Imperfect Legal Unbundling of Monopolistic Bottlenecks

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Abstract

We study an industry with a monopolistic bottleneck supplying an essential input to several downstream firms. Under legal unbundling the bottleneck must be operated by a legally independent upstream firm, which may be partly or fully owned by an incumbent active in downstream markets. Access prices are regulated but the upstream firm can perform non-tariff discrimination. Under perfect legal unbundling the upstream firm maximizes only own profits; with imperfections it is biased and to some extend accounts also for the incumbent's downstream profits. We show that increasing the incumbent's ownership share increases total output if the upstream firm's bias is sufficiently small, while otherwise effects are ambiguous. Stronger regulation that reduces the bias without changing ownership shares generally increases total output. We also endogenize the bias and show that it can depend non-monotonically on the ownership share.

Keywords: Network industries, regulation, vertical relations, ownership, sabotage, corruption
JEL-Classification: L11, L42, L43, L51

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1 Introduction

In many network industries, some important parts of the network are still regarded as a natural monopoly (e.g., rail tracks, the "last mile" in telecommunications, or the electricity distribution networks). Access to these network elements is an essential input for firms competing in downstream markets. For these industries, an important policy issues is whether the firm that controls the essential input should be allowed to be active also downstream. Instead of either allowing full integration, or requiring complete ownership separation, many jurisdictions have opted for some compromise: legal unbundling. This allows an integrated company full ownership of the network assets, but requires that the network is operated independently, in a legally separated entity. In Europe, legal unbundling is the standard requirement for the energy industry[1], and similar forms of partial separation are (or were) common in the telecommunications industry in Europe and the US.[2]

It is however frequently doubted whether legal separation and its accompanying provisions for making the network management independent can be successful in separating the interests of the network company. In particular the EU commission has supported the view that only ownership unbundling is desirable and can achieve a non-discriminatory behavior of the network companies. Neelie Kroes, former 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.[3]

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

[2] For the US see Section 272 of the Telecommunications Act of 1996; for the European Union see Directive 2002/21/EC, Article 13 (1b). In the UK, the "functional separation" between *British Telecom (BT)* and its affiliate *Openreach* is another important example. The UK regulator *Ofcom* and *BT* agreed on "legally binding undertakings" that are meant to ensure that the network provider *Openreach* acts independently, while still remaining a 100% subsidiary of *BT*. See, e.g., *Ofcom*'s annual report 2005/06, Section B, p. 18-20.

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

The aim of the paper is to analyze vertical structures if legal unbundling is not perfect in the sense of achieving full separation of interest. We investigate how the market outcome is affected if an incumbent fully or partially owns a legally unbundled network firm which, to some extent, cares about the incumbent's profits.

To do so, we study an industry structure with an imperfectly legally unbundled network firm that sells an essential input to multiple downstream firms. One of the downstream firms, the downstream incumbent, holds an *ownership share* in the upstream firm. We will refer to the network firm as an upstream firm, although in some industries the bottleneck might actually not be at the upstream stage (e.g., in the gas industry it is rather the midstream distribution network). That legal unbundling is imperfect is reflected in the fact that, in its objective function, the upstream firm attaches a positive weight, the *bias*, to the downstream incumbent's profits.

The upstream firm sells the essential input at regulated terms. Regulation is exogenous and such that the network firm's profits are increasing in the quantity sold. Yet, regulation cannot avoid non-tariff discrimination, i.e. the upstream firm has means to sabotage some of the downstream firms. In the main part of the paper, we assume that the downstream incumbent moves first in downstream markets. This allows us to derive general results without making assumptions on functional forms, or on the mode of downstream competition.

Our analysis proceeds in two steps. We first conduct separate comparative statics with respect to the upstream firm's bias and the downstream incumbent's ownership share. This reflects the idea that regulatory policy can affect these two parameters separately, e.g., by imposing maximum ownership shares and by alternative provisions that strengthen the independence of the upstream management or increase fines for discriminatory behavior.

We find that, unsurprisingly, reducing the bias of the network firm always tends to be beneficial in the sense of yielding larger total industry output (the high level of generality prevents us from deriving direct welfare implications; yet, in many instances, larger quantities will imply larger consumer surplus and larger total surplus). A smaller bias makes the network firm less inclined to use sabotage to support the downstream incumbent. Less obvious are comparative statics with respect to the ownership share. We find that for sufficiently low values of the bias, total quantity increases with the ownership share. This is due to a "downstream expansion effect". In its downstream decisions, the downstream firm takes into account that higher output increases upstream profits given the access price regulation. The higher is the ownership share, the more inclined is the downstream incumbent to act in a way that increases total output. However, for large biases, this might no longer hold and output can decrease with an increasing ownership share. We show that this effect can arise because higher ownership shares can make the upstream firm more inclined to perform sabotage — even if the bias does not depend on the ownership.

In the second step of the analysis, we endogenize the upstream firm's bias as a result of manipulation efforts by the downstream incumbent. This makes the bias a function of the ownership share. Typically, a larger ownership share will facilitate manipulation, but, due to the downstream expansion effect, there also exists a counteracting effect. If the downstream incumbent participates more in the upstream firm's profits, it is less inclined to manipulate the upstream firm towards sabotage that increases downstream profits at the cost of upstream profits. Since the net effect of the ownership share on the bias is ambiguous, it may well be the case that the bias is not minimized with zero ownership but with a strictly positive ownership share. However, the ownership share that minimizes the bias and the ownership share that maximizes the total output will generally not coincide.

Afterwards, we apply the two steps of the general analysis to a Cournot example. It (i) shows that our results do not hinge upon the assumption that the downstream incumbent moves first, (ii) allows for a welfare analysis, (iii) provides an example for the case where increasing the ownership share can lead to quantity (and welfare) reductions if the bias is sufficiently large, (iv) for the endogenized bias, shows that zero ownership or mandating an ownership share that minimizes the bias is generically welfare inferior, (v) allows to derive comparative statics for the optimal ownership share.

While the older economic literature on vertical industry structure focused on the extreme ownership structure (full separation vs. full integration), see, e.g., Perry (1989) or Vickers (1995), there is now a growing literature dealing with legal unbundling as an "intermediate" structure. We follow Cremer, Crémer, and De Donder (2006) in modeling legal unbundling as a subsidiary which acts only to maximize the own (not the group) profits. Sibley and Weisman (1998) in a similar fashion deal with a specific form of legal unbundling, which might be called "downstream legal unbundling". Not the essential facility is unbundled, but the operations in the competitive market. In our terminology: the upstream firm holds interest in the downstream firm, but the downstream firm acts independently. This resembles the former RBOC regulation in the US telecoms industry (see footnote 2). Höffler and Kranz (2011) provide an analysis of "perfect legal unbundling", including various applications and discussions of investment decisions. Also Van Koten (2008) deals with perfect legal unbundling in the context of auctions. Reitzes (2008) analyzes price caps in legally unbundled industries. Our contribution to this strand of literature is that we look at imperfect legal unbundling.

We also build on the extensive literature on "sabotage" in vertical industry structures, see, e.g. Economides (1998), Beard, Kaserman, and Mayo (2001), Mandy (2000), or Mandy and Sappington (2007). This literature shows the importance of non-tariff discrimination; the various approaches reveal that the exact effect of sabotage can delicately depend on assumptions on the form of downstream competition, or the form of the "sabotage technology". Not at least for this reason we have chosen a more general approach; the cost of this is, of course, that we can derive less detailed predictions, e.g., in terms of welfare effects.

The remainder of the paper is structured as follows. Section 2 sets out the model. Section 3 contains the first step of our analysis where we investigate exogenous variations in the ownership share and the bias. Section 4 endogenizes the bias. Section 5 contains the Cournot analysis, Section 6 concludes.

2 The model

Industry structure There is a monopolistic upstream firm F_0 that produces a good at constant marginal costs c_0, which is used as an input good for n competing downstream firms, $F_1, ..., F_n$. For simplicity, we assume that each downstream firm needs exactly one unit of the input good to produce one unit of the output good. Firm i's output is denoted by q_i and total output by $Q = \sum_i^n q_i$.

Regulation and non-tariff Discrimination We assume that F_0 is a regulated natural monopoly, e.g. the owner of an essential network element in electricity or telecommunication markets. We call ϱ the regulatory regime, which satisfies two conditions. First, the monopolist's profits π_0 depends only on the total amount of the input sold, and thereby on the total downstream output Q. It does not matter, to which downstream firm the input is provided. Second, π_0

is strictly increasing in Q. A simple and realistic regulation satisfying these conditions would be that the regulator fixes a per-unit access price a that F_0 must charge from all downstream firms, and where a exceeds the constant marginal cost of providing access (e.g., to allow for the recoupment of fixed cost of F_0).

Regulation ϱ cannot prevent non-tariff discrimination. F_0 chooses a sabotage or discrimination strategy $s \in S$ that can influence output, costs or consumer prices of downstream firms. Sabotage can mean to "degrade the quality of the [essential] input" (Beard, Kaserman, and Mayo, 2001, 320), but it can also reflect any other activity that affects the profits of downstream firms. For instance, the strategy s can describe measures like a lack of transparency, or disclosure of confidential information to the affiliate downstream firm, delays or excessive formalities when dealing with requests, or network repairs at times that are especially inconvenient for some downstream firms. Sabotage can be targeted at individual firms, e.g., it can increase the cost of firm j but not of firm i.

We make the simplifying assumption that the choice of s has no direct impact on the profits of F_0, although perhaps indirectly if it changes the total quantity sold. (We discuss costs of sabotage in the context of the Cournot analysis in Section 5.)

Downstream market The strategic variable of downstream firm i is denoted by $x_i \in X_i$ and $x = (x_1, ..., x_n)$ denotes the vector of downstream strategies. Strategies can be very general, for example, they could describe decisions about quantities, prices, investments, or entry. Downstream strategies x together with upstream discrimination s determine downstream firms' outputs $q_i(x, s)$, their market prices $p_i(x, s)$ and their total costs $C_i(x, s|\varrho)$, conditional on the regulatory regime. Profits of downstream firm i are given by

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

Upstream profits are given by a function

$$\pi_0(x, s|\varrho) = \pi_0(Q(x, s)|\varrho) \quad (2)$$

Except for a condition on equilibrium existence (see below) there are no further restrictions on functional forms.

Vertical integration Among all downstream firms F_i, we call F_1 the downstream incumbent, and F_j, $j \geq 2$, downstream entrants. The idea is that prior to market liberalization, the upstream firm and F_1 were fully integrated. Liberalization required the integrated firm to unbundle the monopolistic bottleneck F_0.

However, F_1 can still own some or all shares of F_0. We denote F_1's ownership share by σ. Thus, F_1 maximizes its overall payoff of

$$u_1 = \pi_1 + \sigma\pi_0 \text{ with } 0 \leq \sigma \leq 1. \tag{3}$$

Imperfect legal unbundling and upstream bias Under perfect legal unbundling the upstream firm F_0 has an independent management, which maximizes only upstream profits π_0, even if F_0 is wholly or partially owned by the downstream incumbent. Experiences from network industries suggest that the separation of interest does not always work perfectly. If the ownership share σ is positive, there are various reasons why the management of the upstream firm might take into consideration also the profits of the affiliated downstream firm, even if the two firms are legally separated. Consider an integrated electricity company which has sold 25% interest in its network business to a third party. However, the remuneration of the network company's (in our model: the upstream firm's) managers might include stock options of the integrated company (in our model: the downstream company). And even without direct financial interests in the downstream firm, the managers might take effects on the group profits into account due to career concerns. To model this, as a shortcut, we assume that F_0 attaches a positive weight β (a bias) to the downstream profits of the incumbent. Thus F_0 maximizes

$$u_0 = \pi_0 + \beta\pi_1 \text{ with } 0 \leq \beta. \tag{4}$$

The bias β and the ownership share σ are not isomorphic. If the enforcement of legal unbundling is very strict, even with a high ownership share σ, the bias will be small. Vice versa, if the enforcement is weak, even a small ownership share might suffice for the upstream firm to be heavily biased.[4]

Timing The regulation ϱ is exogenously given in our model. For the given ϱ, first the upstream firm F_0 chooses its sabotage strategy s. Afterwards the downstream incumbent F_1 chooses its strategy x_1. These decisions are observed by the downstream entrants $F_2, ..., F_n$, who then make their downstream decisions. Whether downstream entrants move simultaneously or sequentially does not matter for our model. Having the incumbent F_1 moving first considerably facilitates

[4] The stringency of regulation affects the degree of the bias β. Alternatively, and perhaps more common, is the idea that the stringency of regulation will affect the downstream firm's ability to "manipulate" the upstream firm into the downstream firm's favor. These two approaches are not qualitatively different, as can be seen from the discussion of endogenizing the bias in the Cournot analysis in Section 5.2.

the analysis and allows derivation of results without having to assume specific forms of strategic interaction or functional forms for sabotage or costs. However, the Cournot analysis in Section 5 demonstrates that the key insights do not depend on F_1 moving first.

Regularity conditions For every pair of ownership share and bias of the upstream firm (σ, β), our model formally consists of a multi-stage game. The timing and strategy-space of these games is the same for all (σ, β) and only the payoff functions for F_0 and F_1 differ. We call a *situation* a pair of (σ,β) and some history of the corresponding multi-stage game, where at least one player still has to move. 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 a given situation may have multiple subgame-perfect continuation equilibria. We also make a regularity condition on equilibrium selection for those cases:

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.*

This regularity condition avoids tedious comparison of sets of equilibria. Note that condition C2 is obviously not needed when in every situation there is a unique continuation equilibrium.

3 Exogenous variations of the bias β and the ownership share σ

In this section we treat the ownership share σ and the bias β as independent variables. We investigate how exogenous changes in σ and β affect the market outcome in terms of total quantity produced. That economic policy can affect σ is straightforward, at least in the sense that too high ownership shares can be prohibited. Exogenous variations in the bias β could stem from the intensity of regulation. Regulation can – and frequently does – use complex provisions to limit the influence of the parent company on the network firm's management. For instance, the European energy regulation (Article 10 of Directive 2003/54/EC, as of 26 June 2003) requires not only separate accounts and a separate legal form for the network operations; it also prescribes that network managers must not be paid in stocks of the parent company; managers must not, at the same time, hold position in parent and network companies; managers of network firms can not directly change to positions in the parent company; etc. Increasing the intensity of such regulation, imposing higher fines for violations thereof, or intensifying the prosecution of violations should all act towards decreasing the bias β, for any given ownership share σ.

We start the analysis by a direct implication of the regularity conditions C1 and C2.

Remark 1 *Given C1 and C2, downstream entrants' equilibrium decisions depend only on the upstream decision s and the decision of the downstream incumbent x_1. This means that, given the upstream decision s, the downstream incumbent can choose between different decision profiles $x = (x_1, x_2(x_1, s), ..., x_n(x_1, s))$. Furthermore the incumbent's decision x_1 only depends on s and on his ownership share σ. Thus the equilibrium choices in the downstream markets x can be described as a function of the upstream firm's decision s and the incumbent's ownership share σ.*

Provided with this observation, it is easy to answer how variations in the bias β influence the total output Q.

Proposition 1 *For every given ownership share of the downstream incumbent σ, total output is weakly decreasing in the bias of the upstream firm β.*

Proof. Consider two vertical structures (β^a, σ) and (β^b, σ) with $\beta^a < \beta^b$. Since the incumbent's ownership share σ is the same in both structures, the strategy profile selected by downstream firms only depends on the upstream firm's choice of s (recall Remark 1). Let $\pi_i(s) = \pi_i(x(s, \sigma), s)$ denote the resulting profits of firm $i \in \{0, 1, ..., n\}$ as a function of s only. Let s^a and s^b denote those sabotage strategies that maximize F_0's objective function u_0 under (β^a, σ) and (β^b, σ), respectively. Optimal choice by the upstream firm F_0 implies:

$$\pi_0(s^a) + \beta^a \pi_1(s^a) \geq \pi_0(s^b) + \beta^a \pi_1(s^b) \tag{5}$$

$$\pi_0(s^b) + \beta^b \pi_1(s^b) \geq \pi_0(s^a) + \beta^b \pi_1(s^a). \tag{6}$$

If $\beta^a = 0$, then the first inequality directly yields $\pi_0(s^a) \geq \pi_0(s^b)$. If $\beta^a > 0$ we divide the first inequality by β^a and the second inequality by β^b. Adding the two resulting inequalities yields $(\frac{1}{\beta^a} - \frac{1}{\beta^b})\pi_0(s^a) \geq (\frac{1}{\beta^a} - \frac{1}{\beta^b})\pi_0(s^b)$. Dividing by $(\frac{1}{\beta^a} - \frac{1}{\beta^b})$ yields again $\pi_0(s^a) \geq \pi_0(s^b)$. Since total output is strictly increasing in upstream profits π_0 this inequality implies that total output must be weakly higher under (β^a, σ) than under (β^b, σ). ■

A biased upstream firm might undertake sabotage to improve the own affiliate's competitive position. In the extreme, it might make market participation prohibitively costly for all entrants $F_2, ..., F_n$. For a biased firm this has the beneficial effect that downstream profits increase (compared to a more competitive downstream situation). However, it also has a drawback: total downstream quantity decreases, and so does the own (upstream) profits. Only if the first effect dominates the second, the upstream firm will engage in the sabotage. If the second effect is more important, which happens if the bias β is small, the upstream firm will usually abstain from sabotage and be mainly interested in choosing its upstream strategy such that the own upstream profits are maximized. And towards this end, it wants the downstream quantity to be as large as possible.

While the result with respect to the bias β is unambiguous and unsurprising, the same is not true for the comparative statics with respect to the ownership share σ. Increasing the ownership share can either increase or decrease the total output. An unambiguous result can be obtained only for sufficiently low values of the upstream bias. In that case, increasing the ownership share always increases total output. That generally the effect of increasing σ can go either way, depending on the level of β, will be illustrated in Section 5. That for sufficiently low levels of β the effect is unambiguous is stated in the following Proposition.

Proposition 2 *If the upstream firm is unbiased, i.e. $\beta = 0$, then total output is weakly increasing in the incumbent's ownership share σ. Furthermore, the following limit result holds: Consider two ownership shares σ^a and σ^b with $\sigma^a < \sigma^b$ and let Q^a and Q^b be the corresponding resulting total outputs for a given upstream bias β. Then $Q^b - Q^a$ has a lower bound that converges to zero as $\beta \to 0$.*

Proof. Let s^a and s^b denote the optimal choice of F_0 under σ^a and σ^b, respectively. Let x^a denote the resulting downstream equilibrium after optimal choice of F_1 given σ^a and s^a. We define x^b correspondingly. Furthermore, let x^{ba} denote the resulting downstream equilibrium after optimal choice of F_1 given σ^b and s^a.

Optimal choice by the incumbent F_1 implies

$$\pi_1(x^a, s^a) + \sigma^a \pi_0(x^a, s^a) \geq \pi_1(x^{ba}, s^a) + \sigma^a \pi_0(x^{ba}, s^a) \tag{7}$$

$$\pi_1(x^{ba}, s^a) + \sigma^b \pi_0(x^{ba}, s^a) \geq \pi_1(x^a, s^a) + \sigma^b \pi_0(x^a, s^a). \tag{8}$$

Adding these two inequalities and dividing by $(\sigma^b - \sigma^a)$ yields

$$\pi_0(x^{ba}, s^a) \geq \pi_0(x^a, s^a). \tag{9}$$

Optimal choice by the upstream firm F_0 implies

$$\pi_0(x^b, s^b) + \beta \pi_1(x^b, s^b) \geq \pi_0(x^{ba}, s^a) + \beta \pi_1(x^{ba}, s^a). \tag{10}$$

Combining with the previous inequality and rearranging yields

$$\pi_0(x^b, s^b) - \pi_0(x^a, s^a) \geq \beta \left(\pi_1(x^{ba}, s^a) - \pi_1(x^b, s^b) \right). \tag{11}$$

The term on the right hand side equals 0 for $\beta = 0$. Also its limit for $\beta \to 0$ is 0, because we assumed that minimal and maximal downstream profits are bounded. Since π_0 only depends on total output Q and is strictly increasing in Q the proposition is implied. ■

Imagine the upstream firm has chosen a strategy s. Now let the ownership share increase. This has two effects. The downstream incumbent will now take the upstream firm's profit into account to a larger extent. Thus, it is more inclined to choose a strategy x_1 that increases total output, because the upstream firm's profits increase in total output. This we call *downstream expansion effect.* For instance, it could engage in more aggressive pricing in the downstream market, which reduces the own downstream profits, but increases overall downstream supply. Another well known form of the downstream expansion effect is the double marginalization problem, which is reduced, the higher the ownership share.

At the same time, the upstream firm anticipates this reaction of the downstream incumbent, and it is this anticipation which can generate a quantity reducing effect. In particular for high values of the bias β, the upstream firm is generally very interested in hampering the entrants in order to increase the downstream incumbent's profits, e.g. by providing the downstream incumbent with market power. The drawback for the upstream firm is that generating market power for the incumbent will typically reduce the total market output. This negative effect on π_0 makes F_0 reluctant to engage too much in this sort of sabotage. However, as the ownership share σ increases, this reluctance can weaken. The upstream firm can now find it optimal to provide market power to the downstream incumbent, knowing that it will not execute it excessively. Overall, the adjustment of the sabotage strategy can lead to an output reduction. Section 5 provides an example where this happens. If the bias is sufficiently low, this indirect quantity reducing effect won't arise and the downstream expansion effect causes output to increase in the incumbent's ownership share.

4 Endogenous bias

Up to now, we assumed an exogenous bias β of the upstream firm, and we performed comparative statics for β and σ independently. However, one key argument against legal unbundling, and in favor of ownership separation, is that ownership facilitates the interference in the upstream firm's decisions. Implicitly, the idea is that the higher the ownership share, the easier it will be for the downstream incumbent to manipulate the upstream firm's decisions. This means that, at least to some degree, the bias β is a function of the ownership share σ.

A simple way to endogenize the bias is to assume that (for any ownership share σ), without any manipulation by the downstream incumbent, the upstream firm would act according to the unbundling obligations, i.e., would only care about the own profits, and therefore chooses $s^o \in \arg\max_{s \in S} \pi_0(s)$. Only if the downstream incumbent undertakes some active manipulation effort, the upstream firm's management will deviate from this behavior. The effort cost could be, for instance, direct bribes to the upstream management, or promising future attractive employment opportunities.

How costly it is to manipulate the upstream affiliate can depend on various factors. First, cost of manipulation will increase in the size of manipulation, measured by $\pi_0(s^o) - \pi_0(s)$, i.e., the foregone profits of the upstream firm. If this is large, for instance, outside shareholders will have to be compensated by a larger side payment; and large deviations will arouse suspicion on the side of the regulator. Second, for any given level of manipulation, its cost will increase with the toughness of regulation, e.g., size of fines. Third, influencing an affiliate company might not only take the form of illegal manipulation. One of the core problems of vertical sabotage is that it is often very difficult to exactly determine whether the upstream firm is indeed sabotaging a certain downstream firm. Frequently, there is a grey area between illegal and still legal activities which make the life of a downstream firm more difficult. Such "still legal" sabotage activities will typically not be pursued by a non-manipulated upstream firm. However, if the downstream incumbent has (still legal) means to influence the upstream management (for instance, voting rights as a majority shareholder, and the right to elect the upstream firm's top management) such manipulation towards "legal sabotage" becomes easier. Thus, it is natural to assume that the effort cost of sabotage is decreasing in the ownership share.

Taking these considerations into account, we can think of the downstream incumbent F_1 as deciding on the sabotage strategy s by manipulating the upstream firm F_0. This means that, ultimately, s is now determined by F_1; F_0 just does what F_1 has manipulated F_0 to do. Manipulation costs are $\widetilde{\mu}(\mu,\sigma)(\pi_0(s^o)-\pi_0(s))$, where μ measures the stringency of regulation. We assume that $\widetilde{\mu}>0$,[5] $\partial\widetilde{\mu}/\partial\mu \geq 0$, and $\partial\widetilde{\mu}/\partial\sigma \leq 0$, which reflects the three cost drivers of manipulation cost discussed above, respectively.

Thus, F_1 maximizes an objective function of the following form:

$$\max_{s\in S}\left\{\pi_1(s)+\sigma\pi_0(s)-\widetilde{\mu}(\mu,\sigma)(\pi_0(s^o)-\pi_0(s))\right\}.$$

This maximization problem is equivalent to

$$\max_{s\in S}\left\{\pi_0(s)+\frac{1}{\sigma+\widetilde{\mu}(\mu,\sigma)}\pi_1(s)\right\}. \tag{12}$$

This corresponds to the maximization problem of the upstream firm in the original model (see (4)) if the bias of the upstream firm is given by

$$\beta(\sigma)=\frac{1}{\sigma+\widetilde{\mu}(\mu,\sigma)}. \tag{13}$$

This offers a simply way to endogenize the bias and to incorporate it in the previous analysis.

Expression (13) reflects that the ownership share and the stringency of regulation μ will determine the bias, i.e., β is a function of σ and μ. That the bias is decreasing in μ is obvious and intuitive. The ownership share σ has two different effects on β. First, a "cut into the own profits effect". The larger σ, the more the

[5] This does not only reflect that manipulation costs are costs and not benefits, but also that $\widetilde{\mu}$ has a positive lower bound. This will imply that the endogenized bias (13) can not become arbitrarily large as $\sigma\rightarrow 0$, even if also μ becomes small.

downstream firm cares about the profit loss of the upstream affiliate from manipulation; this lowers the bias. Second, a "facilitate manipulation effect". Since a larger ownership share makes "legal" manipulation easier, this tends to increase the bias when σ becomes larger. The former effect will strictly dominate if and only if $|\partial\widetilde{\mu}/\partial\sigma| < 1$.

An important goal of regulatory policy is to ensure non-discrimination, i.e., to minimize the bias of the upstream firm. One obvious (and heavily discussed) way to achieve this is to determine the (maximum) ownership share σ. From the ambiguity of the effect of σ on β it is obvious that it is not at all clear that the minimum bias $\beta(\sigma)$ is realized with $\sigma = 0$. The bias β might be minimized at an interior solution (given by $\partial\widetilde{\mu}/\partial\sigma = -1$), or alternatively, the bias is minimized at a corner solution. Thus, it can even happen that the bias is minimized with a maximum ownership share if the marginal costs of manipulation are sufficiently small (i.e., $|\partial\widetilde{\mu}/\partial\sigma| < 1 \forall\sigma \in (0, 1)$).

In general, it is not clear that the cost function $\widetilde{\mu}(\sigma)$ is a differentiable or even smooth function. Laws for corporate companies frequently have thresholds that identify discontinuous changes in the power to influence an affiliated company (25%, 50%, thresholds for squeeze outs, etc.). It might be plausible that between such thresholds, the "cut into the own profits" effect dominates, while at these thresholds, the cost of manipulation discretionally decrease. This would imply that not only the function $\widetilde{\mu}(\sigma)$ exhibits jumps, but also the bias. Thus, the function $\beta(\sigma)$ might well take the form indicated in Figure 1. In this example, the minimum bias $\underline{\sigma}$ is given by an interior solution ($\underline{\sigma}$ at slightly below 0.25).[6]

It should be clear from our previous discussion that minimizing the bias need not be welfare optimal; in particular, it will generally not maximize the downstream output. If the minimal level of β is sufficiently small, increasing σ will weakly increase total output and therefore the level of σ that maximizes total output is likely to be above $\underline{\sigma}$. We illustrate the suboptimality of choosing an ownership share that minimizes the bias in the next section.

[6] Note that we assumed here that the bias is not zero for $\sigma = 0$; this would reflect that the upstream incumbent could manipulate the downstream firm even without any shareholding in that company. This would be reasonable in particular if the downstream incumbent can offer attractive employment opportunities in the industry (which entrants are less able to provide).

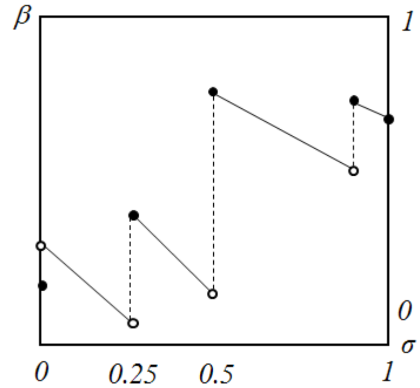

Figure 1: A possible $\beta(\sigma)$-function

5 Legal unbundling with downstream Cournot duopoly

To illustrate the general model and to gain additional insights, we now analyze a linear Cournot duopoly and cost increasing sabotage. There are two downstream firms which simultaneously set quantities q_1 and q_2. Market demand in the final good market is given by $p = 1 - q_1 - q_2$. The two firms produce with constant marginal cost c_1 and c_2. The first downstream firm, F_1, holds an ownership share σ in the upstream firm F_0. Downstream firms need one unit of an essential input per unit of output, and buy it at a regulated price $a > 0$ from the upstream firm.[7] The essential input is produced at zero marginal production cost. The fact that $a > 0$ might be due to fixed cost which the upstream firm has to cover by selling the input. Before quantity competition takes place, the upstream firm can sabotage the downstream firms by increasing the downstream firms' costs. It is straightforward that in this model sabotage against the own affiliate never happens. We denote by $s \geq 0$ the level of sabotage against the entrant. The resulting marginal cost of F_2 are $c_2 + s$. Sabotage may be costly for the upstream firm and we assume that sabotage costs are given by $r \cdot s$, with $r \geq 0$. Sabotage costs may reflect technological costs of sabotage, or expected fines for the upstream firm which increase in the amount of sabotage.

[7] For simplicity, we assume that the regulator sets the price a, i.e., a is not a price cap, but is always binding for F_0. We discuss this issue in the Conclusion.

5.1 Exogenous bias

In line with the discussion of the general model, we first investigate a setup with an exogenous bias β of the upstream firm. This means F_0 maximizes $u_0 = \pi_0 + \beta\pi_1$, where $\pi_0 = a(q_1 + q_2) - rs$ and $\pi_1 = (p - a - c_1) q_1$. Firm F_1 maximizes $\pi_1 + \sigma\pi_0$, and firm F_2 maximizes $\pi_2 = (p - a - c_2 - s) q_2$.

Whenever both downstream firms produce positive quantities, equilibrium outputs in the downstream stage are given by

$$q_1 = \frac{1 - 2c_1 + c_2 + s - a(1 - 2\sigma)}{3}, q_2 = \frac{1 + c_1 - 2c_2 - 2s - a(1 + \sigma)}{3} \quad (14)$$

We assume that c_1, c_2 and a are such that both firms choose positive outputs when there is no sabotage. Total outputs, prices and upstream profit π_0 are linear in the sabotage level s, and the downstream profit π_1 is strictly convex in s. This implies that for $\beta > 0$, the payoff u_0 of the biased upstream firm is strictly convex in s and only corner solutions will be optimal. F_0 will either choose no sabotage or will fully foreclose the downstream entrant F_2 by choosing the lowest sabotage level that induces zero output from F_2. This sabotage level is given by

$$s^F = \frac{1 + c_1 - 2c_2 - a(1 + \sigma)}{2}. \quad (15)$$

The resulting total outputs Q^C and Q^F for the two types of downstream equilibria (competition, or foreclosure) are

$$Q^C = \frac{2 - c_1 - c_2 - a(2 - \sigma)}{3}, Q^F = \frac{1 - c_1 - a(1 - \sigma)}{2}. \quad (16)$$

Total output Q strictly increases in the incumbent's ownership share σ within each equilibrium region. This reflects the downstream expansion effect, which, in the Cournot case, is solely driven by the reduction of the double marginalization problem. With a higher ownership share, the downstream incumbent internalizes a higher percentage of the upstream firm's markup between access price and the lower marginal cost of input provision and therefore increases total output.

Within each case, total quantity is independent of the bias β, but β influences which of the two cases will be selected by the upstream firm. On a (σ, β) plane the two downstream equilibrium regions are separated by a "border" $\beta^F(\sigma)$, at which the upstream firm is just indifferent between no sabotage and full foreclosure (see Figure 2). This border is given by

$$\beta^F(\sigma) = \frac{6(a + 3r)}{5 - 7c_1 + 2c_2 - a(5 - \sigma)}. \quad (17)$$

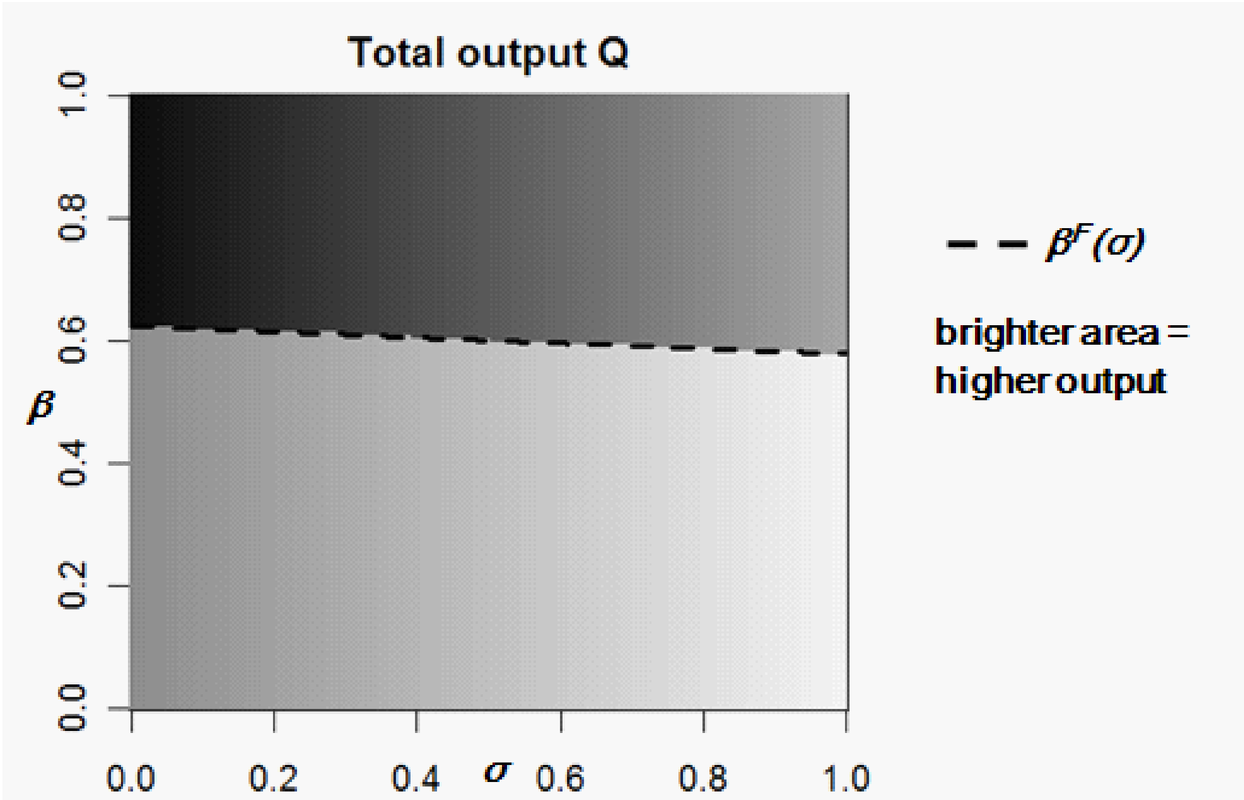

Figure 2: Quantity results with downstream competition

The critical level of the bias $\beta^F(\sigma)$, above which foreclosure happens, decreases in σ. While quantities are increasing in σ within each equilibrium region (see (14)), they are strictly decreasing in σ, when an increase in σ leads to "crossing the border": In that case, the increase in σ changes the market outcome from downstream competition to downstream monopoly, and quantity therefore goes down discontinuously at the border. Figure 2 illustrates this border and the quantity results for the parameters $a = 0.2, c_1 = c_2 = 0.3$, and $r = 0.02$.

The Cournot example demonstrates four aspects of the general discussion. First, due to the additional structure imposed we can make statements about consumer surplus and total welfare:

Result 1 *When applied to the Cournot case, the comparative statics with respect to quantities in Propositions 1 and 2 also hold with respect to the consumer surplus; a sufficient condition that they also hold for total welfare is that the entrant's marginal cost c_2 are not larger than the incumbent's c_1.*[8]

[8] It is well known in the Cournot model that welfare can increase if the marginal cost of a

Second, the Cournot example demonstrates that Propositions 1 and 2 do not hinge upon the assumption of the incumbent (F_1) moving first in the downstream market. Third, introducing upstream cost of sabotage strengthens Proposition 2: we find that $\beta^F(\sigma)$ increases in the upstream cost of sabotage r, i.e. the larger the upstream cost of sabotage r, the larger is the range of β, for which increasing σ always increases output. We also find that the border $\beta^F(\sigma)$ is positive and bounded away from zero.[9]

Result 2 *Proposition 1 and 2 also hold in the Cournot case with simultaneous downstream moves. Proposition 2 is strengthened such that there exists a strictly positive value* $\underline{\widehat{\beta}} \equiv \beta^F(\sigma = 1)$*, which is increasing in* r *and in* a*, such that for all* $0 \leq \beta \leq \underline{\widehat{\beta}}$*, total quantity strictly increases in* σ*.*

Forth, the Cournot specification provides an intuitive example for the case that for large levels of the bias, increasing the ownership share σ can decrease total output.

Result 3 *There exist levels of* β *for which an increase in* σ *strictly reduces output and strictly reduces consumer surplus.*

Consider Figure 2 and fix an upstream firm's bias of $\beta = 0.6$. If σ is very low, making the downstream incumbent F_1 a monopolist by foreclosing the entrant F_2 is costly for the upstream firm F_0 since the F_1 will choose only a very low quantity, due to the double marginalization problem. Thus, competition is preferred by F_0, although this leads to lower downstream profits (to which F_0 attaches a weight of β). As σ increases, F_1 increasingly internalizes the double mark-up. Increasing σ works like a decrease in F_1's costs with respect to its output decision. This perceived reduction in marginal cost increases output under competition, as well as under monopoly. However, output increases faster (as can be seen also from (16)) under monopoly, since quantities are strategic substitutes and an increase of F_1's quantity under competition is answered by a decrease in F_2's quantity. Thus, as σ increases, there exists a cutoff $\widehat{\sigma}$ where foreclosing becomes attractive. This implies that at $\widehat{\sigma}$ total output falls as σ increases.

sufficiently inefficient firm increases, because then a higher share of production is conducted by the more efficient firm. Yet if the entrant is as least as efficient as the incumbent, increasing the entrant's marginal cost via sabotage cannot increase welfare.

[9] It is easily verified that our assumption that c_1,c_2 and a are such that both downstream firms choose positive outputs if there is no sabotage implies that the denominator of $\widehat{\beta}(\sigma)$ is strictly positive.

5.2 Endogenous bias

In Section 4, we endogenized the bias β by arguing that the choice of s from a biased upstream firm F_0 is isomorphic to the choice of s by a downstream firm F_1 who manipulates F_0 at cost $\widetilde{\mu}(\mu, \sigma) \cdot (\pi_0(s^o) - \pi_0(s))$, where s^o is the sabotage strategy chosen by an unbiased upstream firm. In the Cournot example, we have $s^o = 0$ and the difference in upstream profits is given by

$$\pi_0(s^o) - \pi_0(s) = \left(\frac{a}{3} + r\right) s, \text{ for } s \in (0, s^F). \tag{18}$$

Manipulation costs are simply a linear function of the sabotage level s. Manipulation costs increase in the upstream cost of sabotage r and in the access price a, since for higher access prices, sabotage leads to higher foregone upstream profits. Let us specify $\widetilde{\mu}$ as:

$$\widetilde{\mu}(\mu, \sigma) = \mu - m\sigma^{\lambda}, \text{ with } \mu \geq m > 0, \text{ and } \lambda > 0. \tag{19}$$

This is a formulation in line with our general assumptions on $\widetilde{\mu}(\mu, \sigma)$, where $\mu \geq m$ ensures that $\widetilde{\mu}$ reflects costs of manipulation (not gains). The parameter μ reflects the stringency of regulation (e.g., expected fines for the downstream firm), while m and λ measure how strongly downstream ownership facilitates manipulation. The downstream incumbent now manipulates the upstream firm to choose a sabotage strategy s that solves

$$\max_{s \in [0, s^F]} \left\{\pi_1 + \sigma\pi_0 - \left(\mu - m\sigma^{\lambda}\right)\left(\frac{a}{3} + r\right) s\right\}. \tag{20}$$

This is a convex function in s, i.e. as before, we either have an outcome without sabotage $s = 0$ or full foreclosure, $s = s^F$. The endogenous bias is given by

$$\beta(\sigma) = \frac{1}{\sigma - m\sigma^{\lambda} + \mu}. \tag{21}$$

For small (large) values of m, the bias is strictly decreasing (increasing) in σ. If the "facilitate manipulation" parameter m takes on intermediate values, there will be an interior minimum (maximum) bias if $\lambda \geq 1$ $(\lambda < 1)$.

Let σ^* denote the ownership share that maximizes total output and consumer surplus. Typically, maximizing output will imply that no foreclosure occurs. Two cases can then be distinguished. First, the $\beta(\sigma)$-function ends below the border, i.e., $\beta(1) \leq \beta^F(1)$. This implies that $\sigma^* = 1$. Alternatively, the $\beta(\sigma)$-function crosses the "border" from below and ends in the foreclosure area, i.e., $\beta(1) >$

$\beta^F(1)$. Then, $\sigma^* \in [0, 1)$ and it is determined by the (last) "crossing of the border", i.e., by the largest solution to

$$\beta(\sigma^*) = \beta^F(\sigma^*). \tag{22}$$

In principle, maximizing output might alternatively require foreclosure. This happens if the $\beta(\sigma)$-function never leaves the foreclosure region (i.e., $\beta(\sigma) > \beta^F(\sigma)$ for $\sigma \in [0, 1]$). Alternatively, $\beta(\sigma)$ might cross $\beta^F(\sigma)$ from below and the quantity Q^C at the border is smaller than the quantity at $\beta^F(1)$. In either case, full ownership is optimal, $\sigma^* = 1$. We obtain the following comparative statics for the optimal ownership share.

Proposition 3 *Assume that there is an interior welfare optimal output level* $\sigma^* \in (0, 1)$. *Then, generically,* σ^* *increases if (i) there is a small increase in the strength of the unbundling regulation* μ*, or if the parameter* m *which measures how strongly ownership facilitates manipulation decreases; (ii)* σ^* *also increases if there is a small decrease in the sabotage cost* r*, the access price* a*, the incumbent's downstream production cost* c_1*, or the entrant's downstream cost* c_2*. (iii) The same shifts in parameters increase the parameter region for which we find* $\sigma^* = 1$ *without foreclosure. (iv) These comparative statics with respect to* r, a, c_1*, and* c_2 *hold for any continuous* $\beta(\sigma)$*-function.*

Proof. First we note that at an interior solution $\sigma^* \in (0, 1)$ it holds generically true that the $\beta(\sigma)$ curve crosses the $\beta^F(\sigma)$ curve from below. That is because $\beta(\sigma)$ can't cross $\beta^F(\sigma)$ from above at σ^*, since then one would be in the competitive region also for $\sigma > \sigma^*$ and since we have a strictly positive downstream expansion effect, σ^* would then not be optimal. The only case in which $\beta(\sigma)$ may not cross $\beta^F(\sigma)$ from below at σ^* is a case where $\beta(\sigma)$ touches (but not crosses) $\beta^F(\sigma)$ from above at σ^*, but that case is non-generic.

A small increase in μ shifts $\beta(\sigma)$ upwards and thereby increases σ^*, while the opposite holds true for a small increase in m, which proves (i). Similarly, a small increase in a, r or c_1 shift $\beta^F(\sigma)$ upwards and thereby increase σ^*, while a small increase in c_2 has the opposite effect, which proves (ii). Statement (iii) can be derived in a similar fashion by investigating the inequality $\beta(1) < \beta^F(1)$. For (iv) note that we do not make use of the form of the $\beta(\sigma)$ function, but use only the definition of $\beta^F(\sigma)$. ■

Due to the downstream expansion effect, the optimal ownership share increases when foreclosure becomes less attractive. Foreclosure becomes directly less attractive if the manipulation effort becomes less effective (lower m), if regulation becomes more stringent (higher μ), or if the direct cost or sabotage (r) decrease. Also an increase in the access price a makes foreclosure less attractive since higher output is more valuable for the upstream firm. If the entrant is more efficient (smaller c_2) foreclosure is less profitable, since output without foreclosure increases. Finally, sabotage becomes less attractive if the incumbent's marginal cost c_1 increase since then output drops more strongly under foreclosure.

We get the following additional results for the optimal ownership share.

Result 4 *Generically, in the Cournot example with a continuous endogenous bias $\beta(\sigma)$, (i) total output and consumer surplus is maximized for a strictly positive ownership share $\sigma^* > 0$, and (ii) the ownership share that minimizes the bias does not implement the maximum total output and consumer surplus, except for the case where bias is minimized at $\sigma = 1$.*

Output would be maximized under full ownership unbundling, i.e. $\sigma^* = 0$, only if there would be foreclosure for any positive ownership share but no foreclosure under $\sigma^* = 0$. This occurs only in the non-generic case where the $\beta(\sigma)$-function happens to start at the same point as the border, i.e., if $\beta(0) = \beta^F(0)$. In all other cases, movements away from $\sigma = 0$ remain within one equilibrium region, which implies an increase output.

Similarly, only in the non-generic case where $\beta(\sigma)$-function has an interior minimum and where this minimum lies exactly on the border $\beta^F(\sigma)$, does the ownership share $\sigma < 1$ that minimizes the bias coincide with the ownership share that maximizes output. Intuitively, one would think that $\beta(\sigma)$ is upward sloping when it cuts $\beta^F(\sigma)$ from below. In this case, the ownership share σ^* that maximizes total output is strictly larger than the ownership share that minimizes the bias $\beta(\sigma)$. Yet, since $\beta^F(\sigma)$ is downward sloping, it can happen that also $\beta(\sigma)$ is downward sloping (though less steep) when it cuts $\beta(\sigma)$ from below at σ^*. This means it could be the case that the output maximizing ownership share σ^* is smaller than the bias minimizing ownership share.

The statement (ii) probably holds in many contexts beyond this Cournot analysis and its functional specification, and it illustrates that bias minimization is generically quite different from maximization of consumer surplus. For the statement (i) on the generic suboptimality of full ownership unbundling we should note that this strongly hinges on the assumption that $\widetilde{\mu}(\mu, \sigma)$ – and therefore $\beta(\sigma)$ – is continuous at 0. If we consider a noncontinuous formulation for $\beta(\sigma)$ (like in Figure 1), ownership separation ($\sigma = 0$) may become optimal.

Finally, it is worth mentioning that in this Cournot analysis we have focused on a regulatory rule where the regulator sets a binding access price a. This is a simple example for the larger class of regulatory regimes assumed in the general analysis, where we require that the upstream firm's profit increases in the total output, and where for the upstream firm it does not matter which downstream firm demands its essential input. However, it is possible to construct situations where these conditions are violated if the regulator uses a price cap. Consider a high β – low σ situation. Then the downstream incumbent cares little about the upstream firm's profits, and therefore the double marginalization problem, caused by an access price above marginal cost of access, is severe for the downstream incumbent. If at the same time β is high, the upstream firm cares a lot about the downstream firm's profits. In such a situation, an upstream firm subject to a price cap regulation might be inclined to set an access price below the price cap to mitigate the double marginalization problem. Our Proposition 1 might then no longer hold since an increase in the bias might lead to a larger output. Formally, our results would then apply only under the additional assumption that the bias can not be too large. However, more intuitively, we might ask whether such high β – low σ constellations are very plausible in the first place. When discussing what determines the bias, we argued that "legal manipulation" becomes more difficult with low ownership shares, such that a strong bias β might not be realistic if σ is small.

6 Conclusion

A lack of independence of legally unbundled network operators is a major concern in many network industries. In this paper, we tried to shed some additional light on the incentives in vertical industry structures if legal unbundling does not work perfectly. On a very general level we found that increasing the independence of the network operator's decision making by the use of exogenous mechanisms (like fines for violation of independence requirements) is always beneficial in the sense of increasing final market output. Increasing the degree of vertical integration, i.e., allowing for higher ownership shares of a downstream firm in the network operator, is also beneficial if the degree of independence of the network operator's decision making is sufficiently ensured (though not necessarily perfect). Since ownership and independence tend to interact, we also endogenized the degree of independence as a function of the ownership share. We showed that the optimal ownership share is usually not zero, and that it increases the easier it is to ensure independence by other means (e.g., by increasing fines).

These findings are important for a policy discussion which frequently sees reductions in vertical ownership as the most important tool to increase independence. Like the citation in the introduction suggests, many competition authorities want full vertical separation to achieve independence. Our analysis puts a question mark on this logic since we found that lower ownership might even reduce the independence. And even if it achieves its intended goal of increasing independence, it must not be neglected that this comes at the cost of reducing incentives to increase the final output which can be stronger in a vertically integrated entity. As a policy recommendation, this suggests that regulators should try to increase independence primarily by other tools than by imposing a low ownership share. This would allow to avoid the costs of vertical separation in terms of lower interest in large final output, and at the same time to reap the benefits from independent decision making.

Our analysis has neglected a couple of other important aspects. First, vertical integration might have other benefits, e.g., technological vertical economics of scope. For instance, Kaserman and Mayo (1991), Fraquelli, Piacenza, and Vannoni (2005), or Kwoka (2002) find evidence that in the electricity industry positive vertical economies exists. This tends to strengthen our argument since it increases the cost of vertical separation. We also did not discuss the important issue of investment incentives in network industries. Höffler and Kranz (2011) show that the effect of (perfect) legal unbundling on investment decisions depends on the type of investment that is considered. We also abstracted from the interaction between vertical structure and regulation; we assumed that the regulatory rule is exogenous, and we ignored the threat of regulatory capture. Incorporating these aspects opens scope for interesting further research.

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