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Legal unbundling can be a golden mean between vertical integration and ownership separation ☆

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ABSTRACT

We study an industry in which an upstream monopolist supplies an essential input at a regulated price to several downstream firms. Legal unbundling means in our model that a downstream firm owns the upstream firm, but this upstream firm is legally independent and maximizes its own upstream profits. We allow for non-tariff discrimination by the upstream firm and show that under quite general conditions legal unbundling never yields lower quantities in the downstream market than ownership separation and integration. Therefore, typically, consumer surplus will be largest under legal unbundling. Outcomes under legal unbundling are still advantageous when we allow for discriminatory capacity investments, investments into marginal cost reduction and investments into network reliability. If access prices are unregulated, however, legal unbundling may be quite undesirable.

1. Introduction

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

We analyze a third alternative: legal unbundling. Legal unbundling means that the essential input must be controlled by a legally independent entity with an autonomous management, but a firm that is active in the downstream market is still allowed to own this entity. Ownership under legal unbundling entitles the downstream firm to receive the entity's profits, but interferences in the entity's operations are forbidden.

Forms of legal unbundling are commonly observed in network industries. In Europe, legal unbundling is the current standard requirement for the energy industry in Europe, and it can also be imposed by national regulators in the telecoms market.[1] An interesting

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[1] For the electricity market, see Directive 2009/72/EC. For distribution, Article 26 requires legal unbundling. For transmission, Article 9 generally requires ownership unbundling, but as an exemption, allows for an independent Transmission System Operator (TSO), Article 18 and 19. The TSO is essentially also a form of legal unbundling. Similar for the gas market, see Directive 2009/73/EC, Articles 9, 18, 19. For telecommunications, see Directive 2009/140/EC, Article 2 (introducing Article 13a into Directive 2002/19/EC) for the option to impose further "functional separation". Cave (2006) provides an overview on different intensities of vertical separation.

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example in the telecoms market is the UK, where the incumbent British Telecom has separated the network access part into a separate legal entity ("Openreach"). Detailed arrangements with the regulator Ofcom are meant to ensure independence of Openreach.[2] In the US, forms of legal unbundling exist for natural gas pipelines and in large parts of the electricity transmission systems.[3] In all these regulations, it is the bottleneck facility which must be legally separated, while it can still be owned by a group active on the non-bottleneck part. An important alternative setup is one which requires the non-bottleneck activity to be legally separated, while still owned by the firm controlling the bottleneck. The latter was formerly required in the US in the telecommunications industry: the Regional Bell Operating Companies (RBOC) were obliged to legally separate long-distance call business (i.e., the non-bottleneck part of telecommunications).[4] Thus, in addition to analyzing whether legal unbundling can be beneficial, it is import to understand which kind of legal separation is most promising.

Irrespective of how the industry is vertically structured, the price for the essential input is usually regulated. Typically, regulators use linear tariffs above the marginal cost, e.g., in order to allow for the coverage of fixed costs. While non-discrimination with respect to the access tariff is relatively easy to impose,[5] non-tariff discrimination remains an important problem in practice. Regulators and competitors report of such "sabotage" in the form of discriminatory information flows, undue delays in delivery of the service, overly complex contractual requirements, requiring unreasonably high bank guarantees, and the like.[6] Our research question therefore is: how does legal unbundling compare to the outcomes of vertical integration and ownership separation if access prices are regulated while non-tariff discrimination cannot be prevented?

To answer this, we propose a fairly general setup. There is 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 c_0, which the downstream firms need in a fixed proportion 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. In the downstream market, the incumbent moves first; no other restrictions are imposed on the downstream competition. Strategies could, for example, affect quantities, (non-linear) prices, investments or entry decisions. That the incumbent moves first is mainly a simplifying assumption; we exemplify with Cournot competition that the main results also apply with simultaneous moves in the downstream market.

The upstream firm F_0 sells the input to all downstream firms at a regulated linear access price a above marginal cost (we also extend this setup to more general forms of price regulation). Although price discrimination is not possible, F_0 can "sabotage" the downstream firms, i.e., it can influence the cost and demand situation of each downstream firm.

Four different vertical structures are compared: integration of F_0 and F_1; ownership separation (i.e., all firms are independent); legal unbundling (F_0 is legally independent and maximizes its own profits; F_1 owns F_0 and therefore acts to maximize joint profits, taking as given that F_0 cares only about its own profits); and finally, we discuss also "reverse unbundling" where the downstream firm is legally unbundled (F_1 acts independently and maximizes its own profits, while F_0 acts to maximize joint profits, taking as given that F_1 cares only about its own profits). "Reverse unbundling" is close to the former telecoms (RBOC) regulation in the US.

Our main result is that legal unbundling leads to (weakly) higher levels of output than all the other vertical structures. In many cases, higher output will translate into higher consumer surplus under legal unbundling. The intuition why legal unbundling leads to higher quantities than vertical integration is as follows. Due to the access price regulation, upstream profits of F_0 are maximized when total output is maximal. Thus, if F_0 is legally unbundled, it wants to maximize total output and refrains from sabotage of the downstream firms. In contrast, with vertical integration, F_0 also takes into account downstream profits of F_1 and may engage in sabotage of downstream competitors in order to increase downstream profits. We call this the *"sabotage effect"*.

When comparing legal unbundling to ownership separation, different forces are at work. First, since in both cases the upstream firm wants to maximize total output, neither under legal unbundling nor under ownership separation will the upstream firm (usually) sabotage downstream firms, i.e., there is essentially no sabotage effect.

Second, while a vertically separated downstream firm F_1 is interested only in its own profits, under legal unbundling F_1 also has an interest in high upstream profits — and thereby in a high overall output. Under legal unbundling, the downstream firm F_1 will therefore select strategies that yield higher total output compared to separation. We call this the *"downstream expansion effect"*.

Part of the downstream expansion effect is explained by the well-known intuition from the double marginalization problem: Under legal unbundling the incumbent calculates with the true input costs c_0 and not – as under separation – with the higher access price a and is therefore willing to expand output. In addition, the incumbent takes into account that he can induce an output change by downstream competitors. We call this the *"induced output effect"*. For instance, in the case of legal unbundling and price competition, the incumbent sets a lower price than under separation, in order to increase the output of entrants, who respond to the more aggressive pricing by lowering their own prices. That the induced output effect is indeed additional to the effect from double marginalization becomes apparent when one considers more sophisticated regulatory schemes that solve the double marginalization problem. We also provide a Bertrand example to highlight this.

Since one of the main policy concerns is about efficient network investments, we extend our analysis to different forms of investment decisions. Given our quantity results, it is quite intuitive that incentives for reducing the upstream firm's marginal costs are highest under legal unbundling. We also discuss capacity investments, which can discriminate between downstream firms, and incentives to invest in network reliability. For these two types of investments it is not generally clear that legal unbundling provides the highest investment incentives, although legal unbundling exhibits some desirable properties also for these sorts of investment decisions.

Despite its great policy relevance, there is little literature on legal unbundling. Two important exceptions are Sibley and Weisman

[2] See, e.g., Ofcom's annual report 2005/06, Section B, p. 18–20, or the consultation on "Re-prioritising BT's remaining Undertakings commitments on information systems separation", published 29 May 2009.

[3] See Federal Energy Regulatory Commission, Order 636 (issued 1992-04-18) for natural gas and Order 2000 (issued 1999-12-20) for electricity transmission.

[4] See Section 272 of the Telecommunications Act of 1996.

[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 skeptical about such tariffs. See, e.g., European Commission, Energy Sector Inquiry, Competition report on energy sector inquiry (Jan. 10, 2007), part 1, para 155, p. 58. In the German telecommunications market, the incumbent Deutsche Telekom used to offer an access product (needed to offer narrowband internet access, and called T-Online-Connect-Interconnect) with a quantity rebate. Only its own subsidiary, "T-Online" had enough sales to benefit from this rebate. 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 (Jan. 10, 2007), Competition report on energy sector inquiry, part 1, para 169, or para 493, p. 163: For the Telecommunications sector in the UK, see Cave (2006), p.91, or for Germany see a submission of the VATM (Association of competitors to Deutsche Telekom) to the European Commission, "Markteintrittsbarrieren im deutschen Telekommunikationsmarkt", September 2001.

(1998) and Cremer, Crémer and De Donder (2006). They introduced the idea that the unbundled firm independently maximizes its own profits, while being a fully-owned subsidiary. A major difference is that they focus on "reverse unbundling". Sibley and Weisman analyze in a Cournot model whether an upstream monopolist has stronger incentives for sabotage under reverse legal unbundling than under vertical integration. They find mixed results. Cremer et al. (2006) compare reverse legal unbundling to ownership separation and find that the former leads to higher total output, while our analysis tends to predict the opposite. The reason for the difference in results is that Cremer et al. (2006) analyze a situation with unregulated access charges and they do not consider sabotage. In Section 5.3 we briefly highlight that access price regulation is an important precondition for our results to apply.[7] It is important to stress that we focus on "perfect legal unbundling". In a companion paper, (Höffler and Kranz, 2007), we analyze the effects of imperfections in legal unbundling, and in Section 6 we briefly review these results.

Our contribution is related to the general literature on vertical integration, where an overview is provided, e.g., in Perry (1989). Vickers (1995) is also related, who compares vertical integration with separation under access price regulation and finds mixed welfare results. More recent papers compare investment incentives under vertical integration and separation, like Buehler, Schmutzler and Benz (2004), who find that generally incentives for quality investments are higher under vertical integration. Foros (2004) also analyzes a situation where an integrated firm competes downstream with a rival who needs an essential input from the integrated firm. His paper focuses on the trade-off between generating downstream competition (by introducing access regulation) versus providing incentives for investments in the quality of the input (when the integrated firm is restricted to linear tariffs for the input).

Our paper is also related to a literature that focuses on the issue of sabotage; see, e.g., Economides (1998), Beard, Kaserman and Mayo (2001) or, for an overview, Mandy (2000). Most recently, Mandy and Sappington (2007) compared cost increasing to demand decreasing sabotage in vertical relationships. We analyze a more general setup without restrictions on the downstream firms' cost functions, the strategic variables of downstream competition, or the impact of sabotage. We also allow for more general regulatory schemes than linear access pricing and introduce legal unbundling as an alternative ownership structure.

Studying legal unbundling also offers interesting insights into the role of ownership in the theory of the firm. The defining characteristic of ownership can be the right on residual cash-flows (i.e. profits) as in Alchian and Demsetz (1972) or, alternatively, a residual right of control as in Grossman and Hart (1986). Whereas under vertical integration both rights are granted to the incumbent, under legal unbundling ownership entitles to a claim on residual cash-flows, but grants no (or very limited) residual rights of control.

The remainder of the paper is organized as follows. Section 2 presents the basic model, where we assume a regulated linear access price, and where we derive the general results. Section 3 discusses the robustness of our results with respect to the timing of the downstream competition. It also applies the general results to well-known set-ups for the downstream competition (Cournot, Bertrand) and to a simple example of downstream investments with externalities. Section 4 examines the different types of upstream investments. In Section 5, we present a general class of regulatory pricing schemes (including two-part tariffs for downstream firms), for which our results hold. Section 6 discusses the results, policy implications, and the effects of imperfect legal unbundling. Section 7 concludes. Unless otherwise stated, all proofs can be found in the Appendix.

2. Basic model and main results

2.1. Structure and regulation

There is a monopolistic upstream firm F_0 that produces a good at constant marginal cost c_0, which is used as input good for n competing downstream firms, $F_1,\ldots,F_n$. 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. We assume F_0 is a regulated natural monopoly, e.g. the owner of an essential network element in electricity or telecommunication markets. The regulator fixes a per-unit access price $a>c_0$ that F_0 must charge from all downstream firms (in Section 5, more general pricing schemes are considered).

2.2. Non-tariff discrimination

The regulator can enforce the access price 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 discrimination or sabotage strategy against downstream firms, like non-disclosure of essential information or undue delays in the provision of ancillary services. Discrimination can influence costs for certain downstream firms or influence their demand, e.g. by creating inconveniences for customers. We assume that the choice of h has no direct impact on the profit of F_0, although perhaps indirectly it does, if it changes the total quantity sold.

2.3. Downstream decisions and payoffs

An action of downstream firm i is denoted by x_i and $x=(x_1,\ldots,x_n)$ denotes a profile of actions selected by the downstream firms. Downstream actions can describe a broad range of decisions, e.g., about quantities, prices, investments, or entry.

Downstream actions, together with upstream discrimination, determine downstream firm i's output $q_i(x,h)$, its market price $p_i(x,h)$ and total costs $C_i(x,h|a)$. Total output quantity is given by $Q(x,h)=\sum_{i=1}^{n} q_i(x,h)$. F_0's profits are given by

$$\pi_0(x,h|a) = (a-c_0)Q(x,h)-K+S \tag{1}$$

The constant K represents fixed costs and the constant S possible state subsidies. Note that these upstream profits π_0 are strictly increasing in total output Q. Profits of downstream firm i are given by

$$\pi_i(x,h|a) = p_i(x,h)q_i(x,h)-C_i(x,h|a) \text{ for } i=1,\ldots,n \tag{2}$$

Besides a regularity condition on equilibrium existence (Condition C1 below), we make no restrictions on functional forms.

2.4. Timing

We consider the following timing. First, F_0 chooses its sabotage strategy h. Unless otherwise stated, we assume that the downstream incumbent F_1 moves first and that $F_2,\ldots,F_n$ can observe the chosen action x_1. Whether the other downstream firms afterwards move simultaneously or sequentially does not matter for our results. The assumption that the incumbent moves first significantly facilitates the analysis. The basic intuition carries over also to standard simultaneous move games (Cournot, Bertrand); however, for these games some additional standard regularity assumptions are required. We solve for subgame perfect equilibria.

[7] Van Koten (2008) discusses an alternative interesting problem in the presence of legal unbundling: the bottleneck capacity is limited and sold in an auction, where one of the bidders is the owner of the bottleneck firm. In this context, legal unbundling gives rise to a "toehold effect" (Bulow et al., 1999), which tilts the auction result in favor of the integrated firm.

2.5. Vertical structures

We compare the following four vertical structures.

v:Vertical integration. F_0 and F_1 maximize their joint profits π_{01}, given by

$$\pi_{01} = \pi_1 + \pi_0 \tag{3}$$

s:Ownership separation. All firms maximize their own profits π_i.
u: Legal unbundling: F_0 maximizes its own profits, whereas F_1 maximizes the joint profits π_{01}.
r: Reverse legal unbundling: F_0 maximizes joint profits π_{01} and F_1 maximizes its own profits π_1.

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

Legal unbundling requires that the network part, or more generally, the part of the company controlling the essential facility, has to be separated into a legally independent entity. The EU legislation on energy explicitly states, however, that legal unbundling does not imply that the integrated firm has to sell the network operations. (Directive 2009/72/EC, Article 9 (Economides, 1998); Directive 2009/73/EC, Article 9 (Economides, 1998)). Thus, 100% ownership of the network operations F_0 by the incumbent F_1 is current practice under legal unbundling in many European countries (e.g. in the energy industries in France and Germany).

Legal unbundling in our model is perfect in the sense that we assume that regulators are able to incentivize the management of F_0 such that it maximizes only upstream profits π_0 without considering the incumbent's downstream profits π_1. Arguably, this does not always reflect the actual practice of legal unbundling; however, existing legislation explicitly excludes direct instructions of the mother company (Directive 2003/54/EC, Article 10 and 15) or prescribes arm's-length relations (US Telecommunications Act 1996, Section 272 (b) (Cave, 2006)). Other rules and initiatives may help to implement legal unbundling in a way that comes closer to the "ideal" form assumed in the model. This includes the current requirement in the EU energy industry to have strict personnel separation, ensuring that professional interests of the upstream firm's employees are separated from downstream interests (e.g. the network unit's managers should not participate in the group's stock option programs). However, to see how our results are affected by a less stringent separation of interests, we discuss the effects of "imperfect legal unbundling" in Section 6.

2.6. Regularity conditions

Since we compare different vertical structures, we essentially compare outcomes of different games. Note, however, that – although payoffs of F_0 and F_1 differ – the timing, the set of players and the strategy space is the same under every vertical structure. To facilitate the comparison of different vertical structures, we introduce two regularity conditions. A *situation* shall describe a vertical structure and a non-terminal history of the multi-stage game, i.e. a history where at least one player still has to move. In order to avoid technical complications that could arise if some continuation games have no subgame-perfect equilibrium, we require:

C1. *In every situation there is a subgame-perfect continuation equilibrium.*

Note that for some forms of downstream competition and sabotage technologies, a given situation can have multiple subgame-perfect continuation equilibria. To simplify comparison between vertical structures in those cases, we also make a regularity condition on equilibrium selection:

C2. *Assume two situations have an identical set of subgame-perfect continuation equilibria. Then in both situations the same subgame-perfect continuation equilibrium shall be selected from this identical set.*[8]

This regularity condition avoids tedious comparison of sets of equilibria. Note that C2 is obviously not needed when, in every situation, there is a unique continuation equilibrium. The following remark summarizes the essential implications of the regularity conditions for the subgame-perfect equilibria in our model:

Remark. *Since downstream entrants' profits do depend on h and x, but not directly on the vertical structure, our regularity condition implies that the equilibrium actions of downstream entrants are a function of h and x_1 only. Furthermore, assuming the same sabotage strategy h is chosen under legal unbundling and vertical integration, then downstream firms choose the same equilibrium actions x, since the incumbent maximizes joint profits $\pi_0+\pi_1$ under both vertical structures.*

We are now ready to state our first basic result.

Proposition 1. *Under (perfect) legal unbundling, total output Q and upstream profits π_0 are at least as high as under vertical integration. The result still holds under downstream competition in simultaneous moves.*

Intuitively, total output is higher under legal unbundling than under vertical integration because vertical integration can cause a *sabotage effect*. Recall from the remark that the outcome under legal unbundling and vertical integration can differ only if F_0's sabotage strategy h differs. (This still holds true if the downstream incumbent moves simultaneously with downstream entrants.) Under legal unbundling, F_0 considers only upstream profits π_0 and therefore chooses h in order to maximize total output Q. This choice can usually be interpreted as performing no sabotage. Under vertical integration, however, F_0 has incentives to sabotage downstream competitors whenever sabotage sufficiently increases the incumbent's downstream profits π_1 — even though the sabotage may decrease upstream profits π_0 and total output Q. We now state our second basic result:

Proposition 2. *Under (perfect) legal unbundling total output Q and upstream profits π_0 are least as high as under ownership separation.*

The intuition for Proposition 2 differs from that of Proposition 1. Under both legal unbundling and separation, the upstream firm F_0 wants to maximize total output Q, i.e. there is no sabotage effect. In contrast to separation, under legal unbundling the downstream incumbent F_1 participates in the upstream profits π_0 and therefore has an interest to select a decision x_1 that expands total output Q. We call this the *downstream expansion effect*.

To gain further intuition for the downstream expansion effect, we consider some specific examples of downstream competition. It is helpful to decompose the output expansion under legal unbundling into two parts: the change in the incumbent's own output q_1 and an *induced output effect* that measures the aggregate change in downstream entrants' output.

Consider first the simple case that there are no entrants and F_1 is a downstream monopolist, i.e. there is no induced output effect. Then the output expansion under legal unbundling is due to the intuition known from the double marginalization problem: Under legal unbundling F_1 considers only the true marginal cost c_0 instead of the higher access price a and therefore chooses a higher output than under separation.

[8] Note that there is no conceptual problem in determining whether continuation equilibria under different vertical structures are identical or not, since equilibria are strategy profiles and the strategy space is the same under every vertical structure.

In the presence of entrants, the incumbent additionally takes the induced output effect into account. In the case of price competition, basically, the incumbent sets an aggressively low price in order to induce higher output by the downstream entrants who match the low price. If firms compete in quantities, a quantity expansion by the incumbent typically induces an output reduction by the entrants. Since the incumbent moves first, he will always take the induced output effect into account and we will thus never find that F_1 takes an action such that total output is lower under legal unbundling than under separation. This means the downstream expansion effect will never be negative when F_1 moves first.

What is left to discuss is the case of "reverse unbundling". F_0 maximizes $\pi_0+\pi_1$, whereas F_1 has an independent management and maximizes π_1. Therefore, the upstream firm F_0 has the incentive to sabotage entrants, i.e., the sabotage effects reduce output compared to ownership separation. At the same time, the downstream incumbent F_1 does not take the downstream expansion effect into account. This leads to lower output than the case of vertical integration. Therefore, reverse unbundling combines the negative effects of ownership separation (no downstream expansion) and of vertical integration (sabotage).

Proposition 3. *Total output Q and upstream profits π_0 under reverse legal unbundling are never larger than under ownership separation. The result still holds under downstream competition in simultaneous moves.*

Whether output is higher under reverse legal unbundling or vertical integration depends on the details of downstream competition and the sabotage technology. Results are ambiguous because the downstream-expansion effect can sometimes increase incentives for upstream sabotage (for examples, see Sibley and Weisman, 1998, and Höffler and Kranz, 2007).

2.7. Welfare Implications

Our output results suggest that from the consumers' perspective, legal unbundling is likely to be superior to the other vertical structures. In particular, if the downstream products are homogenous (like, e.g., voice calls, electricity, or gas) and if downstream 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.*

Legal unbundling can also be preferred by taxpayers, since F_0 makes higher profits than under the other vertical structures: if the regulatory regime requires an ex ante subsidy that ensures that F_0 will break even, then such a subsidy would be lowest under legal unbundling.

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

Without assumptions on how discrimination works and how downstream competition works, results on total welfare are not possible. Clearly there are cases where legal unbundling leads to higher output but to lower welfare, for example if there are sunk costs and legal unbundling facilitates excess entry (see, e.g., Mankiw and Whinston, 1986). Nevertheless there will be many cases where total welfare is also highest under legal unbundling. For example, it is always true in the homogeneous goods duopoly with price competition discussed in the Section 3.

3. Robustness and applications

For our main result, Proposition 2, we used that the downstream incumbent F_1 moves first in the downstream competition. Nevertheless, the basic intuition of the downstream expansion effect prevails even if downstream firms move simultaneously, i.e., F_1 still prefers higher total output under legal unbundling than under ownership separation. However, without putting more structure on downstream competition and sabotage, one cannot generally exclude the possibility that the incumbent's desire to have higher total output may paradoxically lead to lower total output in equilibrium. We illustrate robustness by investigating a standard model of simultaneous move downstream competition, namely Cournot competition.[9]

Afterwards, we highlight with a model of price-competition that the "induced output effect" is an additional, output expanding effect that is independent of the well-known double marginalization issue. We then investigate costly sabotage, before finally we illustrate the downstream expansion effect for an example with downstream investments.

3.1. Robustness: Downstream simultaneous moves (Cournot)

Consider Cournot competition downstream and a sabotage technology that linearly increases costs. This means the upstream decision is described by a vector $h=\{h_1,\ldots,h_n\}\in R^n$ and the costs of a downstream firm i become $C_i(h) = (a + h_i)q_i + \tilde{C}_i(q_i)$ where $\tilde{C}_i(q_i)$ is just some arbitrary function of q_i. With this assumption, we retain our result of larger quantities under legal unbundling also for the case of simultaneous quantity competition:

Proposition 4. *Consider the special case of the linear sabotage technology. Assume downstream firms compete by simultaneously setting quantities. Then total output is (weakly) higher under legal unbundling than under separation, vertical integration, and reverse unbundling.*

Under Cournot competition, the incumbent does not directly take the induced output effect into account, i.e., its best reply function takes competitors' output as given. The downstream expansion effect is therefore driven by the double marginalization problem: under legal unbundling, the incumbent calculates with true marginal cost c_0 instead of the higher access price a. Typically,[10] a reduction in one firm's marginal costs will lead to a higher total output in the Cournot equilibrium, which then would imply strictly higher quantities under legal unbundling.

3.2. Induced output effect: price competition (Bertrand)

Consider a market where the downstream incumbent engages in price competition with a more efficient entrant. The products of the incumbent and entrant are perfect substitutes. Total demand in the market is given by a downward sloping demand function $Q(p)$.We assume that the incumbent F_1 moves first. Downstream firms have constant marginal cost with a cost disadvantage for the incumbent. Considering a cost disadvantage for the incumbent is of interest since a standard argument for liberalizing markets is to allow more efficient firms to enter the downstream market.

As in our Cournot example, sabotage shall linearly increase downstream costs. Thus, cost functions are given by

$$C_i(q_i) = (c_i + a + h_i)q_i,\ i = 1,2,\ \text{with}\ c_1 > c_2.$$

To avoid uninteresting case distinctions, we make the following regularity conditions. First, we assume that for some prices above the incumbent's marginal cost plus access price $a+c_1$ there is still

[9] For the case of simultaneous price competition (possibly with differentiated products), a sufficient condition for a non-negative downstream expansion effect is that prices are strategic complements and that total demand is weakly decreasing in the price of each firm.

[10] For standard stability conditions, see Dixit (1986) and the summary in Shapiro (1989).

positive demand, i.e. a separated incumbent could make positive profits if it were a downstream monopolist. Second, we assume that if F_2 were a monopolist on the downstream market, its optimal monopoly price lies above $a+c_1$. Third, we assume that the access price a is not so high that it is Pareto-dominated by some lower access price. This means it is not the case that all firms and consumers would be weakly better off (and at least one of them strictly better off) by some lower access price. As is well known, in this set-up multiple equilibria can arise. We only consider equilibria in which firms do not play weakly dominated strategies.

Finally, if both firms charge the same price the following tie-breaking rule applies. (i) If the price is above F_2's marginal cost, i.e. $p>c_2+a$, we assume that F_2 gets the whole market (for the out-of-equilibrium event that $p_1=p_2<c_2+a$, we assume F_1 gets the whole market). (ii) 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. $q_1 = q_2 = \frac{1}{2}Q$.[11]

In this framework, ownership separation is almost identical to the textbook Bertrand case, where the equilibrium price equals the constant marginal cost of the less efficient firm, $p=a+c_1$ and the more efficient firm gets the whole market. The only slight complication is that we assume that the less efficient firm moves first:

Lemma 1. *Under ownership separation in every equilibrium F_2 gets the whole market. The infimum of the market prices from all equilibria where no firm plays a weakly dominated strategy is $p=a+c_1$.*

No sabotage occurs, since this would only reduce output and thereby lower F_0's profits. Under legal unbundling F_0 again wants to maximize total output and therefore will not sabotage. Contrary to ownership separation, now the downstream incumbent F_1 has an incentive to increase total output, since F_0's profits will accrue to F_1 under legal unbundling. Therefore, F_1 will price more aggressively in order to increase output and thereby increases upstream profits sufficiently. This form of aggressive pricing is taken to the extreme in our case of price competition with homogeneous goods, because here F_1 prices more aggressively without even having some positive market share:

Lemma 2. *Under legal unbundling F_0 sets $h_2=0$. F_1 and F_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 be below F_1's true marginal cost c_0+c_1, it is not a weakly dominated strategy for F_1 to price below $a+c_2$. This is because if F_1 would set a higher price, F_2 would react with a higher price, and therefore the profit of the integrated firm $\pi_0+\pi_1$ would be reduced.

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), or F_0 does not sabotage F_2 and then F_1 acts in the same way as under legal unbundling (the "competitive" outcome).

Lemma 3. *If F_0 and F_1 are integrated, there are two candidates for equilibrium: (m) monopoly case: set $h_2=\infty$ and let F_1 serve the whole market at the monopoly price of the integrated firm, denoted by p_{01}^m. (u) competitive case: 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. The monopoly outcome applies whenever the cost disadvantage of the incumbent is sufficiently small.*

[11] The assumptions capture the idea that, if prices were discrete on a sufficiently fine grid, then (i) F_2 as second mover would prefer minimally to undercut the price if $p>c_2+a$ and prefer not to sell any output if $p<c_2+a$; and (ii) 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.

Therefore, integration can never lead to a higher quantity than legal unbundling but sometimes (in the monopolistic outcome) to a strictly lower. With very inefficient own downstream operations, even the integrated firm might find it optimal to use F_2 as its "sales channel" and receive only the upstream profits. In this case, clearly, sabotage would not make sense.

Under reverse legal unbundling we either have the same market price as under separation or the monopoly price of an integrated firm. In fact, the worse of these two outcomes is realized, i.e. reverse legal unbundling is weakly worse than both separation and vertical integration.

Lemma 4. *Under reverse legal unbundling the market price will be $p=max\{p_{01}^m, a+c_1\}$. At price $a+c_1$ firms F_1 or F_2 may produce, but at price p_{01}^m, F_1 will serve the whole market.*

From comparing the four cases, we can immediately conclude:

Proposition 5. *In the Bertrand example, under legal unbundling, prices are strictly lower, and total output, profit of F_0, consumer surplus and total welfare are strictly higher than under separation, reverse legal unbundling and the monopoly case of vertical integration. (In the competitive case of vertical integration, we have identical outcomes to legal unbundling).*

Finally, we turn to the question what happens when the double marginalization problem becomes negligible. This happens when $a\to c_0$, since then also in the case of separation the downstream firm calculates with (almost) the true marginal cost of the input good. Only under legal unbundling will the outcome approach the welfare-optimal outcome, i.e. a first-best market price of c_0+c_2. Under separation, the market price converges to a higher level of c_0+c_1 and under vertical integration always the sub-optimal monopoly case arises.

Proposition 6. *For $a\to c_0$, the welfare-optimal outcome is approached under legal unbundling, but not under the other vertical structures.*

What is responsible for this striking difference is the induced output effect: in this example, it yields significantly larger quantities under legal unbundling, i.e. a significant downstream expansion effect, even when the double marginalization problem becomes arbitrarily small.

3.3. Sabotage that is costly for the upstream firm

So far we assumed that sabotage is costless. However, sabotage might cause costs, e.g., in the form of expected fines for violating non-discrimination obligations. Costly sabotage does not tend to qualitatively change our results since direct cost of sabotage would make quantity reducing sabotage activities even more unattractive for the network firm.

That the quantity results hold with costly sabotage is true explicitly in the Cournot and Bertrand example just discussed. With Bertrand, the network firm could induce the highest output by not sabotaging any downstream firm. The same applies for the Cournot example if standard regularity conditions (see footnote 10) are satisfied. Therefore, the result that perfect legal unbundling leads to least as high output as the three other vertical structures would still hold true if higher levels of sabotage would be costly for the network firm (in the sense that sabotage costs increase in h_i). There would be no incentive for sabotage under legal unbundling and ownership separation. The incentives for sabotage under vertical integration and reverse legal unbundling would be reduced, but sabotage may still occur if sabotage costs are not too high.

3.4. Downstream investments and technological externalities

Consider the situation where several railway companies compete using the same rail infrastructure. These downstream firms can invest in improving reliability of their service, which increases the probability of trains being on time. If the downstream activities are meshed, i.e., passengers take connecting trains from other operators, such that an investment will increase not only quality of (and thereby the demand for) the investing company, but also for the other firms.

Such a constellation directly gives rise to an induced output effect. With ownership separation, we will see underinvestment in quality since each downstream firm does not take into account the positive externality on the other firms. In the case of legal unbundling, the incumbent F_1 at least partially internalizes the externality. It takes into account that the own investment will increase the downstream competitors' quality, thereby also their demand, which in turn will lead to more demand for the essential input (using the rail tracks).

For a simple example, consider a market in which an incumbent and more efficient entrant, who has lower marginal costs, offers perfect substitutes and competes in prices (similar to our previous example). In addition, the incumbent F_1 can make an investment $A \in \{0,1\}$ that increases demand. Market demand shall be inelastic and given by $Q(p) = 1 + A$. Choosing $A = 1$ costs the incumbent $k > 0$, while choosing $A = 0$ is costless.

If upstream sabotage is not possible the incumbent will choose $A = 0$ under ownership separation, since the more efficient entrant will always serve the market. Under legal unbundling, the entrant also serves the whole market, but the incumbent receives the network profits $(a - c_0)(1 + A - c_2 - a)$, which are strictly increasing in A. Thus, whenever the costs k are below $a - c_0$, the incumbent will optimally choose $A = 1$.

If we allow for upstream sabotage in the same form as in the previous examples, it can happen that the upstream firm sabotages the entrant under ownership separation. The reason is that sabotage can make the incumbent capture the whole market and induce him to perform demand expanding investments. Also in that case, output under legal unbundling will be strictly higher whenever $k < a - c_0$, since the investment of $A = 1$ can then be induced without sabotage. A detailed comparison of all four vertical structures requires somewhat tedious case distinctions, but Propositions 1–3 guarantee that resulting output under legal unbundling will always be as least as high as under the other vertical structures.

4. Upstream investments

4.1. Investments in network capacity and discriminatory investments

Many types of upstream investments, e.g. expansion of network capacity, will influence operational and investment decisions of downstream firms and thereby affect the total output.[12] Benefits and impediments from upstream investments can accrue differently to different downstream firms. For example, investments into interconnection capacity to a foreign country can benefit foreign energy producers who can expand their sales in the domestic market of the network operator.

In the policy debate, there are severe concerns that vertical integration and legal unbundling lead to socially inefficient allocations of such investments, because of overlapping interests of the network operator and the downstream incumbent. The EU Commission states:

> Vertically integrated network operators have no incentive for developing the network in the overall interests of the market and hence for facilitating new entry at generation or supply levels; on the contrary, they have an inherent interest to limit new investment when this will benefit its competitors and bring new competition onto the incumbent's "home market". Instead, the investment decisions made by vertically integrated companies tend to be biased to the needs of supply affiliates. Such companies seem particularly disinclined to increase interconnection or gas import capacity and thereby boosting competition in the incumbent's home market to the detriment of the internal market.[13]

The Commission also makes clear that in its opinion only ownership unbundling, i.e. complete separation, can effectively solve this problem in energy markets:

> 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. (EU Commission, 2007, p. 7)

As we have shown, not all overlapping interests are problematic. Under legal unbundling, the downstream expansion effect as one sort of an overlapping interest is rather beneficial. Therefore, a more careful analysis of the investment incentives may turn out to be useful.

For the theoretical analysis it is helpful to split F_0's investment decisions into two steps. One step is to decide on the allocation of investment if the total amount that shall be invested is given. The other step is to decide which total amount shall be invested.

4.1.1. Investment allocation with given budget

Assume that the total amount of upstream investment spending is given. Then we can take our basic model and interpret F_0's strategic variable h not only as a sabotage strategy, but also as a decision about the investment allocation, which influences downstream firms' costs and output. This interpretation is completely consistent with our model where downstream firms' output, prices and costs are given by some general functions $q_i(x,h)$, $p_i(x,h)$ and $C_i(x,h|a)$. It is also fulfilled that the allocation of investment has no influence on F_0's costs, because the total amount invested is assumed to be given in this step. Thus, our general results apply, i.e., investment decisions under legal unbundling will lead to an output at least as high as under the other ownership structures.

4.1.2. Endogenous investment budget

Examining the second step, we cannot rule out, however, that the total amount of investment is lower under legal unbundling than under the alternative vertical structures. There even exist cases in which the resulting quantities can be lower under legal unbundling.

We first explain why investments I^s and resulting total output Q^s under separation may exceed the investments I^u and total output Q^u under legal unbundling in some circumstances. Assume that (i) the incumbent is more efficient than the entrants, such that absent an investment, no entrants would be active and (ii) an investment would yield a level playing field for entrants and the incumbent. Under separation and without investment, the double marginalization problem would lead to a quantity lower than under legal unbundling. Thus, investing would yield a large increase in downstream quantities

[12] To avoid misunderstandings, note that in this section terms like "capacity investments" will refer to the decisions h of the upstream firm. We do not present a formal model of downstream capacity investments in the sense of, e.g., Kreps and Scheinkman (1983). Instead, we will stick with the general formulation that downstream decisions x can affect downstream profits and output in arbitrary ways.

[13] Proposal for amending Directive 2003/54/EC concerning common rules for the internal market in electricity, (issued 2007-09-19), p.5.

if, due to the investment, we moved from, say, a downstream monopoly to a Bertrand duopoly with identical costs. This increases upstream profits significantly and implies that the investment would be undertaken even if it is relatively costly. With legal unbundling, however, the network unit F_0 might find it optimal not to invest, since it can anticipate that in the quantity decision of the incumbent F_1, the double marginalization problem is internalized and the quantity is relatively large already without an investment.

That investments under vertical integration, I^v, can be higher than under legal unbundling, $I^u < I^v$, is less surprising and applies already in quite intuitive examples. Consider an investment that benefits only the incumbent F_1, who might then be able to drive competitors out of the market. This might reduce overall quantity, such that with legal unbundling the network unit F_0 would abstain from such an investment. While, in this case, investments are lower under legal unbundling, and quantities will (typically) be higher under legal unbundling. However, it is not possible to generally rule out that legal unbundling with discriminatory investments can yield lower quantities than vertical integration.

Although total output may be lower under legal unbundling when the investment budget is endogenous, we can establish the following results:

Proposition 7. *With general upstream investments, F_0's profits from network operations π_0 minus investment costs are weakly higher under legal unbundling than under both separation and vertical integration. Total output fulfills the following inequalities:*

$$(a-c_0)(Q^s-Q^u) \leq I^s-I^u \text{ and } (a-c_0)(Q^v-Q^u) \leq I^v-I^u.$$

Concerns about the incumbent's downstream profits play no role in those cases where investment levels are lower under legal unbundling. If investments and total output are lower under legal unbundling this is because higher investment is not worthwhile for the network operator itself.

The inequalities of Proposition 7 show that the output differences $Q^s - Q^u$ and $Q^v - Q^u$ can become large only if the difference in investment costs becomes large. One can, therefore, conjecture that such "expensive" expansions of downstream quantities are not welfare-enhancing. However, a comprehensive welfare analysis is not possible in our general framework.

The inequality also shows that possible under-investment may be reduced by increasing the access price a. This might be done in ways that do not distort downstream firms' demand when using the more general regulatory schemes discussed in Section 5.1.

4.2. Investments in reducing upstream marginal costs

We now consider process innovations, i.e., investments of F_0 which reduce its marginal cost c_0 by some amount δ. Investment costs $I(\delta)$ are strictly increasing in the level of the marginal cost reduction δ. We first establish the following helpful lemma, which just proves the intuitive idea that for a lower level of upstream marginal costs total output will be weakly higher.

Lemma 5. *Total output under legal unbundling is weakly decreasing in F_0's marginal cost c_0.*

Provided with this intuitive result, it can be shown that investments and resulting output are highest with legal unbundling.

Proposition 8. *Investment into upstream marginal cost reduction and total output under legal unbundling are weakly higher than under ownership separation, vertical integration, and reverse unbundling.*

This investment result is, of course, mainly driven by the output results of Propositions 1–3. When a higher quantity is sold under legal unbundling there are obviously higher gains from cost reduction. Although intuitive, Proposition 8 is not completely trivial, since investments change the output and the extent to which marginal cost reduction increases output can be larger under vertical integration than under legal unbundling. Proposition 8 shows that investments are nevertheless always weakly higher under legal unbundling.[14]

4.3. Investments into network safety and reliability

An important issue for energy and railway networks is safety and reliability. If the network breaks down, severe costs may be inflicted upon the network operator itself, on downstream firms, as well as on final consumers and on other members of society.

Appropriate investments into network reliability are therefore an important issue. Integrated electricity companies sometimes claim that vertical integration is essential to guarantee reliable network operations. One may argue that reliability investments could, indeed, be larger under vertical integration, since not only losses of the network operator but also losses of the own downstream operations are taken into account. However, as long as the losses for the rest of society are not considered, reliability investments will be too low under all vertical structures, including vertical integration.

Sufficient levels of reliability investments therefore require contractual solutions that can impose fines in case of network breakdowns or – in cases where contractual solutions are not feasible – fines imposed by the regulator or direct regulation. We do not see a compelling reason why such contractual and regulatory arrangements should be more difficult to achieve under legal unbundling than under the other vertical structures.

Sometimes, however, there may be problems to identify who was responsible for some network failure. Was it a mistake on the part of the upstream firm or on the part of the downstream firm that led to the break-down? In those cases there may be welfare losses due to costly litigation in case of ownership separation. Such conflicts would not arise in case of vertical integration. In the case of legal unbundling, since F_1 receives all profits from F_0, F_1 also has limited interests in costly arguments over the responsibility for failures.

5. Alternative regulatory pricing schemes

5.1. A general class of price regulation schemes where legal unbundling is optimal

So far we assumed that the regulator sets a linear access price $a > c_0$. In this section we show that our results are not restricted to linear access prices but apply under a larger class of regulatory regimes.

Linear access prices fulfill two conditions:

(**L1**) F_0's profits π_0 only depend on total output Q, but it does not matter which downstream firms produce how much of it.
(**L2**) F_0's profits π_0 are strictly increasing in total output Q.

Our main results hold for every price regulation scheme that fulfills conditions (L1) and (L2). Let α denote a price regulation scheme that fulfills (L1) and (L2). It determines how much money F_0 receives when selling a total output Q, which we denote by a revenue function $R(Q|\alpha)$. Furthermore the scheme α specifies how much

[14] We also have extended the price competition example of the previous section to investments into marginal cost reduction. Legal unbundling then always yields the welfare-optimal level of investments. A proof is available from the authors upon request.

downstream firms have to pay when actions x are chosen (which imply quantities q_i). Thus profits are given by

$$\pi_0(x,h|\alpha) = R(Q(x,h)|\alpha) - c_0 Q(x,h) - K + S$$
$$\pi_i(x,h|\alpha) = p_i(x,h)q_i(x,h) - C_i(x,h|\alpha) \text{for } i = 1,\ldots,n$$

To ensure that (L2) is fulfilled, we require that for all $Q', Q' > Q$, it holds that $R(Q'|\alpha) - c_0 Q' > R(Q|\alpha) - c_0 Q$.

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 9. *The following results hold for every regulatory pricing scheme that fulfills (L1) and (L2): Proposition 1, 2, 3, 7 (first sentence) and 8.*

Our proofs for the mentioned propositions in the Appendix all use the more general class of regulatory schemes introduced in this section. 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 good investment incentives.

Many regulatory regimes try to drive access prices down to marginal cost. This tends to be beneficial since it reduces the double marginalization problem for the downstream competitors. However, at the same time it may reduce the downstream expansion effect (though it need not eliminate it, see Proposition 6). One (theoretical) solution would be to de-couple the network firm's remuneration from the price that network users have to pay. Consider the following scheme: the regulator pays the upstream firm a linear access price $a > c_0$, while the regulator charges the downstream firms a two-part tariff with an access price equal to c_0 plus a fixed fee (e.g., to transfer it to F_0 to cover its fixed cost). Although this scheme is exposed to the problem of regulatory capture (since the network firm receives direct payments from the regulator), it has two benefits: first, it solves the double marginalization problem for the downstream firms. Second, a high access price a provides strong incentives for F_0 to maximize total output. Thus this scheme reaps the benefits from the downstream expansion effect, without having the costs of the double marginalization problem.

For an illustration that even in the total absence of the double marginalization problem the quantity can be *strictly* larger under legal unbundling, consider the price competition example from Section 3.2. If we assume that F_0's markup $a - c_0$ is financed by a subsidy (rather than a fixed fee), the analysis under this regulatory scheme is very similar to the original analysis and the results are straightforward: under legal unbundling the entrant serves the whole market at the welfare-optimal price of $c_0 + c_2$, while under ownership separation the entrant serves the market at a higher price of $c_0 + c_1$.

5.2. Industry structure-dependent optimal access regulation

So far we compared the outcomes for different vertical structures holding fixed the access price regulation. However, the regulator might well be aware that optimal access regulation depends on the vertical industry structure. For example, the regulator could choose the access regulation optimally for each industry structure in the sense that it maximizes total output (i.e., we assume that welfare or at least consumer surplus increases in quantity), under the restriction that the upstream firm can recover its fixed costs.

Our results imply that legal unbundling leads to (weakly) higher total output than under ownership separation, vertical integration, and reverse unbundling also for the case that such optimal access prices are chosen in every vertical structure. Recall that we have shown that for *every* linear access price $a > c_0$ (and for every general price regulation α fulfilling conditions L_1 and L_2) legal unbundling leads to (weakly) higher output than the other vertical structures. Thus even for the access price that e.g. yields the highest output under vertical integration, legal unbundling will lead to (weakly) higher output. The output difference will even increase if for legal unbundling one would also choose the optimal access price.

5.3. Absence of access regulation

It is important to note that legal unbundling can yield very bad outcomes if access prices are unregulated. If F_0 could freely decide on access prices, the strategy that maximizes upstream profits π_0 would be to charge the incumbent F_1 a very high access price and at the same time use all available measures to maximize F_1's output, which could involve massive sabotage of downstream competitors. F_1 is willing to pay such a high access price, because it gets the money back through F_0's profits. Although in reality this mechanism will likely not appear in this extreme form, the basic incentive distortions are nevertheless likely to exist without price regulation. Along the lines of this example, a seemingly harmless rule that only prescribes a maximum access price for downstream competitors, but allows (or requires) higher access prices for the downstream incumbent may have quite negative outcomes. Thus whenever there is no access price regulation or the conditions (L1) and (L2) from above are violated, legal unbundling may lose its appealing properties.

6. Discussion

6.1. EU energy markets

What does our approach contribute to economic policy debates? We want to illustrate this using one of the most important regulatory debates in the European Union, namely the discussion about ownership unbundling in the electricity and gas industry.

While our analysis suggests that under rather general assumptions legal unbundling exhibits desirable properties, the European Commission holds a negative view on legal unbundling in the European energy market. Neelie Kroes, European Competition Commissioner, expressed her views 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.[15]

A key concern in the European policy debate on vertical industry structures are investment incentives, in particular, for investments in cross-border transmission capacities. Such investments could pave the way for an integrated European market for electricity with an increased level of competition. Also for this issue, the EU Commission prefers ownership separation over legal unbundling. In the words of Commissioner Kroes:

> As you will know, where interconnector capacity is scarce, it is auctioned off to the highest bidder, generating congestion revenues. If you look at our report, you will find that from 2001 to 2005, three German TSOs generated congestion revenues of over 400 million Euros. Of these revenues, under 30 million Euros were used to build new interconnectors — that's less than 10%!In contrast, our experience shows that fully unbundled operators see clearer incentives for investment in interconnectivity, and act on those incentives, because they are focused on optimizing the use of the network.[16]

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

[16] Neelie Kroes, European Commissioner for Competition Policy, "A new European Energy Policy; reaping the benefits of open and competitive markets" Energy conference: E-world energy & water, Essen, 5th February 2007.

Although the European Commission views ownership separation (or ownership unbundling) as the most preferred vertical industry structure, it has positively considered an alternative structure with an "independent systems operator":

> […] the Commission has also examined an alternative approach known as 'ISO' or Independent System Operator, whereby the vertically integrated company maintains ownership of the network assets and receives a regulated return on them, but is not responsible for their operation, maintenance or development.[17]

We believe that our analysis helps to understand better the effects from measures mentioned in the three quotes. We discuss the three points in turn.

6.2. Imperfect unbundling

First, our theoretical analysis assumed that legal unbundling works perfectly in separating the interests of the network company from the rest of the integrated group. This seems often not to be the case. Thus, it is important to understand what happens if the network company acts not completely independently and also takes into account the profits of the downstream firm F_1.This is analyzed in detail in Höffler and Kranz (2007). There it is shown that reducing the independence of the network firm yields the expected result of lowering total output. Put differently: more independence, i.e. a stronger regulation, increases the output. The optimum ownership structure therefore can depend on the strength of regulation. Höffler and Kranz (2007) show that if regulation is weak, ownership separation can indeed yield higher quantities than legal unbundling. However, if regulation is sufficiently strong, the results of the current paper apply (i.e. highest quantities under legal unbundling).

Since the effect of legal unbundling therefore seems to depend on the strength of regulation, the negative experiences of regulators may well be explained by insufficiently strong regulation. Although "sufficiently strong" regulation might not be implementable as such, it might also be the case that intensifying regulation is possible and that such a strengthening of regulation will lead to a situation where legal unbundling is the preferred vertical structure. This could be done either by stronger legal requirements or by stricter implementation of existing rules. The second quote illustrates the point. Only since 2005 have German network companies been legally obliged to reinvest profits from the interconnector auctions[18] — thus, legal requirements have become more strict (irrespective of the question whether this particular tightening of regulation is sensible — below we propose an alternative approach to this problem). If the integrated companies still get away with not reinvesting, this would be due to a lack of enforcement of legal rules. The European Commission itself states that the existing rules are not yet fully implemented.[19] Thus, too little independence might at least partially be due to too weak implementation of existing regulation.

The resulting policy implication, therefore, is to strengthen regulation and to thoroughly implement the existing regulations in order to increase the independence before changing the regime towards full separation. Additionally requiring legally unbundled firms to take on a minority outside investor, could help to increase independence. Consider a minority stake of, say 10%, of an institutional investor in the network company. The interest of the downstream firm in the network profits would still be large, such that beneficial effects of legal unbundling are still significant; at the same time, the investor has an interest in enforcing that the network company maximizes only its own profits.

6.3. Investment incentives

The issue of investments, addressed in the second quote, is also interesting in light of our findings. From a theoretical perspective, completely separated network operators will also have incentives to provide only a monopoly amount of interconnector capacity – below the socially optimal level – if they directly receive the congestion revenues from the interconnector auctions.[20] Theory can also predict that legal unbundling can aggravate this problem, since under legal unbundling the downstream incumbent may bid higher prices in the capacity auction in order to increase congestion revenues and thereby the profits of the network operator.

In this context, our discussion of more general regulatory schemes proves useful. One suggestion is to modify the capacity auction as follows: The regulator receives the revenues from the capacity auction and pays the network operator a regulated fixed access price for every unit that is sold in the auction. Then the network operator cannot influence the price it receives and therefore has no incentives to act like a capacity-reducing monopolist. Such a regime satisfies the assumptions of Section 5.1; thus, we expect that legal unbundling will yield a higher output than separation under this modified regulation scheme.

6.4. Independent system operator

Finally, consider the issue of independent system operators, subject to a rate of return regulation, mentioned in the third quote. The driving force for the benefits of legal unbundling over separation in our model is the fact that the downstream incumbent receives the network operator's profits and therefore wants to increase total output. But if, as suggested, the downstream incumbent only receives a regulated return on its network assets (independent of the profits from network operations), it has no incentive to increase total output, and the benefits of legal unbundling compared to separation would not arise.

We conclude the discussion with two remarks. First, concerning the question whether the bottleneck activities should be legally unbundled (the European electricity regulation status quo) or the downstream activities (the former US Telecommunications regulation for RBOCs), our results show that the latter (the reverse unbundling) performs worse at least in terms of total output. Abstracting from all other reasons for abandoning Section 272 of the 1996 telecommunications act, our analysis provides further support for this policy choice.

Second, we have left out some 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 somewhat unclear, however. Fraquelli, Piacenza and Vannoni (2005), Kwoka (2002), or Kaserman and Mayo (1991), for example, find evidence for more or less economically significant vertical economies. Although such economies of vertical integration may not be fully realized under legal unbundling, they should be realized to a larger extent than under complete separation. For example, the hold-up problem is likely to be reduced under legal unbundling, since F_1 would in an investment

[17] Idem. The "ISO", as well as the "Independent transmission system operator" solution were implemented as alternatives to ownership unbundling, see footnote 1.

[18] More precise: the EU electricity regulation requires re-investment, but allows, as an exemption, to alternatively use auction proceeds to reduce network fees (Regulation (EC) No 714/2009, Article 16 (6)). This is taken up in the German regulation, turning the exemption more into an equally valid option (Stromnetzzugangsverordnung as of 25-07-2005, § 15 (3)), which can be seen as a weak implementation of the EU regulatory rule.

[19] That legal unbundling requirements are not yet fully implemented is explicitly noticed by the European Commission: "Even where Member States have adopted unbundling provisions required under the Second Gas Directive, this does not mean that TSOs necessarily comply with them." (Sector Inquiry, Part 1, para 153, p. 57, SEC(2006) 1724, as of 10-01-2007).

[20] See Höffler and Wittmann (2007) for a discussion of "supply reduction" in interconnector auctions.

decision take into account the surplus accruing to F_0 and also has no interest in costly ex-post bargaining with F_0.

7. Conclusion

In this paper, we have demonstrated that legal unbundling can be seen as a "golden mean" between ownership separation and full vertical integration. If access prices are regulated and legal unbundling can ensure that the network company, controlling the essential facility, maximizes only the own profits, legal unbundling ensures higher quantities than the other vertical structures. This result is important, since higher quantities typically imply that also consumer surplus will be higher under legal unbundling. Furthermore, we find that it does make a difference whether the bottleneck part is legally separated, or the non-bottleneck part. If access charges are regulated while non-tariff discrimination remains possible, the latter (our case of reverse legal unbundling) is less favorable than the former (our legal unbundling).

A key message of our analysis is that, in addition to the sabotage effect, policy makers should also consider the *downstream expansion effect*: under legal unbundling – compared to ownership separation – the incumbent's downstream operations not only internalize the double marginalization problem but additionally can induce an output expansion by competitors. Most pronounced, in the case of downstream price competition, the incumbent prices more aggressively compared to a vertically separated downstream company, since this leads to a price reduction and higher quantities of downstream competitors and thereby to higher profits of the upstream operations.

We also analyzed investment incentives. Legal unbundling provides better incentives for investments into the reduction of marginal costs and for the allocation of a given budget for capacity investments. Although we cannot generally rule out cases where legal unbundling leads to lower budgets for capacity investments, our results suggest that even in those cases legal unbundling may often be welfare superior. Concerning investments into network reliability, we argued that contractual solutions or appropriate regulation are needed under all vertical structures to ensure sufficient levels of investment.

We demonstrated that our results not only apply for linear access prices, but also for more general regulatory regimes. In the absence of price regulation, legal unbundling loses its appealing properties, however.

Policy recommendations cannot ignore the negative experiences of regulators so far with legal unbundling. Our contribution is to offer a fairly general economic analysis of legal unbundling which helps to see potential benefits and to identify the necessary prerequisites for these benefits to apply. Our tentative policy recommendation would therefore be as follows. First of all, regulators should try to implement legal unbundling as rigorous as possible, with particular emphasis on the independent decision making in the unbundled network unit. Furthermore, one might consider to oblige legally unbundled network operators to take on minority shareholders. Only if experiences are still negative, or if the cost of a diligent implementation of legal unbundling are too high (for the regulator or the regulated companies) should a regime shift towards full ownership separation be considered.

Appendix. Proofs

We prove Propositions 1, 2, 3, 7 (first sentence) and 8 and Lemma 5 directly for the more general regulatory schemes introduced in Section 5. The original propositions are a special case of this set-up, since a linear access price $a > c_0$ fulfills conditions (L1) and (L2). We will generally use the notation Q^u, Q^r, Q^v and Q^s to denote the resulting outputs, under legal unbundling, reverse legal unbundling, vertical integration and separation, respectively and similarly h^u, h^r, h^v, h^s and x^u, x^r, x^v, x^s for firms' equilibrium choices in the different vertical structures.

Proof of Proposition 1. Under legal unbundling, F_0 sets h in order to maximize upstream profits π_0, and by choosing the same sabotage strategy as under vertical integration, F_0 can guarantee the same level of upstream profits — recall from the remark before Proposition 1 that the outcome under both structures will be the same whenever the sabotage strategy h is the same, even if downstream firms move simultaneously. Since π_0 is strictly increasing in total output Q and vice versa, also total output under legal unbundling is always as least as high as under vertical integration. □

Proof of Proposition 2. We show that F_0 can guarantee a weakly higher total output under legal unbundling than under separation, i.e. $Q^u \geq Q^s$ by choosing under legal unbundling the same sabotage strategy as the optimal sabotage strategy h^s under separation, i.e. by setting $h^u = h^s$. Let $x_{-1}(x_1, h)$ denote the chosen profile of entrants' actions given that the downstream incumbent chooses x_1 and the network firm chooses h. Under full separation, the incumbent F_1 then chooses x_1^s in order to maximize $\pi_1((x_1, x_{-1}(x_1, h^s)), h^s)$, and under legal unbundling F_1 chooses x_1^u to maximize $\pi_1((x_1, x_{-1}(x_1, h^s)), h^s) + \pi_0((x_1, x_{-1}(x_1, h^s)), h^s)$. We denote by $x^s = (x_1^s, x_{-1}(x_1^s, h^s))$ and $x^u = (x_1^u, x_{-1}(x_1^u, h^s))$ the corresponding profiles of downstream actions.

Optimal choice by F_1 implies

$$\pi_1(x^s, h^s) \geq \pi_1(x^u, h^s)$$

$$\pi_1(x^u, h^s) + \pi_0(x^u, h^s) \geq \pi_1(x^s, h^s) + \pi_0(x^s, h^s)$$

Adding both inequalities yields $\pi_0(x^u, h^s) \geq \pi_0(x^s, h^s)$ and since upstream profits π_0 are strictly increasing in total output, this implies that total output is weakly higher under legal unbundling than under separation, i.e. $Q(x^u, h^s) \geq Q(x^s, h^s)$. □

Proof of Proposition 3. If F_0 sets the same sabotage strategy under separation as under reverse legal unbundling, i.e. $h^s = h^r$ the total output and π_0 will be the same, since downstream firms will act in the same way. Since under separation F_0 wants to maximize total output and π_0, it will achieve output and π_0 at least as high as under reverse legal unbundling, which is guaranteed by setting $h^s = h^r$. □

Proof of Proposition 4. (Cournot) F_0 can guarantee the same output under legal unbundling as under separation, 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 ownership separation, i.e. setting $h_i^u = h_i^s$ for all $i = 2, \ldots, n$. With such hampering F_1 maximizes under legal unbundling

$$\pi_1^s(q) + (a - c) \sum_{j=2}^{n} q_j.$$

where $\pi_1^s(q)$ denotes F_1's profit function under ownership separation. The added term $(a - c) \sum_{j=2}^{n} q_j$ has no influence on F_1's best reply function and therefore both firms have the same best reply functions as under ownership separation, leading to the same equilibrium outcome. □

Proof of Lemma 1. Standard case of price competition, see derivation in Section 3.2. In the pricing game, like under simultaneous moves, there are also other equilibria, but they involve the use of weakly dominated strategies. 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. To be precise, in the equilibrium with a price of exactly $a + c_1$, F_1 also plays a weakly dominated strategy since for no action of F_2 will F_1 make positive profits. But there is a sequence of equilibrium prices that converges from above to

$a+c_1$, where in no such equilibrium a firm plays a weakly dominated strategy. □

Proof of Lemma 2. At price c_2+a the incumbent F_1 prefers to give the whole market to the entrant F_2, since π_1 is strictly negative for all prices below c_1+a. The upstream firm F_0 can guarantee this outcome by not sabotaging the entrant F_2. Since output is decreasing in price and F_0 wants to maximize total output under legal unbundling, no equilibrium with a price higher than c_2+a can thus exist. If a is large, there could also exist a case with an equilibrium price p' strictly between c_0+c_1 and c_2+a where the incumbent F_1 supplies the whole market. Although the incumbent's downstream profit π_1 would then be negative, integrated profits $\pi_1+\pi_0$ could be higher than under the outcome where F_2 gets the whole market at price c_2+a, because total output Q and upstream profits π_0 are higher. We show that such an equilibrium price $p'\in(c_0+c_1,c_2+a)$ can only arise if the access price is Pareto-dominated by some lower access price.

To see this, consider an access price $a'<a$ that fulfills $a'+c_2=p'$. If the entrant is not sabotaged, then under access price a', the incumbent F_1 would prefer to give the whole market to the entrant F_2 at price p' instead of supplying the market itself (since π_1 is negative under p'). Also note that the network firm has no means to induce the incumbent F_1 to supply the whole market at a price that is lower than p' by using sabotage against F_2. If that were the case, that sabotage would already been optimal for the network firm under access price a, since if F_1 supplies the whole market the joint profit maximizing price is independent of the access price.

Thus in the equilibrium under access price a' consumers are equally well off and pay the same price p' as under the equilibrium with access price a. The entrant makes again zero profits, but there is a welfare gain from the more efficient organization of downstream production that realizes itself in higher profits for the integrated incumbent. □

Proof of Lemma 3. 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 π_{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, π_{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. In the monopoly case profits of the integrated firm are given by $\pi_{01}^m=(p_{01}^m-c_0-c_1)Q(p_{01}^m)$ and in the competitive case its profits are given by $\pi_{01}^u=(a-c_0)Q(c_2+a)$. We find $\frac{\partial(\pi_{01}^u-\pi_{01}^m)}{\partial c_1}>0$ and $\frac{\partial(\pi_{01}^u-\pi_{01}^m)}{\partial c_2}<0$, i.e. the competitive outcome becomes relatively more attractive for the integrated firm if the cost disadvantage of the own downstream operations is sufficiently large. For $c_1=c_2$ an integrated monopolist can achieve at least the same profit than under the competitive outcome, since by setting a price of $p=a+c_2$, monopoly profits would be given by $(a-c_0)Q(c_2+a)$. Under the optimal monopoly price, profits are weakly higher, however. □

Proof of Lemma 4. Since under reverse legal unbundling F_1 maximizes its own profits π_1 and by assumption plays no weakly dominated strategy, F_1 will never set a price below $a+c_1$. Together with our assumption that the entrant's monopoly price lies above $a+c_1$, this implies that no equilibrium with a price below $a+c_1$ exists. Since F_0 maximizes joint profits $\pi_0+\pi_1$, and since π_1 is non-negative for all prices $p\geq a+c_1$, F_0 weakly prefers that F_1 serves the whole market. Joint profits π_{01} would then be maximized if F_1 gets the downstream market at the monopoly price p_{10}^m. This outcome can be achieved for the case $a+c_1\leq p_{10}^m$ if F_0 sets h_2 such that $a+c_2+h_2=p_{10}^m$. If $a+c_1>p_{10}^m$, integrated profits π_{01} are maximized if F_1 serves the market at price $p=a+c_1$. This outcome can be achieved if F_0 sets h_2 such that $a+c_2+h_2=a+c_1$. □

Proof of Propositions 5 and 6. These results follow immediately from Lemmas 1-4. □

Proof of Proposition 7. If under legal unbundling the same total amount would be invested as under separation (vertical integration), we only have an investment allocation problem, which is equivalent to our basic model as explained in the text. Thus, Proposition 1 applies and we know that π_0 must be weakly higher under legal unbundling. F_0 chooses a different investment level under legal unbundling than the optimal level under separation (vertical integration) only if this would lead to even larger net profits π_0-I^u.Therefore the first sentence is true. The second sentence follows directly from the first result, under a linear access price $a>c_0$, by inserting π_0 and rearranging the inequalities. □

Proof of Lemma 8. Let c_0^a and c_0^b be two marginal costs with $c_0^a>c_0^b$. Let h^a denote F_0's optimal h if marginal costs are c_0^a, and let x^a be the selected downstream equilibrium given h^a and c_0^a. We define h^b and x^b correspondingly. 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 then implies

$$\begin{aligned}&\pi_1(x^a,h^a)+R(Q(x^a,h^a))-c_0^aQ(x^a,h^a)\\&\quad\geq\pi_1\left(x^b,h^a\right)+R\left(Q\left(x^b,h^a\right)\right)-c_0^aQ\left(x^b,h^a\right),\\&\pi_1\left(x^b,h^a\right)+R\left(Q\left(x^b,h^a\right)\right)-c_0^bQ\left(x^b,h^a\right)\\&\quad\geq\pi_1(x^a,h^a)+R(Q(x^a,h^a))-c_0^bQ(x^a,h^a),\end{aligned}$$

where $R(Q)$ is defined in Section 5.1. 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 8. 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. Generally subscripts or superscripts a and b index the investment level that is considered, while u,v,s and r index in the vertical structure in the common way. Let $\Delta^u:=\pi_0^b(h_b^u,x_b^u)-\pi_0^a(h_a^u,x_a^u)$, $\Delta^s:=\pi_0^b(h_b^s,x_b^s)-\pi_0^a(h_a^s,x_a^s)$, $\Delta^v:=\pi_{01}^b(h_b^v,x_b^v)-\pi_{01}^a(h_a^v,x_a^v)$ and $\Delta^r:=\pi_{01}^b(h_b^r,x_b^r)-\pi_{01}^a(h_a^r,x_a^r)$ denote the changes in F_0's objective function when marginal cost 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 Δ^u. Recall that π_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 cost c_0^b and by Lemma 5 also no higher quantity can be achieved under marginal cost c_0^a. Therefore $\pi_0^a(h_a^u,x_a^u)\leq\pi_0^a(h_b^u,x_b^u)$. Furthermore, $\pi_0^b(h_b^u,x_b^u)-\pi_0^a(x_b^u,h_b^u)=(c_0^a-c_0^b)Q(h_b^u,x_b^u)$. Together with the definition of Δ^u, these two results imply

$$\Delta^u\geq\left(c_0^a-c_0^b\right)Q(h_b^u,x_b^u).$$

We will now show that $\Delta^u-\Delta^s\geq0$ and $\Delta^u-\Delta^v\geq0$, which implies that under legal unbundling we will always find weakly higher investment than under separation as well as integration.

(i) $\Delta^u-\Delta^s\geq0$: 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

$$\Delta^s=\left(c_0^a-c_0^b\right)Q^s.$$

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

$$\Delta^u-\Delta^s\geq\left(c_0^a-c_0^b\right)\left(Q_b^u-Q^s\right)\geq0.$$

(ii) $\Delta^u - \Delta^v \geq 0$: since under vertical integration both F_0 and F_1 want to maximize π_{01}, we have $\pi^a_{01}(h^v_a, x^v_a) \geq \pi^a_{01}(h^v_b, x^v_b)$. Furthermore, $\pi^b_{01}(h^v_b, x^v_b) - \pi^a_{01}(h^v_b, x^v_b) = (c^a_0 - c^b_0)Q(h^v_b, x^v_b)$.Together with the definition of Δ^v, these two results imply $\Delta^v \leq (c^a_0 - c^b_0)Q(h^v_b, x^v_b)$. By Proposition 1, we have $Q(h^u_b, x^u_b) \geq Q(h^v_b, x^v_b)$ and using the lower bound on Δ^u, we therefore find $\Delta^u - \Delta^v \geq (c^a_0 - c^b_0)(Q^u_b - Q^v_b) \geq 0$.

(iii) $\Delta^u - \Delta^r \geq 0$: the proof for reverse legal unbundling is similar to the previous case. Since under reverse legal unbundling F_0 wants to maximize π_{01} and F_1's downstream profit does not directly depend on c_0, we find $\pi^a_{01}(h^r_a, x^r_a) \geq \pi^a_{01}(h^r_b, x^r_b)$. Furthermore, $\pi^b_{01}(h^r_b, x^r_b) - \pi^a_{01}(h^r_b, x^r_b) = (c^a_0 - c^b_0)Q(h^r_b, x^r_b)$. Together with the definition of Δ^r, these two results imply $\Delta^r \leq (c^a_0 - c^b_0)Q(h^r_b, x^r_b)$.By Propositions 2 and 3, we have $Q(h^u_b, x^u_b) \geq Q(h^r_b, x^r_b)$ and using the lower bound on Δ^u, we therefore find $\Delta^u - \Delta^r \geq (c^a_0 - c^b_0)(Q^u_b - Q^r_b) \geq 0$. □

References

Alchian, A., Demsetz, H., 1972. Production, information costs, and economic organization. The American Economic Review 62, 777–795.

Beard, T.R., Kaserman, D.L., Mayo, J.W., 2001. Regulation, vertical integration and sabotage. Journal of Industrial Economics 49 (3), 319–333.

Buehler, S., Schmutzler, A., Benz, M.-A., 2004. Infrastructure quality in deregulated industries: is there an underinvestment problem? International Journal of Industrial Organization 22, 253–267.

Bulow, J., Huang, M., Klemperer, P., 1999. Toeholds and takeovers. Journal of Political Economy 107, 427–454.

Cave, M., 2006. Six degrees of separation. Operational separation as a remedy in European Telecommunications Regulation. Communications Strategies 64 (4), 89–103.

Cremer, H., Crémer, J., De Donder, P., 2006. Legal vs. ownership unbundling in network industries. CEPR Discussion Paper, p. 5767.

Dixit, A., 1986. Comparative statics for oligopoly. International Economic Review 27 (1), 107–122.

Economides, N., 1998. The incentive for non-price discrimination by an input monopolist. International Journal of Industrial Organization 16, 271–284.

EU Commission, 2007. An Energy Policy for Europe. COM, Brussels. (10.1.2007).

Foros, O., 2004. Strategic investments with spillovers, vertical integration and foreclosure in the broadband access market. International Journal of Industrial Organization 22 (1), 1–24.

Fraquelli, G., Piacenza, M., Vannoni, D., 2005. Cost savings from generation and distribution with an application to Italian electricity utilities. Journal of Regulatory Economics 28 (3), 289–308.

Grossman, S., Hart, O., 1986. The costs and benefits of ownership: a theory of vertical and lateral integration. Journal of Political Economy 94, 691–719.

Höffler, F., Kranz, S., 2007. Imperfect Legal Unbundling of Monopolistic Bottlenecks. Bonn Econ Discussion Papers 16/2007.

Höffler, F., Wittmann, T., 2007. Netting of capacity in interconnector auction. Energy Journal 28 (1), 113–144.

Kaserman, D.L., Mayo, J.W., 1991. The measurement of vertical economies and the efficient structure of the electricity industry. Journal of Industrial Economics 39 (5), 483–500.

Kreps, D., Scheinkman, J.A., 1983. Quantity pre-commitment and Bertrand competition yield Cournot outcomes. Bell Journal of Economics 14, 326–337.

Kwoka, J.E., 2002. Vertical economies in electric power: evidence on integration and its alternatives. International Journal of Industrial Organization 20, 653–671.

Mandy, D.M., 2000. Killing the goose that may have laid the golden egg: only the data know whether sabotage pays. Journal of Regulatory Economics 17 (2), 157–172.

Mandy, D.M., Sappington, D.E.M., 2007. Incentives for sabotage in vertically related industries. Journal of Regulatory Economics 31, 235–260.

Mankiw, G.N., Whinston, M.D., 1986. Free entry and social inefficiency. The Rand Journal of Economics 17 (1), 48–58.

Perry, M.K., 1989. In: Schmalensee, R., Willig, R.D. (Eds.), Vertical Integration: Determinants and Effects. : Handbook of Industrial Organization, 1. Amsterdam, North Holland, pp. 183–255.

Shapiro, C., 1989. Theories of Oligopoly Behavior. In: Schmalensee, R., Willig, R.D. (Eds.), Handbook of Industrial Organization. Amsterdam, North-Holland.

Sibley, D.S., Weisman, D.L., 1998. Raising rival's costs: the entry of an upstream monopolist into downstream markets. Information Economics and Policy 10, 451–470.

Van Koten, S., 2008. "The Effects of Vertical Integration on Auction Outcomes in the EU and US Electricity Markets", mimeo. Charles University Prague.

Vickers, J., 1995. Competition and regulation in vertically related markets. The Review of Economic Studies 62, 1–17.