Biased Quality Investments and Organisational Structures in Network Industries –

An Application to the Railway Industry

Benjamin Pakula* and Georg Götz*

February 2011

WORKING PAPER

Abstract

This paper analyses the incentives to upgrade input quality in vertically related (network) industries. Upstream investments have a biased effect on the downstream companies and lead to vertical product differentiation. Different vertical structures such as vertical integration, ownership and legal unbundling lead to different investments. We find that, without regulation, vertical integration and legal unbundling regimes provide highest investment incentives and lead to highest welfare. However, we also find foreclosure in the downstream market if the potential degree of horizontal product differentiation of the entrant is low. Under ownership unbundling, investment incentives are lower but there is never foreclosure of the entrant since this would worsen double marginalisation. When the network operator is subject to a break-even regulation, the investment incentives are crowded out under legal and ownership unbundling whereas they remain nearly unchanged under vertical integration. Welfare and consumer surplus decrease under legal unbundling, but increase under the two other regimes.

JEL classification: D2, D4, L43, L51, L92

Key words: Vertical Integration, Investment, Foreclosure, Regulation

* Contact:
Professur VWL I, Justus-Liebig-Universität Gießen, Licher Strasse 62, 35394 Gießen, Germany
benjamin.pakula@wirtschaft.uni-giessen.de

We would like to thank our colleagues at the Justus-Liebig-Universität Gießen and the participants of the conferences "Konferenz Kommunales Infrastrukturmanagement" in Berlin, "Competition and Regulation European Summer School and Conference 2010" (CRESSE) in Chania, as well as "EARIE 2010" in Istanbul for helpful comments. Furthermore, we gratefully acknowledge financial support from the department of Regulatory Affairs of Deutsche Bahn AG which provides third-party funding to the Justus-Liebig-Universität Gießen. The views expressed in this paper remain those of the authors alone.

1 Introduction

During the last thirty years there has been a growing body of literature on pros and cons concerning vertical integration of formerly state-owned monopolies in the postal, energy, telecommunication, and railway sectors. For the railway industry, this topic has gained more importance since the beginning of the 1990ies when the European Union issued the Directive 91/440 (EU 1991) followed by the three so-called railway packages. The reference point of this directive for the member states is to establish at least separate accounting entities for service provision and infrastructure (essential facility) management in the railway industries and to allow for competition in and for the market respectively. In Article 1 it is stated: *"The aim of this Directive is to facilitate the adoption of the Community railways to the needs of the Single Market and to increase their efficiency; [...] by separating the management of railway operation and infrastructure from the provision of railway transport services, separation of accounts being compulsory and organizational or institutional separation being optional, [...]."*[1] It is worth noting that the law does not prescribe full organisational vertical separation, but only accounting separation.

Interestingly, economic literature with regard to these industries generally considers complete vertical integration or separation although these forms remain rare exceptions in reality. To our knowledge, Crémer/ Cremer/ De Donder (2006) (henceforth: CCD (2006)) and Höffler/ Kranz (2007a/b) (henceforth: HK (2011a/b)) are the first to introduce legal unbundling to economic theory even though this organisational form is quite common in deregulated network industries. The key assumption in these models is that the unbundled entity maximises its profit independently of its parent company and acts, consequently, as if it were independent. Accordingly, an important consequence is that downstream competition can spread on a level-playing field without discrimination.

CCD (2006) examine the network operator's incentives to invest under different organisational regimes. In their model the downstream companies constitute the unbundled entities which compete à la Bertrand. They find that the network operator tends to invest the more the more downstream companies he owns because he considers not only his own profit but equally that of his affiliates.[2] HK (2011a/b) look at the reverse case where the upstream company, the network provider, is unbundled. This assumption is meant to reflect current European legislation more appropriately.

1 Angenendt (2007) provides an overview of the unbundling guidelines in the different network industries as implemented in German law.

2 The vertical integration case where the entire company over all productions steps maximises its profits is not considered.

They focus on the question of which regime provides highest quantities, given a fixed investment budget, in the downstream market when non-price discrimination is possible. They find that legal unbundling achieves this because there is no sabotage incentive, and double marginalisation is moderated. One contribution of our paper is to expand this analysis to a context with endogenous investments and with both horizontally and vertically differentiated products, which seems to be particularly important in the railway sector.[3]

Providing high quality services necessitates not only investment in rolling stock, but equally in the network, e.g. to allow for high-speed services and more comfort through reduced tyre-noise. The analysis of investments in railway infrastructure is of high importance because the share of infrastructure cost makes up to 60% of total industry cost which is far more than in other network industries.[4] Investments in input quality as considered in our paper, often favour one of the downstream companies, commonly the incumbent, because it has a lead over the entrants concerning the use of high-tech products in the industry. This means that building or upgrading tracks often favours specific transportation modes that attract different types of final customer demand with immediate repercussion on the profits of the network operator and the Train Operating Companies (TOCs). Moreover, claims are that an integrated network operator may tend to invest in a way that the services he offers will be favoured.[5] Note that these investments often create new demand. For instance, new consumers that used to choose other transportation modes may switch to the railway once high-speed train services become available.[6]

With regard to Great Britain's privatisation experience Gómez-Ibánez (2003) sums this point up by stating that the routeing of the tracks was often as important as the correspondent origin-destination pair and that "*the various TOCs that used the West Coast Main Line had to agree not only on whether the line should be upgraded but in which types of services should be favoured in the design. Operators of slower freight and regional passenger services needed different tracks, signal, and power distribution systems than the operators of the high-speed services. The broad range of issues in dispute made it much harder to develop a consensus on the appropriate design* [...].[7]

3 e.g. in Germany one can choose at least among three different options to travel by train from Frankfurt/ Main central station to Bonn central station: taking the local train/ the Intercity/ the Intercity Express takes 2:51h/ 1:58h/ 1:39h. So, there is product differentiation at least in two dimensions, comfort and duration of the journey. (www.bahn.de, February 11, 2010).

4 cf. Gómez-Ibánez (2003), p. 328.

5 cf. Mofair (2009), p. 114, for an example of the German market and The Economist (2010) for the North American case.

6 There is also a macro dimension of investments in high-speed rail since it may contribute to bring regions closer together and to promote economic activity. See e.g. Ahlfeldt/ Feddersen (2010).

7 Gómez-Ibánez (2003), p. 334.

We model this potential tension by allowing investments of the upstream network operator to have a biased effect on downstream companies leading to quality differentiation. To capture the differences among the services supplied by the various TOCs, we also allow their products to be horizontally differentiated. Using this set-up, we find that, without regulation, vertical integration and legal unbundling regimes provide highest investment incentives and lead to highest welfare. However, for low levels of horizontal product differentiation, the entrant is foreclosed because investments raise the access charge. Under ownership unbundling, investment incentives are lower but there is never foreclosure of the entrant since this would increase double marginalisation and reduce the network operator's profits. When the network operator is subject to regulation, the investment incentives are wiped out under legal and ownership unbundling whereas they remain nearly unchanged under vertical integration. Welfare and consumer surplus decrease under legal unbundling, but increase for the two other regimes. As a comparison of our results with the findings of CCD (2006) and HK (2011a/b) show, accounting for product differentiation and allowing for demand-increasing investments in the upstream market changes conclusions considerably.

This paper is related to the vertical integration and investment literature. Two extensive overviews of research concerning vertical integration issues – without specific focus on network industries – are provided by Joskow (2005) and Riordan (2008). As mentioned above, CCD (2006) and HK (2011a/b) use a similar setting as we do in this paper.

In his survey, Guthrie (2006) describes infrastructure investment incentives under different regulatory regimes. Investment incentives with vertical integration and separation are at the centre stage of Buehler's et al. (2004) article: They analyse a network provider's incentives to invest in quality upgrades and find that, in general, incentives are higher if companies are vertically integrated. Though, non-linear access prices may be a remedy and compensate for the dis-incentives of vertical separation. Foros (2004) analyses investments with spillovers of an integrated company that faces downstream competition in a regulatory regime where the regulator has limited commitment ability. Both companies differ in their production technology. He shows that access price regulation may lower welfare if the downstream companies do not differ too much. Vareda (2007) studies the quality and cost cutting investment incentives in a similar context. He finds that unbundling lowers the incentives for quality investment, but raises investment for cost-cutting. A lack of regulatory commitment may eliminate all investment incentives, so that no regulation may be superior.

Compared to these models, the contribution of this paper is threefold: First, we extend the analysis of legal unbundling into a differentiated product context where investments are endogenous. Second, we analyse the specific case where these strategic investments are highly biased towards one of the downstream companies. Third, in contrast to Foros (2004), who also considers biased investments, we assume Bertrand competition which seems in the context of this paper the more appropriate way.

The remainder of this paper proceeds as follows: In section 2, we present the model. Section 2.1 provides the results for the unregulated benchmark case. Section 2.2 introduces a regulator into the model. Section 3 discusses briefly the model outcome if the entrant provides high quality services. Section 4 summarises, discusses limitations, and concludes.

2 Organisational Structures and Quality Investments – The Model

We model a network industry, in which there is one network provider and two competing TOCs that offer horizontally differentiated services. The network provider offers the network at a uniform access charge to the TOCs. Moreover, it may invest in quality upgrading so that the services of one of the two downstream companies are favoured. Imagine e.g. that one of the companies could offer high-speed train services but without investment it is restricted to low-speed because the infrastructure is not adequate. Upgrading the tracks is costly for the network operator, but generates new demand because it enhances the willingness to pay for the high-speed services. However, it puts the TOC at a disadvantage that does not offer high speed trains since running these trains does not require the investment. Nonetheless, this TOC has also to pay for the higher quality via the access charge like the high speed train operator.

Demand Side

Final demand derives from a linear-quadratic utility function of a representative consumer where the willingness to pay is scaled to one:[8]

$$U=(1+x)q_I+q_E-\frac{q_I^2}{2}-\frac{q_E^2}{2}-s\,q_E\,q_I \tag{1}$$

The two downstream companies, called incumbent (I) and entrant (E), offer services to final customers. The demands for the product of the incumbent and of the entrant are q_I and q_E respectively. The final consumer prices are p_I and p_E respectively.

The utility function in equation (1) leads to the well-known linear demand functions for differentiated products:

8 For a detailed description cf. Vives (2001: 145-147). Note that we abstracted from the numéraire good.

$$q_I = \frac{(1+x) - p_I + p_E s - s}{1-s^2} \tag{2}$$

$$q_E = \frac{1 - p_E + p_I s - (1+x) s}{1-s^2} \tag{3}$$

s is the exogenous parameter for horizontal product differentiation, where s = 1 means homogeneous and s = 0 independent products. The willingness to pay for products is normalised to 1. If the network operator upgrades quality by a factor x, the willingness to pay for the incumbent's product increases by x. So, if investment takes place, products are horizontally and vertically differentiated. Moreover, the demand of the incumbent, q_I, also increases if there is investment, capturing the fact that quality investments are demand expanding.

As mentioned above, our specification allows for an analysis of both the interaction of freight and passenger rail, which would be classified as independent products in our framework, as well as for competition between intercity (IC) and local passenger services. The latter may be regarded as close substitutes on certain origin-destination pairs.

Compared to other frameworks often used in a product differentiation context, e.g. Hotelling models, the chosen linear-quadratic utility specification also captures the demand increasing effect of horizontal product differentiation.[9]

Supply Side

At the supply side, there are one network operator and two downstream firms. The network operator gains revenue from selling network capacity to the downstream companies. It charges a uniform access charge a, and no discrimination among the downstream companies is possible. We limit the analysis to this type of access charge because they are common in the railway industry throughout Europe. In Germany, Deutsche Bahn Netz offered a menu of access tariffs between 1998 and 2001. Track user could choose among a two-part tariff and a linear tariff. If the TOC opted for the two part tariff it became holder of the "Infracard" which entitled it to use the tracks at a lower linear tariff compared to the standard uniform charge. This access tariff was deemed to be anti-competitive because it favoured the own downstream subsidiary.[10]

The management of the network operator decides whether and how much to invest in quality upgrades. A quality upgrade x increases the willingness to pay and the demand for the products of one downstream company by the factor x. As customary in the industrial organisation literature, quality improvements are achieved through investment in fix costs rather than through higher

9 cf. e.g. Martin (2002), ch. 3.6.

10 cf. Knieps (2006).

marginal or operating costs.[11] Here the investment cost is assumed to be quadratic. The network operator does not incur any other cost. δ is an efficiency parameter that is assumed to be larger than or equal to unity. The higher δ is the more costly is the investment for the network operator. The upstream company's profit Π_U reads

$$\Pi_U = a(q_I + q_E) - \delta\frac{x^2}{2} \tag{4}$$

An incumbent I and an entrant E compete in the downstream market. They charge a final consumer price p_I and p_E, respectively, and pay a uniform access charge a to the upstream company. The access charge is the only cost that the downstream companies incur since we abstract from other marginal costs. Downstream profits Π_i read

$$\Pi_i = (p_i - a)q_i \tag{5}$$

where $i = I, E$.

Welfare Measures

Consumer surplus is derived from the linear quadratic utility function as utility net of expenditure on goods purchased:

$$CS = (1+x)q_I + q_E - \frac{q_E^2}{2} - \frac{q_I^2}{2} - s\,q_E q_I - (p_I * q_I + p_E * q_E) \tag{6}$$

Total welfare is

$$W = \Pi_I + \Pi_E + \Pi_U + CS \tag{7}$$

Consumer surplus and producer surplus (sum of the profits) have an equal weight in the welfare function. Often, especially when explicitly considering the objectives of the regulatory agency it is assumed that profits have a lower weight in the objective function of the regulator. In this case welfare can be defined as $W = CS + \alpha\ (\sum Profits)$, where $\alpha \leq 1$.[12] Below we examine the effects on consumer surplus as a limiting case.

Organisational Forms

We consider three different organisational forms that are all relevant in the current political debate. First, we consider vertical integration with open access for competitors. The integrated company maximises the integrated profit, i.e., it considers the effects that a change in prices on the

11 cf. Beath/ Katsoulacos (1991) ch. 6 for a discussion of vertical product differentiation and see e.g. Foros (2004) and Katakorpi (2006) for recent applications.

12 cf. e.g. Armstrong/ Sappington (2007) and Guthrie (2006).

downstream level has on the upstream profits and vice versa. In the ownership unbundling regime, the upstream and the downstream companies maximise the profit on their own. When there is legal unbundling, the upstream company acts as if it were independent, i.e. it maximises its own profit, whereas the downstream parent company maximises the integrated profit. It is disputed in the political debate if this form separation with Chinese walls within one company is sufficient to guarantee independence of the network company. We examine below the effects of such a separation if it worked as intended.

Figure 1 shows the different organisational forms and the resulting industry structure:

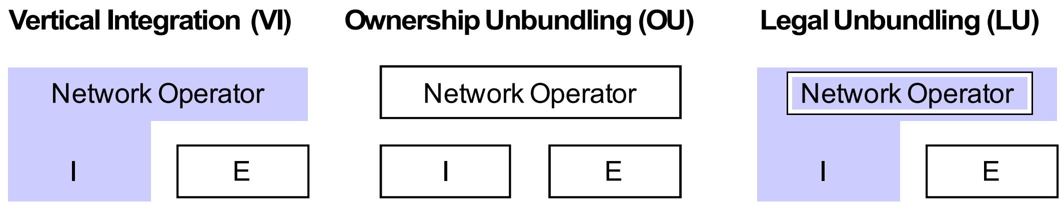

Figure 1: Organisational Forms

We consider a non-regulated benchmark case and a scenario where a regulator fixes the access charge. Throughout the model the following assumption applies:

Assumption: $x \geq 0$

This assumption is necessary to guarantee that there is only quality upgrading and no downgrading.

2.1 The Model without Regulator

The game is played for the three organisational scenarios and is solved recursively:

1. The upstream company decides on the access charge a and on the level x of the quality upgrade.
2. The downstream companies compete in prices (Bertrand competition).

2.1.1 Price Competition Stage

At the second stage of the game, the downstream companies compete in prices. Formally, the incumbent maximises the profit functions (4) and (5) in case of vertical integration.

$$\max_{p_I}: \Pi_I + \Pi_U = (p_I - a) * q_I + a(q_I + q_E) - \delta \frac{x^2}{2} \tag{8}$$

The downstream incumbent maximises the following problem under ownership unbundling as does the entrant in all regimes:

$$\max_{p_i} \Pi_i = (p_i - a) * q_i \tag{9}$$

where $i = I, E$.

The corresponding prices at this stage are

$$p_I^{VI} = \frac{2(1+x) - s(1-3a+s+sx)}{4-s^2}$$
$$p_E^{VI} = \frac{2+a(2+s^2) - s(1+s+x)}{4-s^2} \tag{10}$$

and

$$p_I^{OU} = \frac{(2+s)(1+a-s)+(2-s^2)x}{4-s^2}$$
$$p_E^{OU} = \frac{2+a(2+s)-s(1+s+x)}{4-s^2} \tag{11}$$

When products are independent ($s = 0$) both downstream companies charge the monopoly price which is $p_I^{VI} = p_I^{LU} = \frac{1}{2}(1+x)$, $p_I^{OU} = \frac{1}{2}(1+x+a)$, and $p_E^{VI} = p_E^{OU} = \frac{1}{2}(1+a)$ respectively. Under vertical integration, the access charge a is not relevant for the incumbent's pricing decision. This is due to the fact that the downstream company maximises the integrated profit so that the access charge is irrelevant.

With homogeneous products ($s = 1$) the investment x has a positive influence on the incumbent's price because it increases the consumers' willingness to pay, and a negative influence on the entrant's price: $p_I^{VI} = p_I^{OU} = a + \frac{x}{3}$ and $p_E^{VI} = p_E^{OU} = a - \frac{x}{3}$. When products are homogeneous, the entrant is driven out of the market as soon as there is quality upgrading because its equilibrium price is lower than the access charge. Without an entrant, there is no downstream competition, but a downstream monopoly. The profit maximisation problem is identical to that with independent products: Substituting $s = 0$ in the demand function of the incumbent yields the quantity $q = 1 + x - p$. Profit maximisation again gives the following equilibrium prices, where the subscript *M* stands for monopoly:[13]

13 For simplicity, we assume that the entrant cannot credibly threat to enter the market when there is monopoly so that the monopoly price persists. One can imagine this situation as if there were a very small amount ε of sunk cost necessary to enter the market.

$$p_M^{VI} = \frac{1}{2}(1+x)$$
$$p_M^{OU} = \frac{1}{2}(1+x+a) \tag{12}$$

These prices are equal to those reported above for the case that $s = 0$.

Under legal unbundling, the maximisation problem requires some discussion since the network operator is independent of the downstream parent company. At first sight, one could guess that the optimal values at the second stage of the game are equal to those under vertical integration (10). Under vertical integration, we assume that at both stages of the game the integrated company maximises the integrated profit. Accordingly, this also holds for the first stage when the access charge and the investment are chosen. But under legal unbundling, the case is different, the network operator chooses the access charge and the investment independently of the parent company. Hence by using the optimal values of (10), the upstream company might choose a combination of access charge and investment level that maximises its accounting profit, but drives the parent company into losses. Such can happen since the parent company maximises the integrated profit and offers downstream services as long as the integrated profit is larger than zero. This means that there is a margin squeeze which may be deemed anti-competitive. That is why we re-state the maximisation problem for the legal unbundling regime in the following way:

$$\max_{p_E} \Pi_E = (p_E - a) * q_E$$
$$s.t.\ p_I^{LU} = a^{LU} \tag{13}$$

It follows from (13) that the equilibrium prices of the incumbent and of the entrant depending on a and x are:

$$p_E^{LU} = \frac{1}{2}(1 + a(1+s) - s(1+x))$$
$$p_I^{LU} = a^{LU} \tag{14}$$

p_E is increasing in a and decreasing in x and s. This means that the higher the level of vertical product differentiation, the lower the price of the entrant because from a consumer perspective the service of the entrant becomes less attractive. The negative relation to the level of horizontal product differentiation is straightforward: the less the products are differentiated, the fiercer is competition and the lower is the price.

In case the entrant does not enter the market, the monopoly solution is derived in the same way.

Setting $p_I = a$ guarantees that the integrated profit is maximised. The price is the same as under vertical integration, stated as equation (12). Accordingly, the downstream company that considers the integrated profit cannot do better because the double marginalisation effect is fully internalised.

2.1.2 Investment and Access Charge Setting Stage

At this stage, the upstream company decides simultaneously on the access charge a and on the quality level x. In the vertical integration scenario, the integrated company takes this decision jointly with the downstream parent company (i.e. considering that the investment influences the profit of the downstream parent company); in the legal unbundling and ownership unbundling scenarios, the case is different. The upstream company acts independently. This is evident in case of ownership unbundling because upstream and downstream companies are independent. In case of legal unbundling, the upstream company is owned by the downstream service provider that faces competition, but the network provider acts independently of its parent company.

For simplicity, we assume in this section that $\delta = 1$ so that the investment cost is $\frac{x^2}{2}$, i.e. we analyse the outcomes for only one level of investment efficiency. We will relax this assumption in section Fehler: Referenz nicht gefunden in order to allow for different levels of efficiency.

Vertical integration

The vertically integrated company maximises the integrated profit, i.e., the sum of the upstream and the downstream profit as stated in equations (4) and (5), with respect to the access charge a and the quality level x. The maximisation problem with the reduced profit function takes the following form where an asterisk denotes the optimal values from the second stage of the game:

$$\max_{a,x} : \Pi_I + \Pi_U = p_I^* q_I^* + a q_E^* - \delta \frac{x^2}{2} \tag{15}$$

Maximisation yields the following optimal values for a and x. They depend only on the exogenous differentiation parameter s. Given that the entrant is active and asks for access ($q_E > 0$), they are:

$$\begin{aligned} a_I^{VI} &= \frac{4 - s^2(6 - s + s^3)}{8 - 11 s^2 - s^4} \\ x_I^{VI} &= \frac{8 - s(4 + 3s + s^3)}{8 - 11 s^2 - s^4} \end{aligned} \tag{16}$$

Proposition 1: *Under vertical integration, there is competition in the market if* $s < ½ \equiv s^{VI}$ *(*$q_E > 0$*). The investment level* x *is larger than* 0 *if there is competition.*

Proof: *Inserting the optimal values for the access charge and the investment level (16) into the demand function (3) yields* $q_E^{VI} = \frac{(1-2s)(2+s^2)}{8-11s^2-s^4}$ *. This function is equal to zero at* s^{VI}*. The first derivative of this function with respect to* s *is negative for all values* $0 \leq s \leq s^{VI}$.■

Substituting the equilibrium *a* and *x* from equation (16) into the equilibrium prices of the second stage of the game (10) yields the equilibrium prices in terms of the parameters of the model:

$$
\begin{aligned}
p_I^{VI} &= \frac{s+9s^2+s^3-s^4-8}{11s^2+s^4-8} \\
p_E^{VI} &= \frac{4s+7s^2-3s^3+s^4-s^5-6}{11s^2+s^4-8}
\end{aligned}
\tag{17}
$$

When there is no entry, the monopoly outcome is realised, which is determined as follows:

$$\max_x : \Pi_I + \Pi_U = p^* q^* - \frac{x^2}{2} \tag{18}$$

The resulting equilibrium investment level and the price are:

$$x_M^{VI} = p_M^{VI} = 1 \tag{19}$$

This result can always be secured by setting a sufficiently high access charge. Note that, if there were no possibility for quality upgrading, the incumbent would never foreclose the market ($q_E > 0$ for all s).[14] This already shows that foreclosure stems from the fact that the quality investment is beneficial only to the incumbent and raises the willingness to pay only for its products.

Graphically, prices, access charge, and investment have the following form:

14 See the appendix for the results when there is no investment possibility. See Briglauer/ Götz/ Schwarz (2008) for a similar result.

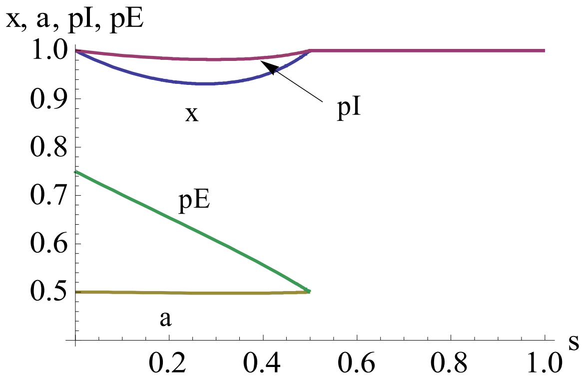

Figure 2: Equilibrium Prices, Access Charge, and Investment (VI) (Benchmark)

Proposition 1 shows that the gain from selling access only dominates the adverse effect stemming from increased competition only if $s < s^{VI}$ and therefore if the demand increasing effect of product differentiation is sufficiently high. Note also that the x-curve is slightly U-shaped implying that the incumbent reduces quality investment below the monopoly case. Higher access revenues more than compensate for the loss in willingness to pay. When products are independent ($s = 0$), the incumbent does not have an incentive to restrict entry because it benefits from selling access to the entrant without its downstream subsidiary loosing any traffic. At this point double marginalisation is highest. But the incumbent's incentives to restrict entry change the more the products become substitutes. At s^{VI} the profits of the entrant and of the network subsidiary are zero. All industry profit is realised within the incumbent's downstream unit. In the vertical integration regime the incumbent always charges a higher price than the entrant because it invests a positive amount of x which increases the willingness to pay of the consumers.

Compared to a situation without investment possibility, allowing for the investment always alters welfare even when investing forecloses the market for the entrant. Here it becomes evident that this type of investment is not a dual problem to sabotage: Sabotage wastes resources and does not increase welfare whereas the investment can increases welfare because it leads to higher willingness to pay and to higher quantities in the market. Sabotage would only lead to higher profits of the firm that engages in sabotage.

Ownership Unbundling

The independent network provider maximises equation (4) with respect to a and x:

$$\max_{a,x}: \Pi_U^{OU} = a(q_E^* + q_I^*) - \delta \frac{x^2}{2} \qquad (20)$$

This yields the following equilibrium values $a^{OU} = \frac{1}{2} + \frac{1}{14+8(1-s)s}$ and $x^{OU} = \frac{2}{7+4(1-s)s}$.

These values are optimal as long as there is entry. This happens for all $s < s^{OU} \equiv \frac{\sqrt{7}-1}{2}$. The ensuing profit is $\Pi_U^{OU} = \frac{2}{7+4(1-s)s}$.

For $s > s^{OU}$, this combination of access charge and investment level would lead to foreclosure of the entrant. Therefore, we have to check if the network operator's maximisation problem changes to one in which he either 1) faces a downstream monopolist or 2) where he chooses a and x in a way to keep the entrant viable. That one that results in higher profits for the upstream company constitutes the equilibrium.

<u>as to 1):</u> It is straightforward to calculate the solution for the bilateral monopoly. In this case the upstream profit maximisation problem reads $\max_{a,x}: \Pi_U^{OU\_M} = a q^* - \frac{x^2}{2}$, where $q^* = (1+x) - p^*$ and $p^* = 1/2(1+a+x)$. Note that in this case, there is no horizontal product differentiation because there is only the incumbent in the market. The upstream firm's profit is $\Pi_U^{OU\_M} = 1/6$.

<u>as to 2):</u> The maximisation problem to keep the entrant viable is the following:

$$\begin{aligned} &\max_{a,x}: \Pi_U^{OU} = a(q_E^* + q_I^*) - \frac{x^2}{2} \\ &s.t.\ q_E = \varepsilon \approx 0 \end{aligned} \qquad (21)$$

The constraint says that the entrant always produces and sells a very small amount. The access charge and the investment level in the entry accommodation (EA) scenario are $a_{EA}^{OU} = 1 - \frac{s}{4-2s-3s^2+2s^3+s^4}$ and $x_{EA}^{OU} = \frac{(1-s)(2+s)}{4-s((1-s)s(3+s)+2)}$. Substituting these equilibrium values into the equilibrium price from the second stage of the game (11) shows that $a_{EA}^{OU} = p_{E\_EA}^{OU} - \varepsilon$ is chosen just to allow the entrant to break even. In this case the profit of the network operator is $\Pi_{\mathrm{U\_EA}}^{OU} = \frac{1}{4s+2(s+s^2-2)^2}$.

Comparison of these results leads to

Proposition 2: *Under ownership unbundling there is always competition in the market. There is an interior solution to the maximisation problem (20) for s < s^{OU}. For less differentiated products the network operator sets* a *and* x *so that the entrant enters with a very small quantity* ε. *The investment level* x *is larger than 0 except for* s = *1.*

Proof: For $s < s^{OU}$, $\Pi_U^{OU} > \Pi_{U\_EA}^{OU} > \Pi_U^{OU\_M}$ and $\Pi_U^{OU} > \Pi_U^{OU\_M}$ holds. For $s > s^{OU}$, $\Pi_{U\_EA}^{OU} > \Pi_U^{OU\_M}$ is true.■

This result shows that it is always optimal for the upstream firm to accommodate entry in order to reduce double marginalisation. Note that the entrant constitutes an effective constraint to the pricing power of the incumbent as soon as he is active. Under Bertrand competition an entrant selling a very small quantity provides sufficient competition to moderate the double marginalisation problem.

From Proposition 2 follows that two cases arise with respect to the equilibrium access charge and the quality level:

$$a^{OU} = \begin{cases} \frac{1}{2} + \frac{1}{14+8(1-s)s} & if\ s < \frac{\sqrt{7}-1}{2} \\ 1 - \frac{s}{4-2s-3s^2+2s^3+s^4} & if\ s > \frac{\sqrt{7}-1}{2} \end{cases}$$

$$x^{OU} = \begin{cases} \frac{2}{7+4(1-s)s} & if\ s < \frac{\sqrt{7}-1}{2} \\ \frac{(1-s)(2+s)}{4+s(-2+(-1+s)s(3+s))} & if\ s > \frac{\sqrt{7}-1}{2} \end{cases} \tag{22}$$

Under ownership unbundling the prices of the incumbent are always higher than those of the entrant if $s < 1$. This is due to the investment that increases the willingness to pay for the services of the incumbent. For $s = 1$, both prices equal the access charges, and investment is zero: $p_I^{OU} = p_E^{OU} = a^{OU}$. The equilibrium prices now take the following form:

$$p_I^{OU} = \begin{cases} \dfrac{(1+s)(13-2s-4s^2)}{(2+s)(7+4s-4s^2)} & \text{if } s < \dfrac{\sqrt{7}-1}{2} \\ \dfrac{5-s(3+s)(1+(1-s)s)}{4-s(2-(1-s)s(3+s))} & \text{if } s > \dfrac{\sqrt{7}-1}{2} \end{cases}$$

$$p_E^{OU} = \begin{cases} \dfrac{(1+s)(11-2s-4s^2)}{(2+s)(7+4s-4s^2)} & \text{if } s < \dfrac{\sqrt{7}-1}{2} \\ 1-\dfrac{s}{4+s(s(2s+s^2-3)-2)} & \text{if } s > \dfrac{\sqrt{7}-1}{2} \end{cases} \quad (23)$$

Graphically prices, access charge, network profits, and investment are depicted in *Figure 3*:

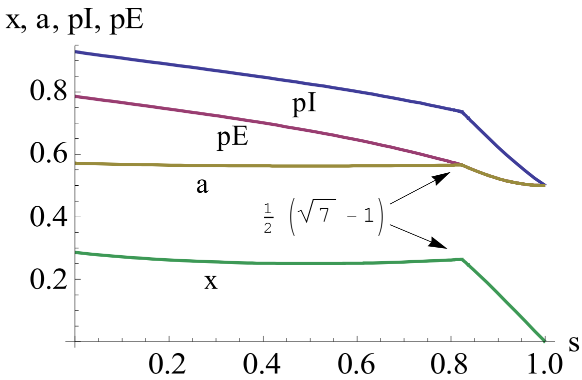

Figure 3: Equilibrium Prices, Access Charge, and Investment (OU) (Benchmark)

Compared to a situation without investment possibility, the downstream company can increase profits by investing. Here it faces a trade-off: The more it invests, the more the equilibrium access charge increases and so do quantities of the downstream incumbent. But the quantities of the entrant decrease until they are driven down to ε at s^{OU}. This trade-off of vertical product differentiation interacts with horizontal product differentiation: The more homogeneous the products are, the smaller is the margin per quantity sold (p - a). The investment in vertical product differentiation works against the entrant because it loses customers and cannot outweigh this effect by reducing its price since the access charge reflects the investment. But the network owner has an incentive to keep the entrant in the market with a very small quantity ε in order to reduce the double marginalisation effect. This is why the network operator reduces investments from s^{OU} on until $x = 0$ for $s = 1$. When there is neither horizontal nor vertical product differentiation prices are driven down to the level of downstream costs, i.e., the access charge.

Legal Unbundling

Under legal unbundling, the network company takes the decision on the access charge and the level of quality upgrading on its own although it is owned by the incumbent downstream company.

In the first stage of the game, the network operator maximises its profit with respect to the access charge and the level of quality upgrading by substituting (14) into the demand function (2) and (3) which yield q_I* and q_E*:

$$\max_{a,x} : \Pi_U^{LU} = a(q_I^* + q_E^*) - \delta \frac{x^2}{2} \tag{24}$$

The equilibrium access charge and investment level read:

$$\begin{aligned} a_I^{LU} &= \frac{2(1+s)(3+s)}{8+3s(4+s)} \\ x_I^{LU} &= \frac{(2+s)(3+s)}{8+3s(4+s)} \end{aligned} \tag{25}$$

The ensuing (accounting) profit is: $\Pi_U = \frac{(3+s)^2}{16+6s(4+s)}$. With these equilibrium values, we can analyse the quantity of the entrant which is $q_E = \frac{s(3+s)-1}{(s-1)(8+3s(4+s))}$. $q_E > 0$ is valid as long as $s < 1/2(\sqrt{13}-3)$. Hence, there are two companies in the market if services are highly differentiated unless the network operator can cause a downstream monopoly by setting another combination of access charge and level of quality upgrading. The network operator would do so if the monopoly profit is higher than the competitive profit.

The monopoly profit under legal unbundling is the same as in the vertical integration case with $\Pi_U^M = 1/2$ and $a_M^{LU} = x_M^{LU} = p_M^{LU} = 1$ since the downstream company sets $p_I = a$ independent of whether there is competition or a monopoly outcome in the downstream market. We can see from the equilibrium access charge for the monopoly case that the entrant is foreclosed because the access charge amounts to the maximum willingness to pay for the services of the entrant. As we assume a very small amount of sunk entry cost, there is no entry.

Hence, to see for which values of s the monopoly solution yields higher profits than the competitive solution, we equate Π_U^M and Π_U for all $s < 1/2(\sqrt{13}-3)$. The network profit functions intersect at $s^{LU} \equiv 1/2(\sqrt{11}-3)$ so that we can derive

Proposition 3: *Under legal unbundling there is competition in the market for* s < s^{LU}. *For less differentiated products the network operator sets* a *and* x *in a way that the monopoly outcome results.*

Proof: *For* s < s^{LU} $\Pi_U^{LU} > \Pi_U^{LU\_M}$ *holds. For* s < s^{LU} $\Pi_U^{LU\_M} > \Pi_U^{LU} \wedge a_M^{LU} \geq p_E$ *so that no entry occurs.*■

Accordingly, prices, investment, and access charge take the following form:

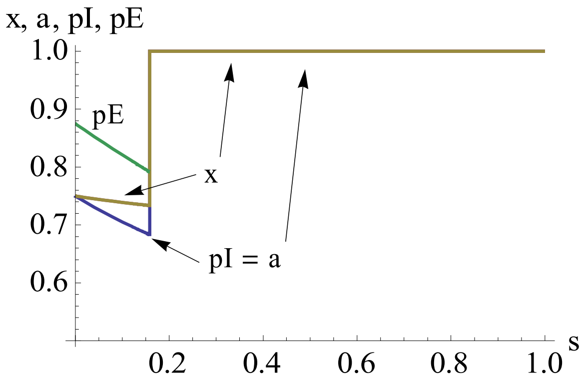

Figure 4: Equilibrium Prices, Access Charge, and Investment (LU) (Benchmark)

This result is interesting since one would presume that legal unbundling would increase competition as intended. This does not happen because the downstream parent company shifts all its market power to the network operator in order to maximise joint profits.

2.1.3 Comparison and Interpretation

The results from the three scenarios of the previous section are compared with regard to consumer surplus and overall welfare because both measures should be considered when deciding on the organisational form. Welfare is defined as the sum of all industry profits and the net consumer surplus as utility minus spending on services (cf. equations (6) and (7)).

To do this, different ranges with respect to the parameter for horizontal product differentiation, *s*, have been defined above:

	$s<s^{LU}$	$s^{LU}<s<s^{VI}$	$s^{VI}<s<s^{OU}$	$s>s^{OU}$
VI	Competition		Monopoly	
OU	Competition			
LU	Competition	Monopoly		

Table 1: Market Outcomes for VI, OU, and LU

The welfare, the consumer surplus, and investment functions for all three regimes look as follows:

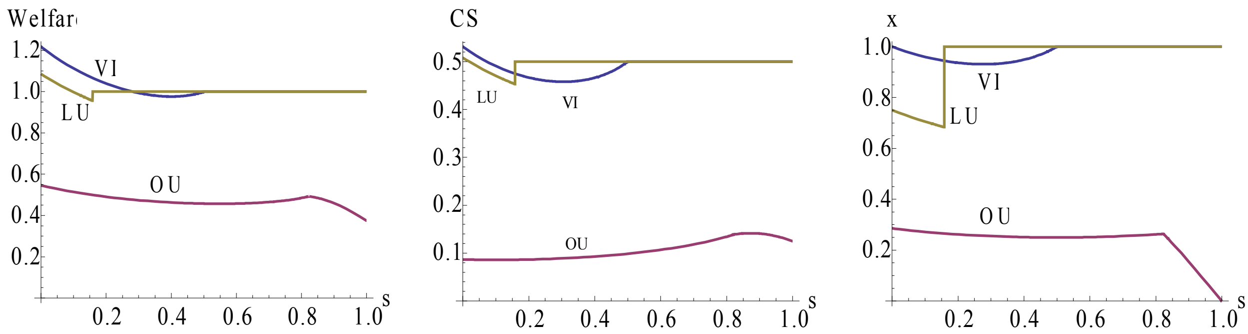

Figure 5: Equilibrium Welfare, CS, and Investment (Benchmark)

Investments are higher under vertical integration and legal unbundling compared to ownership unbundling. This results from the fact that the network operator under own ownership unbundling only partially internalises the effect of its investment on the downstream market. This is different under vertical integration. The integrated company has two instruments available: It can choose a high level of investment in order to maximise own downstream profits quite independently of choosing an access charge that generates high revenue from the entrant. When products are better horizontally substitutable, the integrated company chooses high investments in order to foreclose the entrant to avoid strong competition. Under legal unbundling, the network operator disposes only of one instrument to maximise (accounting) profits: the access charge. Hence, it must compromise between investing a large amount which drives the access charge up and generates more revenues from the incumbent downstream company by reducing the revenues from the entrant (and vice versa). Accordingly, the investment level is lower when products are poor substitutes. But the monopoly investment level is realised for highly differentiated product since the (downstream) parent company aims at joint profit maximisation and shifts all the market power to its upstream subsidiary.[15]

15 See section 2.1.2.

From a welfare perspective, vertical integration and legal unbundling are always superior to ownership unbundling. This stems from the fact that investments are higher and that there is less double marginalisation. Vertical integration yields higher welfare and consumer surplus as compared to legal unbundling for low levels of product differentiation, i.e. $s < s^{VI}$. At this point the welfare and consumer surplus functions for the legal unbundling regime exhibit a jump since the network provider chooses – via his investment decision – a downstream monopoly. This downstream monopoly yields the same welfare and consumer surplus as the vertical integration monopoly.

For $s^{LU} < s < s^{VI}$ legal unbundling is superior to vertical integration since the outcome of a vertically integrated monopolist is attained. This results is due to the fact that the downstream incumbent always sets $p_I = a$ under legal unbundling. This is better from a welfare and consumer surplus perspective because under legal unbundling the company charges a price that is as high as the investment level, but under vertical integration the price exceeds the investment level.

Moreover it is interesting to have a look at the disaggregated profit functions of the incumbent. Under legal unbundling all the profit is realised within the upstream company whereas under vertical integration and with competition in the market, most part of the profit comes from the downstream unit of the vertically integrated company. This result is due to the fact that the integrated profit is maximised in both stages of the game, i.e. it is profit enhancing for the entire company to set a low access charge if products show a high degree of differentiation because the business stealing effect is not very large. In contrast, under legal unbundling the network operator maximises its profit by only using the access charge so that it charges more than would result if integrated profit maximisation were done. In the monopoly case, profits are not separable under vertical integration.

Prices and investments as well as the disaggregated profit functions are depicted in the following graphs for the relevant range of $0 < s < s^{VI}$.

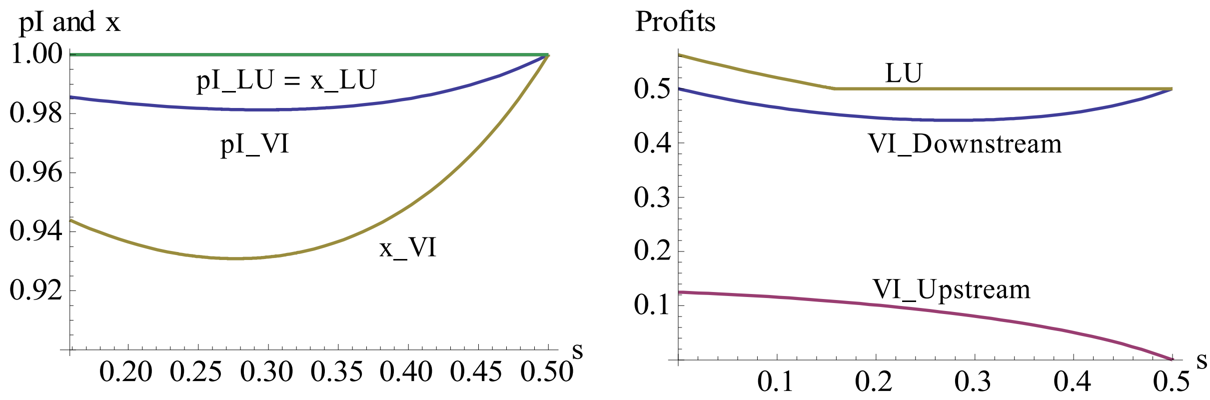

Figure 6: *LHS: Prices and Investments for* $s^{LU} < s < s^{VI}$ *(Benchmark)*

RHS: Disaggregated Profits VI and LU for $0 < s < s^{VI}$ *(Benchmark)*

2.1.4 Variations of the Efficiency Parameter δ

In the sections above, we assumed that the efficiency parameter is $\delta = 1$. In this section we relax this assumption and show that the main results are robust when δ takes values larger than unity. The higher the efficiency parameter the more costly it is for the network operator to increase the willingness to pay for and the demand for the incumbent's services.

The maximisation problems are the same as stated in equations (15), (20) as well as (24).

In the vertical integration regime, the new equilibrium values for the access charge and the investment level are: $a^{VI}=\frac{8\delta-s^2((8-s+s^3)\delta-2)-4}{16\delta-s^4(2\delta-1)-s^2(14\delta-3)-8}$

$x^{VI}=\frac{8-s(4+3s+s^3)}{16\delta-s^4(2\delta-1)-s^2(14\delta-3)-8}$. In this case the entrant is active in the market for $s<1-\frac{1}{2\delta}$. The investment level and access charge are negatively related to δ. This means that upgrading the network becomes less attractive to the incumbent if the cost is higher. If he invests less, he charges a (slightly) lower access price to the entrant.

The monopoly result is realised for all $s>1-\frac{1}{2\delta}$. The investment level of $x_M^{VI}=\frac{1}{2\delta-1}$ is sufficient to foreclose the entrant from entering the market.[16] There is no foreclosure for any s as δ

16 Substituting x^{VI}_{IM} into the equilibrium quantity from the second stage of the game shows that for any $s>1-1/2\delta$ the quantity of the entrant is negative. This means that the investment level is high enough to

converges to infinity. In this case, there is no investment and the access charge is equal to $a = ½$. This is the result from the model where no quality investments are possible.[17]

Including δ in the ownership unbundling maximisation problem yields the following equilibrium values: $a^{OU} = \frac{2(2-s)(1+s)\delta}{4(2-s)(1+s)\delta - 1}$ and $x^{OU} = \frac{2}{4(2-s)(1+s)\delta - 1}$. Both access charge and investment level are negatively related to the efficiency parameter. In contrast to the vertical integration regime where the access charge is only paid by the entrant, in the ownership unbundling case the network operator has no incentive to raise the access charge with δ because this would reduce traffic and decrease its profits. Instead, the network operator reduces investments when they become less efficient.

The threshold for which the maximisation problem of the network operator changes is $s \equiv (\sqrt{9-2/\delta} - 1)/2$. As shown for the specific case above, he would choose the entry accommodation levels $a_{EA}^{OU} = \frac{s + (2-s-s^2)^2 \delta}{2s + (2-s-s^2)^2 \delta}$ and $x_{EA}^{OU} = \frac{(1-s)(2+s)}{2s + (2-s-s^2)^2 \delta}$ for $s > (\sqrt{9-2/\delta} - 1)/2$. For δ converging to infinity, the entry accommodation case does not apply here because the threshold value for s equals unity. If so, the access charge equals $a = ½$, and the investment level is zero.

Under legal unbundling, there is a competitive equilibrium as long as $s < \frac{(\sqrt{1-6\delta+16\delta^2} - 1 - 2\delta)}{2\delta}$,[18] i.e. the less efficient the investment is the smaller the area in terms of s where the monopoly equilibrium applies. The equilibrium access charge and the investment level read $a^{LU} = \frac{2(1+s)(3+s)\delta}{4(1+s)(3+s)\delta - (2+s)^2}$ and $x^{LU} = \frac{(2+s)(3+s)}{4(1+s)(3+s)\delta - (2+s)^2}$. Both are negatively related to changes in δ since it becomes more costly to invest if the efficiency worsens. With δ converging to infinity the access charge converges to ½, and there is no investment any more.

---

foreclose the entrant from entering the market and hence, that the monopoly result is stable.

17 See the results in the appendix.

18 This is the critical s at which the competitive profit equals the monopoly profit. Technically, there would be positive quantities of the entrant for all $s < \frac{(\sqrt{1-4\delta+16\delta^2} - 1 - 2\delta)}{2\delta}$ but the maximisation problem changes here at $s = \frac{(\sqrt{1-6\delta+16\delta^2} - 1 - 2\delta)}{2\delta}$. As soon as the monopoly profit is higher than the profit under competition, the network operator would choose the monopoly outcome. With the monopoly equilibrium values for the access charge and the investment level, the monopoly can be sustained. See the reasoning in section 2.1.2 that applies here, too.

The monopoly outcome is realised for $s > \frac{(\sqrt{1-6\delta+16\delta^2}-1-2\delta)}{2\delta}$ with $a_M^{LU} = \frac{\delta}{2\delta-1}$ and $x_M^{LU} = \frac{1}{2\delta-1}$.

These results show that the propositions established in this chapter are robust to the introduction of a variable efficiency parameter when there is no regulation of the upstream market.

2.2 The Model with Regulator

Regulated prices for bottleneck resources are a characteristic of most network industries. Introducing a regulator adds a step into the game which now takes the following form:

1. The regulator chooses the welfare-maximising access charge *a* under a zero profit constraint for the network company.
2. The upstream company decides on the investment level *x*.
3. The downstream companies compete in prices (Bertrand competition).

When the regulator chooses the access charge before the upstream company decides how much to invest means that the regulator can credibly commit not to expropriate the network company.[19] With this assumption of omniscience we abstract from problems like e.g. information asymmetries. The regulator can determine the access charge *a* but cannot enforce the investment level *x*. Insofar he can reach a second best solution.

2.2.1 Price Competition Stage

The price competition stage remains unchanged under vertical integration and ownership unbundling. Hence, the results from section 2.1.1 apply here as well. The case is different for legal unbundling: We do not need to assume that the downstream unit of the legally unbundled company sets $p_I = a$ in this case because the network operator's profit is regulated down to zero. Hence, the entire company would make zero profits if $p_I = a$. Accordingly, for legal unbundling under regulation, the maximisation problem stated as equation (8) applies here and not that of equation (13).

2.2.2 Investment Stage

The maximisation problems are similar to those established in section 2.1.2 except that the network

19 If we assumed that the regulator cannot commit, this assumption would need to reverse the order of steps 1 and 2.

operator only decides on the level of quality upgrading because the access charge is set by the regulator.

In case of vertical integration/ ownership unbundling/ legal unbundling, the integrated company chooses the following quality upgrades:

$$x^{VI}=\frac{8-s(4+s(8+(a(s-1)-2)s(1+s)))}{8-s^2(16-7s^2+s^4)} \tag{26}$$

$$x^{OU}=x^{LU}=\frac{a}{2+s-s^2} \tag{27}$$

The interpretation of the term for the ownership and legal unbundling regimes is easy: As long as the regulator allows a mark-up on the upstream marginal cost ($a > 0$), the network operator invests. Investments are highest for $s = 0$ and $s = 1$.

In the vertical integration regime, the case is a bit more complex. All else being equal, the integrated company invests more because it earns not only from the access charge, but it also considers the direct effect of increasing the willingness to pay as well as the demand when it invests in x. Therefore a change in a does only affect very few the marginal rate of investment (first derivative of x with respect to a) for low and intermediate levels of vertical product differentiation. The reason for this is that the integrated company has two instruments available to maximise profits: it optimises the access charge with respect to the entrant's price reaction whereas the investment is chosen in order to maximise the profit of the own downstream subsidiary.

2.2.3 Access Charge Setting Stage

At the first stage of the game, the regulator chooses the welfare-maximising access charge subject to a zero-profit constraint for the network operator:

$$\begin{aligned} &max: W=\Pi_I^*+\Pi_E^*+CS^* \\ &s.t.\, \Pi_U^*=0 \end{aligned} \tag{28}$$

where the asterisk denotes the fact that the reduced functions are used here.[20]

In this section, we chose the case of a zero-profit regulation for the network operator, not because that we think this is the most realistic assumption but to highlight one of our results: If investments

20 Alternatively, the problem can also be solved by inserting the equilibrium investment levels from equations (26) and (27) into the relevant profit function of the network operator and by solving that for a.

of the upstream company in a vertically related industry benefit much the companies in the downstream market, it is not reasonable to vertically separate the companies in the industry if the network operator can (not) only partially skim the profits of its investments.

Proceeding like this requires that even the vertically integrated operator has accounting separation. This is in line with European legislation as stated in Directive 91/440 (EU 1991), article 1. Nonetheless, the vertical integration case is ex ante different from the legal unbundling regime because there, the upstream company acts independently of its downstream parent company.

Vertical Integration

In the vertical integration scenario, the regulator sets the following access charge:

$$a_R^{VI} = \frac{64s+272s^2-136s^3-264s^4+72s^5+120s^6-12s^7-26s^8+2s^{10}-96+2B}{A} \tag{29}$$

where an asterisk denotes the equilibrium prices from the third stage of game, R stands for *Regulation*, and A and B are defined as follows:

$$A = -64-32s+240s^2+128s^3-312s^4-172s^5+169s^6+92s^7-40s^8-22s^9+3s^{10}+2s^{11}$$
$$B = \sqrt{(s+s^2-1)(16s^2-7s^4+s^6-8)^2(-20+s(20+(-2+s)s(-6+s+3s^2+s^3)))}$$

The investment is chosen accordingly:

$$x^{VI} = \frac{8-s(4+s(8+(a_R^{VI}(s-1)-2)s(1+s)))}{8-s^2(16-7s^2+s^4)} \tag{30}$$

With these values follows:

Proposition 4: *When products are highly differentiated (*s < s_R^{VI} *) there is competition in the market.*

Proof: *See the case without regulator.*■

This leads to positive quantities for the incumbent and the entrant as long as $s < s_R^{VI}$.

For less differentiated products ($s > s_R^{VI}$), there is no entry, and the monopoly results are obtained. These are equivalent to those of section 2.1.2.

Hence, in the following we only have to compare the outcomes of the regulated case and the unregulated benchmark for $s < s_R^{VI}$. The price of the incumbent is higher than that of the entrant because the investment increases the willingness to pay for its products. The investment is nearly unchanged, but the access charge is lower since regulation deprives the network unit of all its market power. This is the reason why entrant's price and quantities are higher.

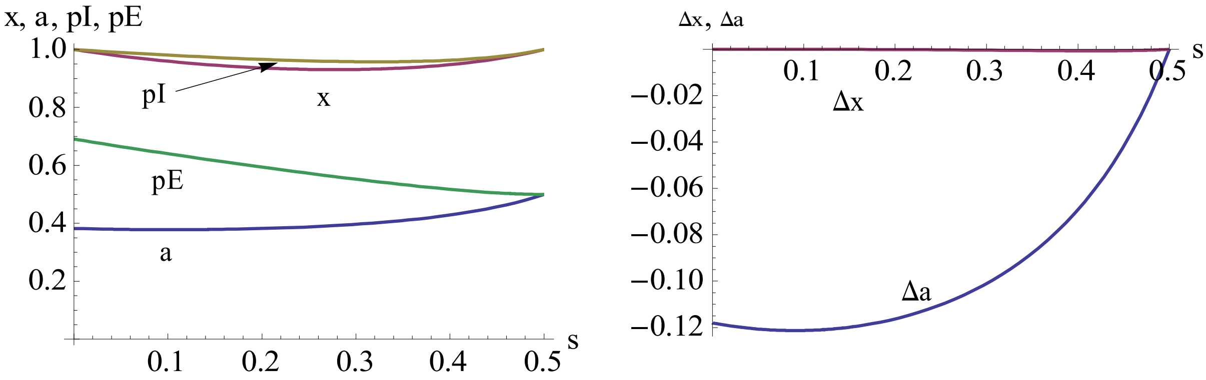

Figure 7: LHS: Prices, Investments and Access Charge VI (Regulation)
RHS: Changes of Investment and Access Charge compared to Benchmark Case

Ownership Unbundling

Under ownership unbundling, the regulator maximises the welfare maximisation problem stated as equation (28). This yields two possible values for *a*: $a_U^{OU}=0 \vee a_U^{OU}=\frac{4(2-s)(1+s)}{4(2-s)(1-s)-1}$ where the second value leads to negative quantities of the entrant because it is larger than unity for any *s*. Hence it does not constitute a possible solution for the economic problem. Therefore the regulator sets $a = 0$. With an access charge that is larger than 0, he would drive the entrant out of the market. The resulting monopoly welfare would be inferior for any *s* to that of the competitive situation even though there is no investment in quality upgrades when $a = 0$.

Proposition 5: *Under ownership unbundling, regulation of the network operator leads to zero investment.*

Proof: *Straightforward from equation (27) when substituting the equilibrium access fee* a = 0.■

The ensuing equilibrium prices are as follows:

$$p_{I\_R}^{OU}=p_{E\_R}^{OU}=1-\frac{1}{2-s} \tag{31}$$

The results are identical for both downstream companies since they are assumed to be symmetric. The only way to differentiate vertically is to supply higher quality input. This does not happen if $a = 0$.

Prices are strictly decreasing in *s*. The more intense competition is, the lower are the prices. Quantities show a U-form. Here we have to discern the product differentiation and the price effect.

First, moving away from totally differentiated products, the product differentiation effect outweighs the price effect: quantities are falling because less variety is available. From s = ½ on, the price effect is stronger than the product differentiation effect so that quantities are increasing. This is due to the fact that prices are strategic complements under Bertrand competition so that the reaction of one firm on a decision of the other becomes more aggressive the better the products are substitutable. Prices are equal to marginal cost ($p_I = p_E = 0$ in this case) when products are homogeneous.

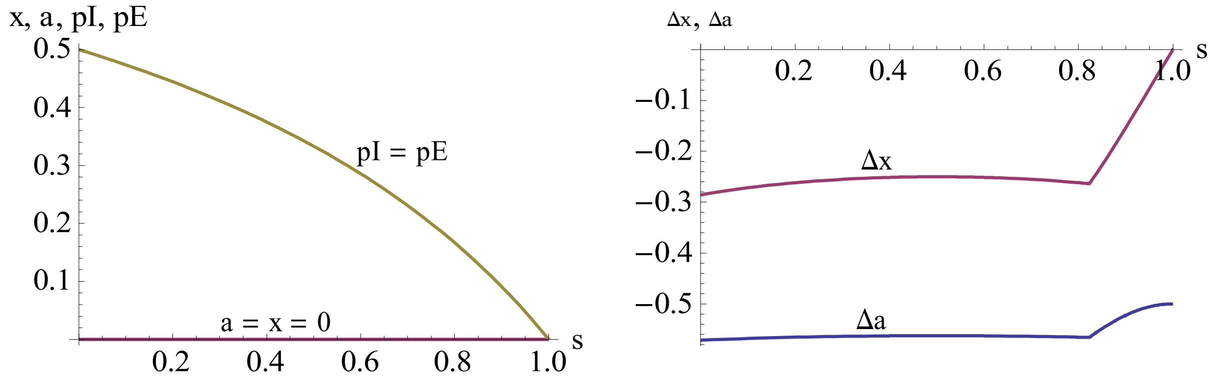

Figure 8: *LHS: Prices, Investments and Access Charge OU (Regulation)*
RHS: Changes of Investment and Access Charge compared to Benchmark Case

Compared to the unregulated benchmark case, investments and also the access charge are lower. The access charge is regulated down to marginal costs, which are equal to zero. This is done since the competitive effect of a zero access charge outweighs the positive effect that investment (and a positive access charge) has on only one downstream firm. Prices, access charge, and investment are the same under regulation and without regulation for $s = 1$.

Legal Unbundling

When the incumbent company is legally unbundled, the regulator maximises equation (28) by substituting the equilibrium level of investment from equation (27) into the maximisation problem. The regulator chooses $a = 0$ as in the ownership unbundling regime. This can be stated as

Proposition 6: *Under legal unbundling with regulation, there is no investment. The resulting equilibrium values are identical to those in the ownership unbundling regime.*

Proof: *Straightforward from equation (27) when substituting the equilibrium access fee* $a = 0$.■

Even though investing could increase the company's (aggregate) profits (see the vertical integration regime), the network operator has no incentive because it only considers its own profit which is negative if $x > 0$ is chosen. The high investment level without regulation is possible because in the non-regulated case, the downstream company shifts all its market power to the upstream subsidiary by setting $p_I = a$ and maximises the aggregated profit in this way. This does not work here since the upstream company is regulated to zero profits.

Prices, investments, and access charge under legal unbundling are plotted in the following graph:

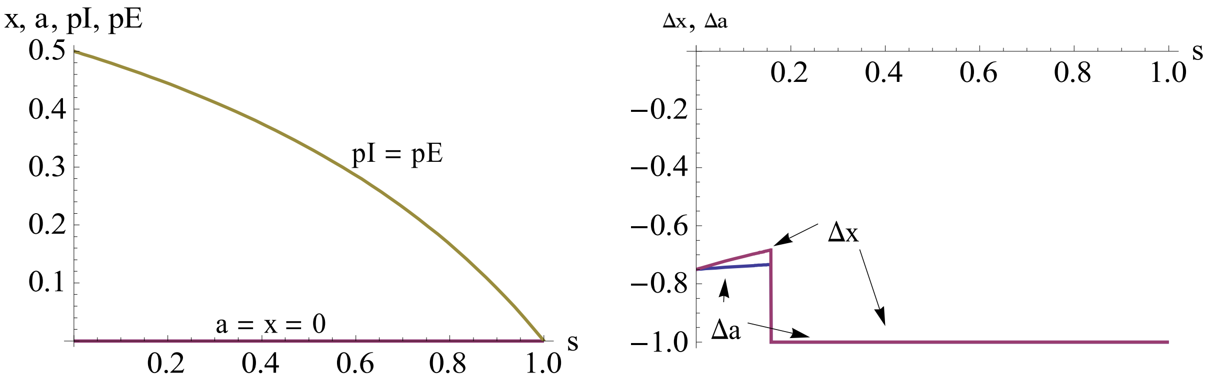

Figure 9: LHS: Prices, Investments and Access Charge LU (Regulation)
RHS: Changes of Investment and Access Charge compared to Benchmark Case

2.2.4 Comparison and Interpretation

As in the model without regulator the results from the three scenarios of the previous sections are compared with regard to consumer surplus and overall welfare. Moreover, differences in the outcome compared to the regulated benchmark are discussed.

When there is a regulator we only have to distinguish two different ranges of horizontal product differentiation as shown in the following table:

	$s < s_R^{VI}$	$s > s_R^{VI}$
VI	Competition	Monopoly
OU=LU	Competition	

Table 2: Market Outcomes for VI, OU, and LU under Regulation

The welfare, the consumer surplus, and investment functions for all three regimes look as follows:

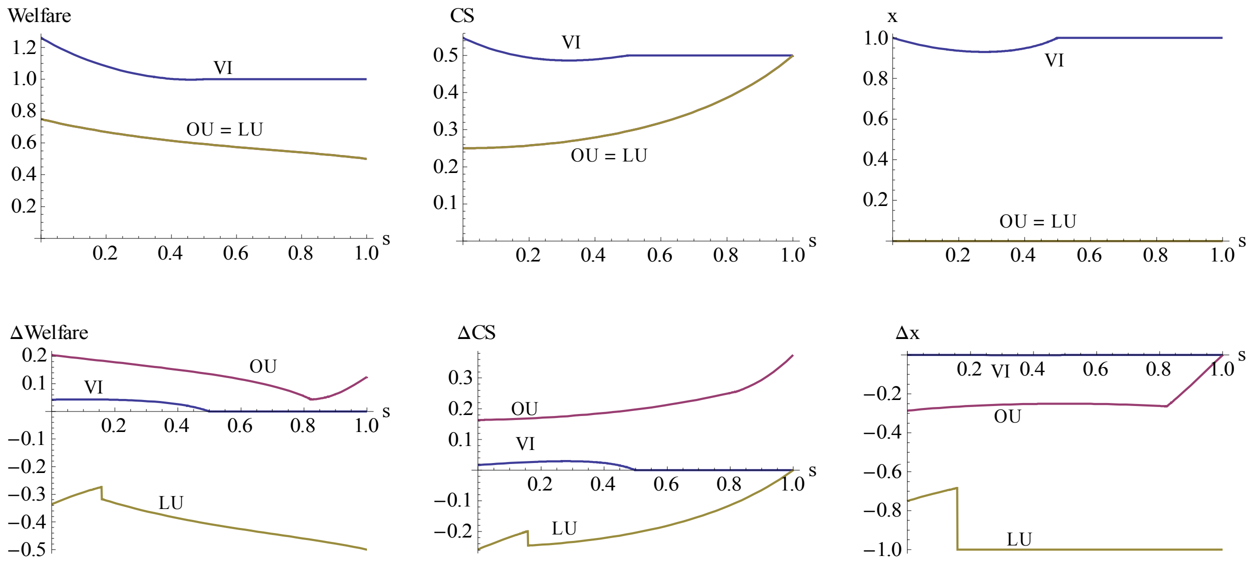

Figure 10: *Equilibrium Welfare, CS, and Investment (Regulation)*
Changes in Welfare, CS, and Investment (Regulation vs. Benchmark)

From a welfare-perspective, vertical integration is superior to the ownership and the legal unbundling regimes, since the network company invests. This increases the incumbent's profits and consumer surplus more than it reduces the entrant's profits compared to ownership and legal unbundling.

In contrast to the unregulated benchmark case, there is no double marginalisation here because the network operator's profits are regulated down to zero. As discussed in section 2.2.3 investments are nearly unchanged, but the access charge is lower. This is why the profits of the integrated company are smaller whereas the profits of the entrant and consumer surplus are higher: $|\Delta \Pi_I| + |\Delta \Pi_U| < |\Delta \Pi_E| + |\Delta CS|$.

Under OU, consumer surplus is larger the less the products are differentiated because the stronger is price competition. At s = 1 consumer surplus and welfare coincide because with intense price competition profits in the downstream market are driven down to zero.

Compared to a situation without regulation, regulation increases welfare and consumer surplus. This stems from the fact the downstream companies do not have market power any more due to vertical product differentiation because all investment incentives are wiped out and the access fee is eliminated. Hence companies charge lower consumer prices. When competition is weak, both downstream companies make higher profits than in the unregulated case, but profits are driven down to zero when horizontal product differentiation converges to s = 1. The price effect outweighs the product differentiation effect. Hence consumer surplus is highest when companies do not have market power and charge low prices.

Comparison of the regulated LU results with the non-regulated benchmark case shows that welfare and consumer surplus are lower. To verify this for consumer surplus, consider the CS function from equation (6) and substitute the demand functions (2) and (3) into it. This yields a consumer surplus function that only depends on p_I, p_E, x and s. The partial derivatives show that changes in either p_I, p_E or x have absolutely the same influence on consumer surplus, i.e. $\left|\frac{d\,CS}{dp_I}\right| = \left|\frac{d\,CS}{dp_E}\right| = \left|\frac{d\,CS}{dx}\right|$ where prices changes are negatively and changes in the investment level are positively related to consumer surplus. When we compare the prices and the investment without and under regulation, we see the changes of the investment level outweigh the sum of the price changes as illustrated in *Figure 11*. This is why consumer surplus is lower under regulation than without regulation:

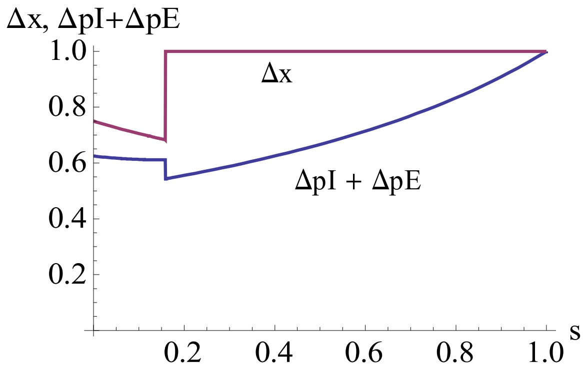

Figure 11: Changes in Investments and in Prices (Regulation vs. Benchmark)

Industry profits are also lower under regulation. Without regulation, there was no profit for the parent company of the legally unbundled network operator, there was a positive profit for the entrant for $s < s^{LU}$, and the most profit was realised within the legally unbundled upstream business unit. This source of profit is wiped out through regulation. So, the companies face at the most horizontal product differentiation which gives them some market power. As competition increases profits go down to zero.

2.2.5 Variations of the Efficiency Parameter *δ*

To begin with the easy cases of ownership and legal unbundling: As the regulator sets $a = 0$ for any relevant value of δ, there is no investment. Hence, it does not matter how efficient the investment is.[21]

In case of vertical integration, the maximisation problem is the same as described in sections Fehler: Referenz nicht gefunden and 2.2.3. The equilibrium values for the access charge and the investment level reads as follows:

$$a_R^{VI} = \frac{p_I^* + (2 - p_I^* - p_E^*)(1-s)^2(1+s)\delta - B}{(2-s)s} \tag{32}$$

where an asterisk denotes the equilibrium prices from the third stage of game, R stands for "Regulation", and B is defined as follows: $B = \sqrt{p_I^{*2}(s-2)s + (p_I^* - (p_E^* + p_I^* - 2)(s-1)^2(1+s)\delta)^2}$. The investment is chosen accordingly:

$$x_R^{VI} = \frac{p_I^* - p_I^* s + (p_I^* + p_E^* - 2)(s-1)^2(1+s)\delta + B}{(s-2)(s^2-1)\delta} \tag{33}$$

The entrant is active in the market as long as δ takes a value within the shaded ranges depicted in the following graph:

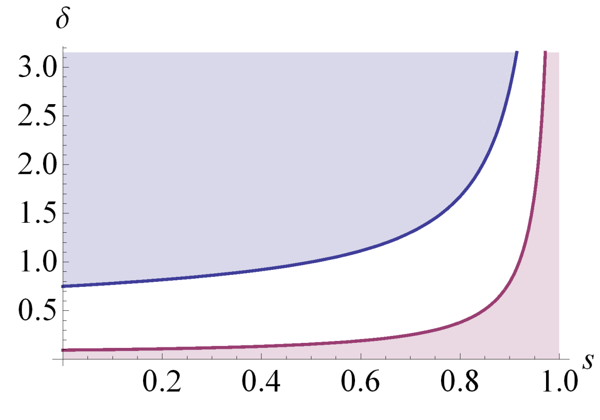

Figure 12: Upper and Lower Bound for δ as Conditions for Entry (Regulation)

As, by assumption, we only consider values $\delta \geq 1$, we see that the upper (lower) bound is only binding for $s \geq$ ½ (0.919). For other values, the monopoly result is valid: $x_{R\_M}^{VI} = \frac{1}{2\delta - 1}$.

21 This holds for all $\delta >=$ ½.

3 The Reverse Case

We assumed throughout this paper that the incumbent downstream company (i.e. that one that is bundled with the network operator) benefits from the investment because it provides high quality services. We motivate this assumption with the fact that in many countries in Europe the formerly state-owned and integrated railway operators offer high-speed train services. But one may imagine the reverse case: the incumbent offers (mainly) standard train services whereas the entrant supplies high-speed transport. In order to simulate the market outcome for this case, we re-formulate the model by assuming that the entrant offers high-quality services.[22]

Looking at the performance indicators investment, consumer surplus, and welfare, we notice that all indicators are lower under VI and LU compared to the case where the incumbents provides high-quality services. The reason for this outcome is the fact that the network operator cannot internalise as many of the benefits of its investment. For the higher willingness to pay, induced by the investment, accrues to the entrant. Therefore the double marginalisation effect is present which leads to lower investments. Hence consumer surplus and welfare are lower, too. The results under OU are equal to those in the previous section as all companies are independent and both downstream companies are identical.

The following *Figure 13* shows welfare, consumer surplus, and investment for the standard and the reverse cases:

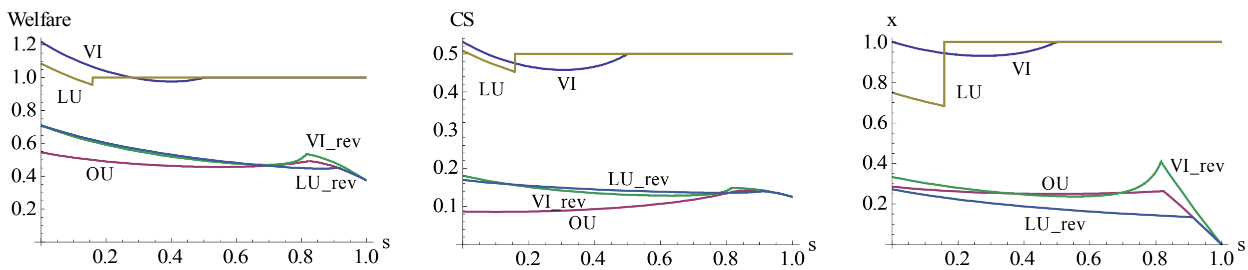

Figure 13: Equilibrium Welfare, CS, and Investment - Reverse Case vs. Standard case

22 The calculations are provided upon request.

4 Discussion and Conclusion

In this paper, we study the investment incentives for upstream quality upgrading under different organisational structures when differentiated products are supplied in the downstream market. The railway industry may serve as an example: The network operator decides on whether to upgrade the infrastructure, e.g. preparing the tracks for high-speed traffic. Infrastructure upgrades benefit only one of the downstream companies because the other company does not offer that type of service which requires an upgraded network. We analyse the investment incentives for the case of a vertically integrated, a vertically separated, and a legally unbundled industry. Moreover, we distinguish between a non-regulated benchmark case and a regulated regime.

Without regulation, we find that investment incentives and welfare are highest under vertical integration and legal unbundling because double marginalisation is low and benefits of the investment in both markets are best internalised. With regulation, the outcome of the vertical integration regime is superior to those of ownership and legal unbundling. In both regimes, investment incentives are wiped out since the regulator does not allow a mark up on marginal cost. Although, investing could increase the profit of the legally unbundled company, there is no investment since the network operator does not internalise the effect of its investment on the business of its downstream parent company. Comparing this setting to the benchmark case yields that welfare is higher under vertical integration and ownership unbundling but lower under legal unbundling.

A tentative policy implication that can be drawn from this model concerns the importance of internalising the effects of investments: The more the investing business unit will benefit from the investment, the higher will be the incentives. Insofar, vertical integration seems a secure option to foster investment whereas legal unbundling may be detrimental to that if the network operator's profit is regulated because it does not internalise the effect on its parent company.

Our results are partially driven by the linear-quadratic utility function. On the one hand this can be interpreted as a limitation to the model. On the other hand, we have not explicitly considered other problems that may arise when separating the industry. There are at least two groups of arguments that are closely related and that should be regarded in this context, too. First, several empirical studies have found economies of scope in integrated railway companies.[23] As we do not consider economies of scope, our approach can be classified as cautious. Second, a separated network from transport operations requires a lot of contracts between the parties involved. This makes

23 cf. among others Bitzan (2003) and Growitsch/ Wetzel (2007).

coordination much harder[24] and may create hold-up problems which may lead to lower investment levels.[25]

The findings are in contrast to previous literature on legal unbundling. HK (2011a/b) who also assumed that the network operator is unbundled, found that legal unbundling could generate highest quantities in the market. Their result strongly hinges on the assumptions of sabotage and an exogenous investment budget in combination with access regulation: The vertically integrated company has an incentive to discriminate against the competitor in the downstream market whereas this effect is ruled out if the network operator acts independently. In this model, we highlight the effect of differentiated products in a setting where quality-enhancing investments are endogenous to the model.

There are some limitations to the model and to the implications derived. First, it is assumed that each company offers only one variety of final consumer services. This is ad odds with reality because in Germany or France e.g., the incumbent railway operators offer a large variety of differentiated products, ranging from first class and second class coaches to coaches with silent and mobile-phone zones. But this critique can partially be rebutted considering the fact that the effects on vertical structures and investments are in the focus of this paper. Second, we assume that investments in quality upgrades only benefit the incumbent company. This assumption was made with regard to high-speed traffic which is, with rare exceptions, only offered by the incumbents. Insofar it is well-founded. Arguing in a future European context with interoperability all over the continent, this example would not necessarily hold because, potentially, the foreign incumbents could compete with their high-speed trains. Nonetheless, also in this setting, network investments that favour one downstream company will be possible because this constitutes a very general phenomenon in the railway industry.[26]

To sum up, the assessment of efficient vertical structures in network industries still continues and deserves further attention.

24 cf. Gómez-Ibánez (2004), pp. 7-9, Pittman (2007).
25 cf. Hartwig et al. (2009).
26 cf. Gómez-Ibánez (2004), p. 333.

5 Appendix: Results without Quality Investment

We restrict ourself here to report only the results after the last stage of the game, where "*nx*" after the supscript for the organisational regime stands for *no investment in x*. Note that there is never foreclosure in any regime ($q_E > 0$ for all possible values of s) when there is no possibility for the quality investment.

Vertical Integration:

$$a_I^{VInx} = \frac{8+s^3}{16+2s^2} \tag{34}$$

$$p_I^{VInx} = \frac{8+s}{8+s^2} - \frac{1}{2}$$
$$p_E^{VInx} = 1 - \frac{2(1-s)}{8+s^2} - \frac{s}{2} \tag{35}$$

Ownership Unbundling:

$$a_U^{OUnx} = \frac{1}{2} \tag{36}$$

$$p_I^{OUnx} = p_E^{OUnx} = 1 + \frac{1}{2(s-2)} \tag{37}$$

Legal Unbundling:

$$a_I^{LUnx} = \frac{1}{2} \tag{38}$$

$$p_I^{LUnx} = \frac{1}{2}$$
$$p_E^{LUnx} = \frac{3-s}{4} \tag{39}$$

6 References

Ahlfeldt, Gabriel M./ Feddersen, Arne (2010): From Periphery to Core: Economic Adjustments to High Speed Rail, MPRA Paper No. 25106, available at http://mpra.ub.uni-muenchen.de/25106/1/MPRA_paper_25106.pdf

Angenendt, Nicole (2007): Entflechtungsvorgaben in Netzwerkindustrien, Netzwirtschaft und Recht, 4/2007, pp. 134-140.

Armstrong, Mark/ Sappington, David E.M. (2007): Recent Developments in the Theory of Regulation, in: Armstrong, Mark/ Porter, Robert: Handbook of Industrial Organization, Vol. 3, pp. 1557-1700.

Beath, John/ Katsoulacos, Yannis (1991): The Economic Theory of Product Differentiation, Cambridge University Press, Cambridge.

Bitzan, John D. (2003): Railroad Costs and Competition: The Implications of Introducing Competition to Railroad Network, Journal of Transport Economics and Policy, (2)37/2003, pp. 201-225.

Briglauer, Wolfgang/ Götz, Georg/ Schwarz, Anton (2008): Margin Squeeze in Fixed-Network Telephony Markets – competitive or anticompetitive, MAGKS Discussion Paper 27/2008.

Buehler, Stefan/ Schmutzler, Armin/ Benz, Men-Andri (2004): Infrastructure quality in deregulated industries: is there an underinvestment problem?, International Journal of Industrial Organization 22 (2), pp. 253-267.

Cremer, Helmuth/ Crémer, Jacques/ De Donder, Philippe (2006): Legal vs. Ownership Unbundling in Network Industries, CEPR Discussion Papers 5767, C.E.P.R. Discussion Papers.

European Union (EU 1991): Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0440:EN:HTML

The Economist (2010): High-Speed Railroading, July 22nd.

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

Gómez-Ibánez, José A. (2003): Regulating Infrastructure – Monopoly, Contracts, and Discretion, Harvard University Press, Cambridge.

Gomez-Ibanez, José A. (2004): Railroad reform: An Overview of the Options, Paper to be presented at the Conference on Railway Reform Conference, Madrid, available at: http://www.hks.harvard.edu/taubmancenter/pdfs/working_papers/gomezibanez_04_railway.pdf

Growitsch, Christian/ Wetzel, Heike (2007): Testing for Economies of Scope in European Railways: An Efficiency Analysis, University of Lüneburg Working Paper Series, No. 72, available at: http://www.leuphana.de/fileadmin/user_upload/Forschungseinrichtungen/ifvwl/WorkingPapers/wp_72_Upload.pdf

Guthrie, Graeme (2006): Regulating Infrastructure: The Impact on Risk and Investment, Journal of Economic Literature, 44(4), pp.925–972.

Hartwig, Karl-Hans et al (2009): Specific Investments and Ownership Structures in Railways – An Experimental Analysis, University of Münster Working Paper Series, No. 12, available at: http://www.wiwi.uni-muenster.de/ivm/materialien/forschen/veroeffentlichungen/Diskussionspapier12.pdf

Höffler, Felix/ Kranz, Sebastian (2011a): Legal Unbundling can be a Golden Mean between Vertical Integration and Ownership Separation, International Journal of Industrial Organization, forthcoming.

Höffler, Felix/ Kranz, Sebastian (2011b): Imperfect Legal Unbundling of Monopolistic Bottlenecks, Journal of Regulatory Economics, forthcoming.

Joskow, Paul (2005): Vertical Integration, in: Ménard, Claude/ Shirley, Mary M.: Handbook of New Institutional Economics, Springer, Boston, pp. 319-348.

Katakorpi, Kaisa (2006): Access Price Regulation, investment, and entry in Telecommunications, International Journal of Industrial Organization, 24/ 2006, pp. 1013-1020.

Knieps, Günter (2006): The Different Role of Mandatory Access in German Regulation of Railroads and Telecommunications, Journal of Competition Law and Economics, 2(1), pp. 149-158.

Martin, Stephen (2002): Advanced Industrial Economics, 2nd edition, Blackwell Publishers, Oxford.

Mofair (2009): Wettbewerber-Report Eisenbahn 2009, available at: http://mofair.de/content/20090707_wettbewerber-report-eisenbahn.pdf

Pittman, Russell (2007): Make or Buy on the Russian Railways? Coase, Williamson, and Tsar

Nicholas II, Economic Change and Restructuring, 40(3), pp. 207-221.

Riordan, Michael H. (2008): Competitive Effects of Vertical Integration, in: Buccirossi, Paolo: Handbook of Antitrust Economics, MIT Press, pp. 145-182.

Vareda, Joao (2007): Unbundling and Incumbent Investment in Quality Upgrades and Cost Reduction, FEUNL Working Paper Series, No. 526.

Vives, Xavier (2001): Oligopoly Pricing, MIT Press, Cambridge.