u$. Recall that $\pi_0$ is strictly increasing in total output. Therefore $Q(h_b^u, x_b^u)$ is the highest quantity that $F_0$ can achieve with marginal costs $c_0^b$ and by Lemma 1 also no higher quantity can be achieved under marginal costs $c_0^a$. Therefore $\pi_0^a(h_a^u, x_a^u) \leq \pi_0^a(h_b^u, x_b^u)$ has to hold. Furthermore, we find $\pi_0^b(h_b^u, x_b^u) - \pi_0^a(x_b^u, h_b^u) = \left(c_0^a - c_0^b\right)(Q(h_b^u, x_b^u))$.Together with the definition of $\Delta_{ab}^u$ these two results imply

$$\Delta_{ab}^u \geq \left(c_0^a - c_0^b\right) Q(h_b^u, x_b^u).$$

We will now show that $\Delta_{ab}^u - \Delta_{ab}^s \geq 0$ and $\Delta_{ab}^u - \Delta_{ab}^v \geq 0$ which implies that under legal unbundling we will always find weakly higher higher investment than under separation as well as integration.

(i) $\Delta_{ab}^u - \Delta_{ab}^s \geq 0$ : Under complete separation the total quantity $Q^s$ is independent of $F_0$'s cost structure. Thus moving from $c_a$ to $c_b$ changes $F_0$'s profits by

$$\Delta_{ab}^s = \left(c_0^a - c_0^b\right) Q^s.$$

By Proposition 1, $Q_b^u \geq Q^s$ and using the lower bound on $\Delta_{ab}^u$ we find

$$\Delta_{ab}^u - \Delta_{ab}^s \geq \left(c_0^a - c_0^b\right)\left(Q_b^u - Q^s\right) \geq 0.$$

(ii) $\Delta_{ab}^u - \Delta_{ab}^s \geq 0$ : Since under vertical integration both $F_0$ and $F_1$ want to maximize $\pi_{01}$, we have $\pi_{01}^a(h_a^v, x_a^v) \geq \pi_{01}^a(h_b^v, x_b^v)$. Furthermore, we find that $\pi_{01}^b(h_b^v, x_b^v) - \pi_{01}^a(h_b^v, x_b^v) = \left(c_0^a - c_0^b\right) Q(h_b^v, x_b^v)$. Together with the definition of $\Delta_{ab}^v$ these two results imply $\Delta_{ab}^v \leq \left(c_0^a - c_0^b\right) Q(h_b^v, x_b^v)$. By Proposition 1 we have $Q(h_b^u, x_b^u) \geq Q(h_b^v, x_b^v)$ and using the upper bound on $\Delta_{ab}^u$ we therefore find $\Delta_{ab}^u - \Delta_{ab}^v \geq \left(c_0^a - c_0^b\right)\left(Q_b^u - Q_b^v\right) \geq 0$.■

Proof of Lemma 2: Standard case of price competition, see derivation in Section 4.

Proof of Lemma 3: At price $c_2 + a$ $F_1$ prefers to give the whole market to firm 2, since $\pi_1$ is strictly negative for all prices below $c_1 + a$. $F_0$ can guarantee this outcome by not hampering firm 2 and therefore no equilibrium with a higher price than $c_2 + a$ can exist. If $a$ is large there could be cases with an equilibrium price $p'$ strictly between $c_0 + c_1$ and $c_2 + a$ where $F_1$ gets the whole market, however. Although $\pi_1$ would be negative this can be compensated by higher total output and therefore a higher $\pi_0$. But such an equilibrium can only arise if the access price is Pareto-dominated by a lower access price. To see this consider an access price $a' < a$ that fulfills $a' + c_2 = p'$. With such an access price $F_1$ would prefer to give the whole market to firm 2 at price $p'$ instead of taking the market itself since at price $p'$ (since $\pi_1$ is negative under $p'$). Access price $a'$ Pareto-dominates access price $a$, because neither firm 2 nor consumers are worse off, and the joint profit of $F_1$ and 0 and therefore also total welfare is strictly higher under this outcome with access price $a'$.■

Proof of Lemma 4: If $F_1$ gets the market then the optimal price is $F_1$'s monopoly price under costs $c_1 + c_0$. If $F_2$ gets the total market it is optimal that this happens at the lowest possible price that $F_2$ is ever willing to pay, i.e. $c_2 + a$. Joint profit $\pi_{01}$ can also not be higher in a situation where both firms split total output at some price $p$. Since goods are perfect substitutes and marginal costs linear, $\pi_{01}$ from splitting the market is at least as high if either only $F_1$ or only $F_2$ gets the

total market at the same price $p$.■

Proof of Proposition 7: We prove the first sentence of the proposition for the case of legal unbundling; for vertical separation the steps are similar. Total welfare, excluding investment costs, under legal unbundling is in our Bertrand model given by

$$W^u = CS(p^u) + p^u Q(p^u) - (c_0 - \delta + c_2)\, Q(p^u)$$

where the market price $p^u = a + c_2$ does not depend on $c_0$ and $\delta$. We thus find $\frac{\partial W^u}{\partial \delta} = Q^u$ and $\frac{\partial^2 W^u}{\partial \delta^2} = 0$. Maximization of $W^u(\delta) - I(\delta)$ is therefore equivalent to the first order condition

$$I'(\delta_u^o) = Q^u.$$

$F_0$ will choose its actual level of cost reduction $\delta_u$ in order to maximize its profit $(a - c_0 + \delta)\, Q(p^u) - I(\delta)$. The profit maximizing $\delta_u$ fulfills the same first order condition than $\delta_u^o$, i.e.

$$I'(\delta_u) = Q^u.$$

Therefore $\delta_u = \delta_u^o$ and $I_u = I(\delta_u) = I(\delta_u^o) = I_u^o$.

The proof of the second sentence is by use of an example. Let $Q(p) = 1 - p$ and $I(\delta) = \frac{3}{4}\delta^2$ such that $I'(\delta) = \frac{6}{4}\delta$. Let $c_1 = 0.3$, $c_2 = 0.25$, $c_0 = 0.5$ an $a = 0.74$. Then for all $\delta$ the monopoly case will be selected under vertical integration since, $1 - 0.8 + \delta - 2\sqrt{(0.24 + \delta)\,(0.01)} \geq 0$ for all $\delta > 0$. We will get $\delta_m^o = 0.2$ and $\delta_m = 0.1$. As well as $\frac{I_m^o}{I_m} = 4$. This means the optimal investment would be 4 times higher than the actual investment under vertical integration.■

# Appendix B: Additional Results

## B1: Outcome when $F_0$ can charge higher access price for $F_1$

What would happen if the regulator would allow $F_0$ to charge a higher access price $a_1 > a$ to $F_1$ than to $F_2$? Under vertical integration the results do not change. Under legal unbundling and vertical separation, $F_1$ makes now more profit on every unit sold to $F_1$ and therefore has incentives to artificially increase the output of $F_1$ by handicapping $F_2$.

Under complete separation $F_1$ will get the whole market at price $p = a + c_1$ and $F_2$ will be handicapped, s.t. $h_2 = c_1 - c_2$.

Under legal unbundling $F_1$ will get the whole market at price $p = c_0 + c_1$.

In general when $F_0$ can charge a higher access price for $F_1$ (or prices are not regulated at all), legal unbundling is not a good option. Why not? Because $F_0$ can charge a very high access price to $F_1$, which still is willing to produce a lot, because it gets all the surcharge $a_1 - c_0$ back from the profits of $F_0$. Thus what we find the extreme is $a_1 \to \infty$ and $F_0$ does all hampering such as to maximize the quantity of $F_1$ $q_1$. This, of course, can be very inefficient if it means to kick out $F_2$ even from niches of the market that are much more efficiently served by $F_2$. In summary for legal unbundling to work, it is important to fix access prices of both firms. If $F_0$ is not regulated, legal unbundling is also not a good idea.