Stähler, Frank; Traub, Stefan

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Universität Bremen
Sonderforschungsbereich 597 / Collaborative Research Center 597
Staatlichkeit im Wandel / Transformations of the State
Postfach 33 04 40
D - 28334 Bremen
Tel.:+ 49 421 218-8720
Fax:+ 49 421 218-8721
Homepage: http://www.staatlichkeit.uni-bremen.de

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Privatization and Liberalization in Vertically Linked Markets

ABSTRACT

State-owned enterprises (SOEs) are often vertically integrated firms which operate in key industries like transport, telecommunication and power generation. They provide an infrastructure and invest in its quality. We discuss the effects of liberalization and their privatization which can be complete or partial such that upstream production is still run by an SOE. We show that granting a downstream rival access to the infrastructure of a vertically integrated private firm is welfare improving in most cases even if a holdup problem exists. For any vertically separated structure we find that privatization through multi-product firms welfare dominates privatization through single-product firms. JEL-Classification: L33, L23, H54.

Keywords: Privatization, vertical integration, state-owned enterprises

CONTENTS

Privatization and Liberalization in Vertically Linked Markets

1 INTRODUCTION

After World War II, a lot of democratic countries had a large public sector which controlled key industries (Zürn and Leibfried, 2005). The worldwide recessions of 1974 and 1980/81, however, made economic policy reconsider whether services of general interest[1] (e.g. gas and water supply, power generation and transmission, air and rail transport, telecommunications) and other key industries (e.g. mining and steal production) should be provided publicly by state owned enterprises (SOEs).[2] Although not being the first privatization, the initial public offering of British Telecom by the Thatcher government in 1984 was a start for a wave of privatization initiatives that filled public cash boxes with more than 1 billion US dollars in the 1990s (for a survey including a historical overview of privatization activities see Megginson and Netter, 2001).

Prior to privatization, even many economists shared the postwar view that general interest services should be provided publicly. A lot of these services have the character of providing an infrastructure which is necessary to offer other services. An infrastructure requires substantial fixed costs and thus implies increasing returns to scale, potentially creating a natural monopoly. Furthermore, the quality of the infrastructure can be crucial for the quality of services which can be provided by using it. An important objective of privatization has been an increase in economic efficiency,[3] which is guaranteed only if privatizing natural monopolies and the resulting need to establish regulatory authorities outperform the business model of an SOE. Laffont and Tirole (1993) emphasized that this is basically an empirical question. Newberry (1997) highlighted that there is a natural complementarity between liberalization (i.e. introducing competition) and privatization (i.e. a change of the ownership structure of a firm). He concludes that introducing competition was the key to achieving the full benefits of privatization and privatization was only a necessary but not a sufficient condition. In contrast to this, regulation was inevitably inefficient. It is obvious that replacing regulation by competition

1 Article 86 (2) of the Treaty Establishing the European Community which was signed on March 25, 1957, explicitly mentions "undertakings entrusted with the operation of services of *general economic interest*" (emphasis added).

2 According to the World Bank (1995) definition, SOEs are "government-owned or government-controlled economic entities that generate the bulk of their revenues from selling goods and services".

3 Price Waterhouse (1989a, b) listed six main goals of privatization: (i) raise revenue for state, (ii) promote economic efficiency, (iii) reduce government interference in the economy, (iv) promote wider share ownership, (v) provide opportunity to introduce competition, and (vi) subject SOEs to market discipline.

would require a vertical restructuring or separation of formerly SOEs into (regulated) network operations and network-bound services.

Building upon works of Boiteaux (1971) and others regarding the regulation and price formation of public monopolies Bos (1987, 1988) developed a formal model of privatization. A central assumption is that privatization involves efficiency gains for the respective firm. Numerous empirical studies seem to support Bos' presupposition (for a survey see Megginson and Netter, 2001). For example, using a panel of internationally operating airlines Ehrlich et al. (1994) demonstrated an annual productivity increase of 1.6 to 2% and a decline of unit costs of up to 1.9% after privatization. Newberry (1997) highlighted that productivity changes can either be due to restructuring and privatization (as in the case the UK's Central Electricity Generating Board) or due to liberalization (as in the case of British Telecom). The effect on consumer welfare was unclear: while telecommunication prices sunk, electricity companies raised profits rather than cutting prices.

In this paper, we study the welfare effects of privatizing SOEs that provide general interest services and establish a vertical link. This can be explained best by the example of railroad transport because "in railways, while the infrastructure of track and stations etc. is naturally monopolistic, the supply of train services might not be" (Vickers, 1995, p. 1).[4] From an industrial organization perspective a public railway enterprise is a vertically integrated firm. The upstream firm erects and maintains an infrastructure in terms of track and stations to be used as an input for the downstream firm. The downstream firm offers transport services to passengers or freight companies.

The reform of the railway sector may proceed in several steps. Formal and material privatization involve a reorganization of a formerly SOE's legal structure and its sale to the public, respectively. Additionally, regulation may still play a crucial role, in particular when upstream and downstream activities are separated and access rules are determined. Liberalization may allow for free market entry at the downstream level, and vertical restructuring may separate network operations from services. Obviously, each step may have different positive and negative welfare consequences. Privatization rules out goals inconsistent with profit maximization (such as redistribution or job preservation) and exposes firms to capital market principles (see, e.g., Shleifer, 1998). Hence, productivity is likely to increase. At the same time, there may be a disadvantageous shifting of

4 For an critical assessments of British rail privatization see Preston (1996) and Gibb et al. (1996). See also Affuso and Newberry (2002). Lodge (2003) provides a comparative analysis of British and German railway regulation. An overview of privatization activities in the EU and Japan is given in Obermauer (2001). Evidence for emerging countries is reported in Estache et al. (2001) [Brazil] and Ramamurti (1997) [Argentine]. The problems associated with liberalizing other network sector such as the electricity industry are discussed, e.g., in Newberry (2002).

consumer surplus towards the firms which exercise market power. Regulation may constrain the monopoly power of the privatized firm, but may itself involve distortions. As long as the vertical structure of the industry is still controlled by a single firm, entrants may find it hard to get access to the network.[5] Separating network operations from services disables the upstream firm from discriminatory behavior but involves the well known double-marginalization problem (Cournot, 1927; Sonnenschein, 1968).

It is this setup of vertical relations in which we will consider the tradeoffs between privatization and keeping an SOE on different vertical stages. To this end, we use a model which is closest to Vickers (1995). Like us, he analyzed whether a natural monopolist in the upstream market should also be allowed to act in the competitive downstream market. However, he applied an imperfect-information-imperfect-competition framework and did not allow for economies of scope. Interestingly, he showed that the welfare comparison between integration and segregation can be ambiguous, that is, the regulation of access prices can make non-integrated downstream firms worse off.[6] Gangopadhyay (2006) challenged the ambiguity result. He re-established the conventional wisdom, that monopoly power of integrated upstream firms may seriously distort competition on downstream markets using a model with perfect information. In the subgame perfect Nash equilibrium of his two-stage game, the integrated monopolist sets a prohibitive input price as to drive non-integrated firms' profits to zero. Sadka and Negrin (2004) demonstrated that "light-handed" regulation (only the access price is fixed by the regulator) of vertically integrated firms can outperform "full" regulation (both access price and final outputs are determined by the regulator) if the regulator faces incomplete information about the entrants' firms costs.[7] Iossa and Stroffolini (2007) investigated the effects of downstream demand uncertainty and found that vertical integration may perform better if the regulator cannot observe information acquisition by the upstream monopolist.[8]

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5 Zauner (2004) reported the results of a survey among German train operating companies (TOCs) with regard to the vertically integrated railway network supplier Deutsche Bahn Netz. The initial track access charges system favored the TOCs of the Deutsche Bahn exhibiting relatively high demand of track kilometers and had to be replaced by a neutral track access charge system in 2001. Interestingly, the survey revealed some instances of non-price discrimination such as disadvantageous allocation of railway slots.

6 Using a contract-theoretic approach Saavedra (2001) shed further light on the ambiguity of the welfare effects of vertical separation.

7 An interesting extension of this literature is Matsukawa (2005), who studied optimal tariff setting in congestible networks.

8 Calzolari and Scarpa (2008) concluded that regulatory policies depend on whether monopolists operate only domestically or also abroad.

In this paper, we consider a full-information theoretical framework and focus on the role of the infrastructure's quality. The innovation of the paper is that we model the upstream firm's decision problem as a quality investment for a given network infrastructure (quantity). Hence, upstream output enters the representative user's utility function as a weight attached to the number of consumed downstream services (train journeys) rather than being combined with downstream output in the downstream production process. To our knowledge, only Economides (1997) has considered the role of quality in an upstream market. However, his model assumes that consumed quality is the minimum of upstream and downstream quality whereas our model assumes that quality is determined by upstream production. A further distinctive feature of our model is that we allow for economies of scope in the case of vertical integration.

The remainder of the paper is organized as follows. Section 2 introduces the model. Section 3 computes our two benchmark scenarios, for the vertically integrated monopolist and the vertically integrated SOE, and discusses the case of a vertically integrated incumbent firm which is potentially challenged by an entrant. Section 4 deals with the case of separation and liberalization under different setups in the downstream and the upstream market. Section 5 concludes.

2 THE MODEL

We assume that there are two services X and Y offered by using an infrastructure as a necessary input. The utility of a representative consumer is given by

$$U(X,Y) = (A+\alpha z)(X+Y) - \beta\left(\frac{X^2}{2}+\frac{Y^2}{2}\right) + \gamma XY - p_X X - p_Y Y$$

with $\alpha, \beta > 0$, $-\beta \leq \gamma < \beta$ and z denoting quality of the upstream input, i.e. infrastructure quality. Maximization yields the inverse demand functions

$$\begin{aligned} p_X &= A+\alpha z-\beta X+\gamma Y, \qquad (1)\\ p_Y &= A+\alpha z-\beta Y+\gamma X. \end{aligned}$$

This simple setup allows us to distinguish three different cases of demand interaction between these two services. Appendix A.1 shows that the sign of a change in demand with the price of the other service depends on γ. If $\gamma \in]0, \beta[$, an increase in price will decrease the other service demand and both services are *complements.* If $\gamma \in [-\beta, 0[$, an increase in price will increase the other service demand and both services are *substitutes.* Finally, in the special case of $\gamma = 0$, both markets are independent. The parameter α measures the strength of quality z as perceived by consumers.

As for costs, we normalize the marginal cost of using the infrastructure to zero. As usual in the industrial organization literature, we will label the provision of infrastructure as upstream production. Since we do not endogenize market structures, we will ignore any fixed cost in the downstream market. The upstream production cost, C_u, depends on vertical integration. In case of vertical integration, there are economies of scope such that

$$C_u^* = \frac{cz^2}{2} - \delta z(X + Y) + F.$$

F denotes the fixed cost to run the infrastructure with lowest quality and is assumed to be substantial such that the upstream production warrants a natural monopoly. The parameter δ measures the strength of economies of scope. Note that this is not a usual upstream production process as the input produced is infrastructure, and not a number of intermediates and the infrastructure's quality affects demand. Hence, an increase in *z* is regarded as an increase in horizontal quality of the service provided by the downstream industry.

If the industry is vertically integrated, quality investment can be more efficient as to support better services, *e.g.* because service and quality improvement are coordinated in-house, and this effect is captured by economies of scope. One way of looking upon it is that a vertically integrated firm coordinates quality investment with its supply and can target its investment to areas where they are most productive. Alternatively, a vertically integrated firm may plan downstream services such that they use quality investments most efficiently as it knows well how to exploit this investment for operating the service. Both effects are not explicitly modelled, but the term $\delta z(X + Y)$ can be regarded as a proxy for the cost reductions which these effects imply. We will assume that this effect is not too strong as to make the marginal cost of quality negative; hence $cz - \delta(X + Y) > 0$. Furthermore, we will assume that economies of scope are also present if one firm controls upstream production and is active in the downstream market but faces competition in this market. In this case, the vertically integrated firm correctly anticipates downstream production of rivals and is able to specify quality investments such that they reduce marginal production costs.

Hence, firms have to be active in the downstream market as well in order to be able to realize economies of scope. Otherwise, their business activities are too remote as to capture these gains, and thus there are no economies of scope in case of separation. Accordingly, upstream costs are equal to

$$C_u = \frac{cz^2}{2} + F$$

without integration. In both cases, quality is produced with increasing marginal costs. Downstream production costs are linear in the service level and given by

$$C_d^X = \theta x_i \text{ and } C_d^Y = \theta y_i,$$

respectively, where $x_i(y_i)$ denotes firm-specific output in market *X(Y).* If upstream and/or downstream production is run by an SOE, all costs are higher by a factor (1 + λ). All private firms are assumed to be profit maximizing, whereas any SOE aims at maximizing social welfare. As for welfare, we have to distinguish several cases, but we will give both consumers and producers equal weight.[9] Welfare is equal to

$$\begin{aligned} U - [C_u^* + C_d^X + C_d^Y] & \quad \text{in case of an integrated monopolist,} \quad (2)\\ U - (1+\lambda)[C_u^* + C_d^X + C_d^Y] & \quad \text{in case of an integrated SOE,}\\ U - [C_u + C_d^X + C_d^Y] & \quad \text{in case of separated private firms,}\\ U - (1+\lambda)C_u - [C_d^X + C_d^Y] & \quad \text{in case of an upstream SOE.} \end{aligned}$$

3 VERTICAL INTEGRATION

We start with the case of vertical integration. We will consider three different setups. The first case is the simplest and deals with a vertically integrated monopolist. The second one is the case of the vertically integrated SOE. Finally, we consider a vertically integrated duopolist which potentially competes or is forced to compete with a rival in the downstream market.

3.1 Vertically integrated monopolist vs. vertically integrated SOE

The vertically integrated monopolist maximizes its profit $\Pi = p_x X + p_y Y - C_d^X - C_d^Y - C_u^*$ over *z, X* and *Y*. The first-order conditions are

$$\begin{aligned} A + \alpha z - 2\beta X + 2\gamma Y - \theta + \delta z &= 0,\\ A + \alpha z - 2\beta Y + 2\gamma X - \theta + \delta z &= 0,\\ \alpha(X+Y) - cz + \delta(X+Y) &= 0. \end{aligned}$$

Appendix A.2 has the details of this computation and shows that the second-order conditions require that $c(\beta - \gamma) > (\alpha + \delta)^2$. The first-order conditions lead to equilibrium outputs and quality of

9 Hence, we do not consider cases in which foreign firms are active and the local government does not take their profits into account. For the role of foreign firms competing against local private or public firms see Long and Stahler (2009).

$$X = Y = \frac{c(A-\theta)}{2(c(\beta-\gamma)-(\alpha+\delta)^2)}, \quad (3)$$
$$z = \frac{c(A-\theta)(\alpha+\delta)}{c(\beta-\gamma)-(\alpha+\delta)^2}.$$

The vertically integrated monopolist is able to realize economies of scope and has lower production costs than its state-owned counterpart. It also exploits its market power in both the *X* and the *Y* market, internalizing the externality between both. According to (2), welfare is equal to

$$\frac{c(3c(\beta-\gamma)-2(\alpha+\delta)^2)(A-\theta)^2}{4(c(\beta-\gamma)-(\alpha+\delta)^2)^2} - F. \quad (4)$$

The vertically integrated SOE maximizes welfare $(A + \alpha z — (1 + \lambda)\theta)(X + Y) – \beta(X^2/2 + Y^2/2) + \gamma XY – (1 + \lambda)(cz^2/2 – \delta z(X + Y))$ over z, X and Y. The first-order conditions are

$$A + \alpha z - \beta X + \gamma Y - (1+\lambda)(\theta - \delta z) = 0,$$
$$A + \alpha z - \beta Y + \gamma X - (1+\lambda)(\theta - \delta z) = 0,$$
$$\alpha(X+Y) - (1+\lambda)(cz - \delta(X+Y)) = 0.$$

Appendix A.3 has the details of this computation and shows that the second-order conditions require that $c(\beta – \gamma)(1 + \lambda) > (\alpha + (1 + \lambda)\delta)^2$. The first-order conditions lead to equilibrium outputs and quality of

$$X = Y = \frac{c(1+\lambda)(A-(1+\lambda)\theta)}{(c(\beta-\gamma)(1+\lambda)-(\alpha+(1+\lambda)\delta)^2)}, \quad (5)$$
$$z = \frac{2(A-(1+\lambda)\theta)(\alpha+(1+\lambda)\delta)}{c(\beta-\gamma)(1+\lambda)-2(\alpha+(1+\lambda)\delta)^2}.$$

Let us compare these results with those for the vertically integrated monopolist. For $\lambda = 0$, we find that

$$X = Y = \frac{c(A-\theta)}{(c(\beta-\gamma)-(\alpha+\delta)^2)}, \quad (6)$$
$$z = \frac{2c(A-\theta)(\alpha+\delta)}{c(\beta-\gamma)-(\alpha+\delta)^2}.$$

Not surprisingly, outputs and quality are twice larger if the business is run by an SOE without cost disadvantage. In general, the welfare level implied by a vertically integrated SOE is equal to

$$\frac{c(1+\lambda)(A-(1+\lambda)\theta)^2}{c(\beta-\gamma)(1+\lambda)-2(\alpha+(1+\lambda)\delta)^2} - (1+\lambda)F. \quad (7)$$

For $\lambda = 0$, we find a welfare level of

$$\frac{c(A-\theta)^2}{c(\beta-\gamma)-2(\alpha+\delta)^2} - F. \quad (8)$$

Comparing (8) with (4) leads to our first result.

Lemma 1 *The vertically integrated SOE welfare dominates (is welfare dominated by) the vertically integrated monopolist if λ is small (large).*

Proof: Expression (8) is strictly larger than (4). Appendix A. 3 shows that (7) decreases with λ.

Lemma 1 is not surprising as there is obviously a trade-off between an SOE running the whole business inefficiently and efficient firm maximizing profits. Welfare levels (4) and (7) will serve as benchmarks for our comparison with other setups.

3.2 Vertically integrated duopolist

Having compared the two different business models for a vertically integrated firm, we now turn to a setup in which an incumbent, vertically integrated firm is potentially challenged by a rival firm which operates in the downstream market. This rival firm needs access to the incumbent's upstream supply of infrastructure, and if it has access, it will also benefit from the infrastructure's quality. We label both firms as duopolists as they potentially compete against each other in the downstream market. We assume that the vertically integrated duopolist (firm 1) correctly anticipates the output of its rival (firm 2), if positive, and is thus able to realize the whole economies of scope. Furthermore, we assume that vertical relations are regulated such that access to the infrastructure warrants firm 2 to pay a user charge q to firm 1 which depends on its services in the downstream market. Hence, we do not allow for two-part tariffs but only for linear pricing.[10] This assumption reflects the idea that access should not be discriminatory and should be independent of the firm size of a potential rival.

We start with considering a two-stage game in which the user price q is exogenous, and the vertically integrated firm determines quality first before it competes against the rival firm in the downstream market. For the moment, we assume that q is not too large so that firm 2 will be active in the downstream market. Later on, we will endogenize q such that (i) either firm 1 has the right to determine q or (ii) a regulating authority determines q as to maximize social welfare. Appendix A.4 has all the details of this case and shows that the outputs for a given q and z are equal to

10 The case of two-part tariffs is trivial under complete information because it enables the upstream firm to appropriate any operating profits of its downstream rival. In our setup, however, results would not change. See footnote 12.

$$\begin{aligned} x_1 = y_1 &= \frac{A + \alpha z - \theta + q + 2\delta z}{3(\beta - \gamma)}, \\ x_2 = y_2 &= \frac{A + \alpha z - \theta - 2q - \delta z}{3(\beta - \gamma)}, \\ X = Y &= \frac{2(A + \alpha z - \theta) - q + \delta z}{3(\beta - \gamma)}. \end{aligned} \tag{9}$$

Firm 1 correctly anticipates these outputs and maximizes its profits with respect to *z* for a fixed *q*. Note that firm 1's profits also depend on firm 2's outputs as it receives revenues from the use of its infrastructure. Appendix A.4 shows that the second-order conditions require that $c(\beta - \gamma) > 4(\alpha^2 + 7\alpha\delta + \delta^2)$. It also shows that the optimal quality provided by firm 1 for a fixed *q* is equal to

$$z = \frac{2(2\alpha(A - \theta) + 7\delta(A - \theta) + 5q(\alpha - \delta))}{(c(\beta - \gamma) - 4(\alpha^2 + 7\alpha\delta + \delta^2)}. \tag{10}$$

How does quality change with the user price *q?* Eq. (10) proves that the effect depends on the size of the quality improvement as perceived by consumers and the size of the economies of scope.

Proposition 1 *An increase in the user price q increases (decreases) quality if* $\alpha > (<)\delta$.

Proposition 1 deserves a thorough discussion. Its intuition can be understood best if we consider the extreme cases of no economies of scope, that is $\delta = 0$, and the case of no effect of infrastructure quality on demand, that is $\alpha = 0$. Suppose that *q* declines which results in less access revenues for firm 1. If $\delta = 0$, firm 1 will not benefit from economies of scope but a substantially high quality level makes its rival strong. Hence, if *q* declines, firm 1 will reduce the quality level as to reduce the positive externality created for firm 2 when access revenues go down. If $\alpha = 0$, there is no positive externality from providing a high quality, and hence quality does not improve firm 2's profits. However, there are economies of scope and since the access revenues from firm 2 become less important, firm 1 will increase quality as to reduce its marginal production costs in the second stage. It thereby commits itself to be more aggressive in the service market, and the increase in profits in the downstream market overcompensates the decline in access revenues.[11] Hence, quality goes up in this case.

Let us now turn to the case in which access is completely controlled by the incumbent firm. In this case, a two-stage game is played in which the incumbent determines both *q* and *z* in the first stage, and both firms compete against each other in the second stage. If the incumbent firm does not charge a prohibitively large user price, it will get

11 This is a well known effect from R&D models in which a firm does excessive R&D as to reduce marginal costs and to steal profits from its rival in the product market. For the pioneering paper see Spencer and Brander (1983).

access revenues from firm 2 for the price of competition in the second stage. The following lemma shows that monopolistic profits are larger.

Lemma 2 *A vertically integrated private firm will always offer a prohibitively large user price to a downstream competitor.*

Proof: See Appendix A.4.

Hence, we cannot expect that a vertically integrated firm will allow access to the infrastructure is controls. The reason is that the sum of duopolistic profit in the second stage and access revenues is substantially lower than the monopolistic profits for any user price which is not prohibitive.[12] Given Lemma 2, we now consider a game in which the government is able to force the private firm to offer a non-prohibitive user price to a downstream competitor.

Of course, it would be easy if the government could commit itself to a user price dependent on the quality provided by firm 1 - mechanism design with complete information is a simple task. However, it seems more realistic that a quality investment will precede the determination of a user price, and hence firm 1 faces a holdup problem. Even if the government promises a high user price, it will take quality as given and maximize social welfare for a given quality level later on, so that it will reconsider and revise its policy once the quality level is fixed. This will, of course, be anticipated by firm 1. Accordingly, we consider the following three-stage game: in the first stage, firm 1 will determine the quality level of the infrastructure, in the second stage, the government sets the user price for which access has to be granted for firm 2, and in the third stage, both firms compete against each other. As for the second stage, we restrict the set of feasible user prices such that they should not fall short of the marginal infrastructure user cost (which we have normalized to zero). This restriction is reasonable because regulation should not allow expropriating firm 1 such that firm 1 has to financially subsidize the access of its rival firm.

We solve the game by backward induction, and we find for the second stage that the lower bound on q is binding.

Lemma 3 *The welfare maximizing user price is equal to the marginal infrastructure cost, that is,* $q = 0$.

12 This result may change if downstream marginal costs are not constant, and hence it may be profitable to share the market if two firms can produce for substantially lower marginal costs than a single firm. However, firm 1 would be better off by employing two production units as to lower marginal costs compared to allowing a rival access to its infrastructure. Note also that our result do not change if we allow for two-part tariffs: since firm 1 cannot credibly commit not to be active in the downstream market, it could appropriate only the duopolistic profit if it allows access.

Proof: See Appendix A.4.

Note that - due to Proposition 1 - it depends on the relative strength of the quality effect on demand compared to the economies of scope effect whether the quality level will be larger or lower than in the case of a monopoly. This is not in contrast to the government seeking to increase aggregate output in both markets. If quality is increased because the economies of scope effect is dominant, aggregate output will increase because quality is increased as to increase firm 1's market share. If quality is decreased because the externality effect is dominant, aggregate output goes up because firm 2 gets access to the market and boosts aggregate output.

In both cases, however, the imposed user price creates a distortion because firm 1, correctly anticipating the user price, responds strategically by adjusting its quality investments. Either it reduces quality as to reduce the externality or it increases quality as to reduce its marginal costs and become more aggressive in the downstream market. This distortion has to be balanced against the effect of the output expansion by this intervention. We now compare the welfare level induced by the laissez faire monopolist as described above with the welfare level implied by intervention. Appendix A.4 shows that the welfare level for a user price of zero is equal to

$$\frac{2(4c(\beta-\gamma)+\delta^2)(A-\theta)^2}{(\beta-\gamma)(9c(\beta-\gamma)-2(2\alpha+\delta)(4\alpha+5\delta)}. \tag{11}$$

Comparing (11) with (4) yields

Proposition 2 *Assume a vertically integrated duopolist who decides on quality before the user price is set equal to marginal infrastructure costs. This duopolist creates a larger social welfare level than a vertically integrated monopolist if δ is sufficiently small.*

Proof: See Appendix A.4

Proposition 2 says that an intervention unambiguously improves welfare if the economies of scope effect is not strong. The reason is that a high δ lets the incumbent firm increase quality excessively for substantial costs as to be more competitive in the downstream market. This strategic behavior is costly because quality costs increase over-proportionately. Furthermore, it will dominate if α is small, and this strategic incentive may reduce social welfare. Note that this is just a possibility but the welfare comparison depends on further parameters. If δ is relatively small, the incumbent firm will reduce quality, but the welfare reducing effect of a lower quality is unambiguously overcompensated by the increase in outputs on the downstream market due to entry of rival firm 2.

4 SEPARATION

The last section has by and large left vertical integration intact. In this section, we consider a vertically separated structure. In case of separation, we discuss two different setups for the upstream market. Either privatization is complete such that the upstream firm providing the infrastructure and investing in its quality is private, too. This profit-maximizing upstream firm, however, is not allowed to employ nonlinear pricing schemes but must use linear prices as to guarantee nondiscrimination in the downstream market. This will obviously give rise to a double marginalization problem. Alternatively, we consider partial privatization such that an SOE still runs upstream production. Note that vertical separation does not allow for economies of scope anymore. Furthermore, SOEs are less efficient than a private firm in the upstream market.

Given the nature of demand for two services which are complements (substitutes) if $\gamma > (<) 0$, we consider three different outcomes in the (privatized) downstream market. First, we consider the case of bilateral monopoly, that is, there is only one firm in the downstream market. Second, we consider a downstream multi-product duopoly, that is, there are two firms which compete against each other in both the *X* and the *Y* market. Third, there are also two firms, but they are single-product firms such that one of them serves the *X* market only and the other only the *Y* market. This case represents regionalization if the *X* and the *Y* market can be regarded as two regional markets. The game is played as follows. In the first stage, the upstream firm determines quality *z* and the user price *q*. In the second stage, downstream firms determine their outputs as to maximize downstream profits. As before, SOEs are considered to maximize social welfare.

Let us first determine the output decisions of downstream firms. The profits of a downstream monopolist are given by $(px - \theta - q)X + (py - \theta - q)Y$ which leads to output levels of

$$X^M = Y^M = \frac{A + \alpha z - q - \theta}{2(\beta - \gamma)}, \tag{12}$$

where the superscript *M* denotes the downstream monopoly. If two multi-product duopolists compete on both markets, firm i's profits are given by $(px - \theta - q)x_i + (py - \theta - q)y_i$ where $x_i(y_i)$ denotes firm-specific outputs and $X = x_1 + x_2$, $Y = y_1 + y_2$. The Nash equilibrium is given by

$$x_i^D = y_i^D = \frac{A + \alpha z - q - \theta}{3(\beta - \gamma)}, X^D = Y^D = 2\frac{A + \alpha z - q - \theta}{3(\beta - \gamma)}, \tag{13}$$

where the superscript *D* denotes the multi-product duopoly. Of course, there is an increase in aggregate output for given *q* and *z* due to increased competition, but *q* and *z* have still to be determined. In case of single-product firms, firm *X*[*Y*] serves the *X*[*Y*] market only and its profits are equal to $(px - \theta - q)X[(py - \theta - q)Y]$. The Nash equilibrium of two single-product firms competing against each other is given by

$$X^S = Y^S = \frac{A + \alpha z - q - \theta}{2\beta - \gamma}, \tag{14}$$

where the superscript S denotes the single-product firms. Note that single-product firms produce less for given q and z than the downstream monopolist as long as $\gamma > 0$. The reason is that single-product firms do not take into account the complementarity of their production on consumption of the other service if $\gamma > 0$. Let us now scrutinize the upstream decision.

We first consider the case of a private firm in the upstream market. A profit maximizing upstream firm will set q and z such that its profit $q(X + Y) - cz^2/2$ is maximal, correctly anticipating the output decisions of downstream firms. The details of the computations are in Appendix A.5. As for quality and outputs we find that the case of two multi-product firms implies the most of all.

Lemma 4 *In case of an upstream monopolist, user prices, qualities and outputs are larger in case of two multi-product firms compared to a downstream monopoly and two single-product firms. User prices, qualities and outputs are larger (smaller) for a downstream monopoly compared to two single-product firms if* $\gamma > (<)0$.

Proof: See Appendix A.5.

Lemma 4 shows that two multi-product firms perform best, although they also face the highest user price. The higher user price is possible because competition between the two firms in both markets implies an increase in supply, and part of the revenues hereof can be appropriated by the upstream monopolist. However, the user price is not that high that it reduces outputs compared to other setups. The downstream monopolist does second-best if $\gamma > 0$. The reason is that the downstream monopolist internalizes the externality (which is positive if $\gamma > 0$) between the two markets. In case of a positive externality, this effect is stronger than the competition effect between two single-product firms. Not surprisingly, these results also imply the welfare ranking.

Lemma 5 *Two multi-product firms welfare dominate both two single-product firms and the downstream monopoly, and the downstream monopoly welfare dominates (is welfare dominated by) two single-product firms if* $\gamma > (<)0$.

Proof: See Appendix A.5.

How does our ranking compare to the case of a vertically integrated monopolist? The vertically integrated monopolist avoids the double marginalization problem and can realize economies of scope. The upstream monopolist controls the infrastructure, but two downstream firms will imply more competition. The control for the upstream market and the double marginalization problem imply that the vertically integrated monopolist does better than any separation involving an upstream monopolist.

Proposition 3 *A vertically integrated monopolist welfare dominates any outcome involving an upstream monopolist.*

Proof: See Appendix A.5.

In Appendix A.5, we show that the welfare implied by a vertically integrated monopolist is larger than the welfare implied by an upstream monopolist dealing with two multi-product firms in the downstream market, even if there are no economies of scope. The reason is that the double marginalization problem lets the upstream monopolist charge a higher user price if two instead of one multi-product firms are in the downstream market. This exacerbates the double marginalization problem such that any competition effect cannot make up the welfare losses compared to a vertically integrated monopolist. In conclusion, if the business should be run by private firms (for example because SOEs are too inefficient), vertical integration welfare dominates any separation because competition is not able to heal double marginalization completely. Furthermore, using Proposition 2, comparing separation with the vertically integrated duopolist is straightforward:

Corollary 1 *A vertically integrated duopolist who decides on quality before the user price is set equal to marginal infrastructure costs implies a larger social welfare level than any separation including an upstream monopolist if δ is sufficiently small.*

Let us now turn to the mixed case in which an SOE runs the infrastructure, but private firms are active in the downstream market. If an SOE is in charge of upstream production, its cost are equal to $(1 + \lambda)cz^2/2$ and its revenues amount to $q(X + Y)$. Not surprisingly, an SOE with no binding budget constraint will run a deficit and will subsidize downstream producers by charging user prices which fall short of marginal infrastructure user cost as to correct for monopolistic distortions. Since we have normalized marginal infrastructure user costs to zero, q will be negative for all cases. The quality investment and the welfare level do not depend on the mode of competition and are respectively given by

$$z = \frac{2\alpha(A-\theta)}{c(\beta-\gamma)(1+\lambda)-2\alpha^2}, W = \frac{c(A-\theta)^2(1+\lambda)}{c(\beta-\gamma)(1+\lambda)-2\alpha^2} - (1+\lambda)F.$$

This welfare level is guaranteed by different (negative) user prices as summarized by the following lemma.

Lemma 6 *If a welfare maximizing SOE faces no budget constraint, it will subsidize infrastructure use such that the welfare level is identical for all modes of competition. The* *subsidy paid to two multi-product firms is lowest. The subsidy paid to a downstream monopoly is lower (higher) than the one paid to two single-product firms if* $\gamma > (<) 0$.

Proof: See Appendix A.6.

How does this welfare level compare to the upstream monopolist and to the vertically integrated SOE? The upstream SOE does not imply a double marginalization problem, so this is definitely an advantage if the cost disadvantage is not too strong. Compared to the vertically integrated SOE, there is a trade-off: on the one hand, the vertically integrated SOE realizes economies of scope; on the other hand, the upstream SOE has higher cost only for running the infrastructure, but employs more efficient private firms on the downstream market. Proposition 4 summarises these comparisons.

Proposition 4 *If λ is sufficiently small, a welfare maximizing SOE facing no budget constraint welfare dominates any separation including an upstream monopolist. If λ is sufficiently large (small) and δ is sufficiently small (large), a welfare maximizing SOE facing no budget constraint welfare dominates (is welfare dominated by) a vertically integrated SOE.*

Proof: See Appendix A.6

Our welfare comparison concerning the type of liberalization in the downstream market and our invariance w.r.t. the welfare levels depends crucially on the assumption that taxes which finance subsidies are lump sum. If taxation is distortionary and implies an excess burden, levels will change and the welfare invariance result will not survive. Given that welfare functions are concave, the welfare ranking can be derived from the size of the subsidy without excess burden, that is, the case with the lowest subsidy level will welfare dominate. Hence, the following conclusions are straightforward.

Corollary 2 *In case of an excess burden of taxation, two multi-product firms welfare dominate a downstream monoply and two single-product firms. The downstream monopoly welfare dominates (is welfare dominated by) two single-product firms if* $\gamma > (<) 0$.

We have also considered the special but realistic case that an SOE has to break even on the variable costs. The difference to the case of an exogenously fixed shadow price of public funds is that the shadow price of this constraint is now endogenously determined. However, the results do not differ qualitatively. Of course, welfare levels differ for a budget-constrained SOE compared to the upstream monopolist, but the welfare ranking is the same.[13][13] Furthermore, it also coincides with the welfare ranking if sub-

13 The details for this case are available upon request.

sidization implies an excess burden. Hence, we have a robust result in terms of welfare for the case of separation:

Proposition 5 *If upstream and downstream activities are separated, two multi-product firms welfare dominate a downstream monopoly and welfare dominate weakly two single-product firms. If* $\gamma > (<) 0$*, the downstream monopoly welfare dominates (is welfare dominated by) two single-product firms.*

5 CONCLUDING REMARKS

This paper has demonstrated that there is no clear ranking of SOE vs. private firms but the ranking depends on the cost disadvantage and the size of the economies of scope. However, we could show that regulating a vertical duopolist as to allow access for a downstream rival firm is welfare improving if the economies of scope effect is not too strong. If production activities are separated, liberalization in the downstream market is welfare dominant if multi-product firms are established. It makes a crucial difference whether private firms will operate in separate or common markets after liberalization. However, we could also demonstrate that liberalization with an upstream monopolist is welfare dominated by a vertically integrated monopolist.

Our paper offers some guidance with respect to the trade-offs to be taken into account, and hence it does not arrive at a clear conclusion whether or not privatization increases social welfare. It is thus not a surprise that empirical studies arrive at different conclusions for different industries. We have focused on the quality of an infrastructure input when it is important for consumers, and this angle distinguishes our paper from the previous literature. It is left to future research to empirically explore the role infrastructure quality plays in these markets as to eventually come up with policy recommendations by which type of firms these markets can be served best.

APPENDIX

A.1 Direct demand functions

Computing the direct demand functions yields

$$\begin{aligned} X &= \frac{A+\alpha z}{\beta-\gamma} - \frac{\beta p_X}{\beta^2-\gamma^2} - \frac{\gamma p_Y}{\beta^2-\gamma^2}, \\ Y &= \frac{A+\alpha z}{\beta-\gamma} - \frac{\beta p_Y}{\beta^2-\gamma^2} - \frac{\gamma p_X}{\beta^2-\gamma^2}, \end{aligned} \tag{A.1}$$

from which we observe that

$$\frac{\partial X}{\partial p_Y} = \frac{\partial Y}{\partial p_X} = -\frac{\gamma}{\beta^2 - \gamma^2}. \tag{A.2}$$

A.2 Vertically integrated monopolist

The second derivatives of the profit function of the vertically integrated monopolist imply a Hessian

$$H = \begin{pmatrix} \Pi_{XX} & \Pi_{XY} & \Pi_{Xz} \\ \Pi_{XY} & \Pi_{YY} & \Pi_{Yz} \\ \Pi_{Xz} & \Pi_{Yz} & \Pi_{zz} \end{pmatrix} = \begin{pmatrix} -2\beta & 2\gamma & \alpha + \delta \\ 2\gamma & -2\beta & \alpha + \delta \\ \alpha + \delta & \alpha + \delta & -c \end{pmatrix}$$

where the subscript denotes the partial derivative. The determinant of the first principal minors have the right sign, i.e. $|H1| = -2/\beta < 0$, $|H_2| = 4(\beta^2 - \gamma^2) > 0$. However, $|H_3| = |H| = 4(\beta + \gamma)((\alpha + \delta)^2 - c(\beta - \gamma)) < 0$ requires $c(\beta - \gamma) > (\alpha + \delta)^2$.

A.3 Vertically integrated SOE

The second derivatives of social welfare imply a Hessian

$$H = \begin{pmatrix} W_{XX} & W_{XY} & W_{Xz} \\ W_{XY} & W_{YY} & W_{Yz} \\ W_{Xz} & W_{Yz} & W_{zz} \end{pmatrix} = \begin{pmatrix} -\beta & \gamma & \alpha + \delta(1+\lambda) \\ \gamma & -\beta & \alpha + \delta(1+\lambda) \\ \alpha + \delta(1+\lambda) & \alpha + \delta(1+\lambda) & -c(1+\lambda) \end{pmatrix}.$$

The determinant of the first principal minors have the right sign, i.e. $|H1| = -\beta < 0$, $|H_2| = (\beta^2 - \gamma^2) > 0$. However, $|H_3| = |H| = 2(\alpha + \delta(1 + \lambda))^2 - c(\beta - \gamma)(1 + \lambda) < 0$ requires $c(\beta - \gamma)(1 + \lambda) > 2(\alpha + \delta(1 + \lambda))^2$. Furthermore, we find that

$$W_{X\lambda} = W_{Y\lambda} = z\delta - \phi < 0, W_{z\lambda} = \delta(X + Y) - cz > 0$$

where the sign follows from the restriction that economies of scope should not be so strong as to imply negative marginal production costs. From

$$H \times \begin{pmatrix} dX \\ dY \\ dz \end{pmatrix} = -\begin{pmatrix} W_{X\lambda} \\ W_{Y\lambda} \\ W_{z\lambda} \end{pmatrix} d\lambda$$

we find that

$$\begin{aligned} \frac{dX}{d\lambda} = \frac{dY}{d\lambda} &= \frac{-(\beta+\gamma)((z\delta - \phi)c(1+\lambda)) + (\delta(X+Y) - cz)(\alpha + \delta(1+\lambda))}{|H|} < 0 \\ \frac{dz}{d\lambda} &= \frac{-(\beta+\gamma)(\delta(X+Y) - cz) + 2(z\delta - \phi)(\alpha + \delta(1+\lambda))}{|H|} < 0 \end{aligned}$$

which proves that outputs and quality decline with λ.

A.4 Vertically integrated duopolist

In case of a non-prohibitive user price q, firm 1 will maximize

$$\begin{aligned} & (A+\alpha z-\beta(x_1+x2)+\gamma(y_1+y_2)-\phi)x_1 \\ + \quad & (A+\alpha z-\beta(y_1+y2)+\gamma(x_1+x_2)-\phi)y_1 \\ + \quad & \delta z(x_1+x_2+y_1+y_2)-cz^2/2 \end{aligned}$$

over x_1 and y_1, and firm 2 will maximize

$$\begin{aligned} & (A+\alpha z-\beta(x_1+x2)+\gamma(y_1+y_2)-\phi-q)x_2 \\ + \quad & (A+\alpha z-\beta(y_1+y2)+\gamma(x_1+x_2)-\phi-q)y_2 \end{aligned}$$

over x_2 and y_2. The first-order conditions yield (9) which in turn can be used to compute the profits of firm 1 as a function of z and q whose first and second derivatives w.r.t. z are respectively equal to

$$\frac{10q(\alpha-\delta)+2A(2\alpha+7\delta)+z(4(\alpha^2+7\alpha\delta+\delta^2)-9c(\beta-\gamma))-2(2\alpha+7\delta)\phi}{9(\beta-\gamma)} \tag{A.3}$$

and

$$\frac{4(\alpha^2+7\alpha\delta+\delta^2)-9c(\beta-\gamma)}{9(\beta-\gamma)}<0 \tag{A.4}$$

which requires $9c(\beta-\gamma) > 4(\alpha^2+7\alpha\delta+\delta^2)$. Setting expression (A.3) equal to zero leads to (10). If firm 1 decides on q as well, we have another marginal profit w.r.t. q to consider which is equal to

$$\frac{10(A-2q+z(\alpha-\delta)-\phi)}{9(\beta-\gamma)} \tag{A.5}$$

the second derivative of which is equal to

$$-\frac{20}{9(\beta-\gamma)}<0. \tag{A.6}$$

The cross derivative of firm 1's profits w.r.t. q and z is

$$-\frac{10(\alpha-\delta))}{9(\beta-\gamma)}, \tag{A.7}$$

and we have to ensure that the Hessian, given by the product of (A.4) and (A.4) minus the square of expression (A.7) is positive, that is

$$\frac{20(c(\beta-\gamma)-(\alpha+\delta)^2)}{9(\beta-\gamma)^2}>0$$

which requires $c(\beta-\gamma) > (\alpha+\delta)^2$. Solving for optimal q and z by setting (A.3) and (A.5) equal to zero yields

$$q = \frac{c(\beta-\gamma) - 2\delta(\alpha+\delta)(A-\phi)}{2(c(\beta-\gamma)-(\alpha+\delta)^2)}, z = \frac{(\alpha+\delta)(A-\phi)}{c(\beta-\gamma)-(\alpha+\delta)^2}. \quad \text{(A.8)}$$

Expression (A.8), however, implies that $x_2 = y_2 = 0$ which proves Lemma 2. The marginal welfare w.r.t. *q* for a given *z* and the outputs level given by (9) is equal to

$$-\frac{2(A+q+z(\alpha+\delta)-\phi)}{9(\beta-\gamma)}. \quad \text{(A.9)}$$

The second-order conditions are fulfilled because the second derivative is equal to $-2/(9(\beta-\gamma))$ and welfare is concave in *q* for a given *z*. However, setting (A.9) equal to zero yields a negative user price of $-(A-\varphi) - z(\alpha + 2\delta)$ which is not feasible. Hence, the regulator will set *q* equal to zero (the marginal infrastructure user costs) which proves Lemma 3.

Setting $q = 0$ in (9) yields the output levels of both firms, and welfare is equal to $U - [C_u^* + C_d^X + C_d^Y]$ where *X* and *Y* denote the aggregate outputs which leads to (11). For $\delta = 0$, (11) is equal to

$$\frac{c(3c(\beta-\gamma)-2\alpha^2)(A-\theta)^2}{4(c(\beta-\gamma)-\alpha^2)}$$

and (4) is equal to

$$\frac{8c(A-\theta)^2}{9c(\beta-\gamma)(A-\theta)^2}.$$

The second expression is smaller because $(c(3c(\beta-\gamma)-2\alpha^2)(A-\theta)^2)(9c(\beta-\gamma)(A-\theta)^2) - (4(c(\beta-\gamma)-\alpha^2))(8c(A-\theta)^2) = c^2(2a^2 + 5c(\beta-\gamma))(\beta-\gamma)(A-\theta)^2 > 0$ which proves Proposition 2.

A.5 Profit maximizing upstream firm

In case of a downstream monopolist, the upstream monopolist maximizes

$$2q\frac{A-q+\alpha z-\theta}{2(\beta-\gamma)} - \frac{cz^2}{2}$$

w.r.t. *q* and *z*. The Hessian is equal to $(2c(\beta-\gamma)-\alpha^2)/(\beta-\gamma)^2$ and warrants $c(\beta-\gamma)-\alpha^2 > 0$ as to guarantee concavity. The first order conditions imply a user price, a quality investment and aggregate outputs

$$q^M = \frac{c(\beta-\gamma)(A-\theta)}{2c(\beta-\gamma)-\alpha^2}, z^M = \frac{\alpha(A-\theta)}{2c(\beta-\gamma)-\alpha^2},$$

$$X^M = Y^M = \frac{c(A-\theta)}{2(2c(\beta-\gamma)-\alpha^2)}$$

respectively. In case of two multi-product firms, the upstream monopolist maximizes

$$4q\frac{A-q+\alpha z-\theta}{3(\beta-\gamma)}-\frac{cz^2}{2}$$

w.r.t. *q* and *z*. The Hessian is equal to $8(3c(\beta-\gamma)-2\alpha^2)/(\beta-\gamma)^2$ and warrants $3c(\beta-\gamma)-2\alpha^2>0$ as to guarantee concavity. The first order conditions imply a user price, a quality investment and aggregate outputs

$$q^D=\frac{3c(\beta-\gamma)(A-\theta)}{2(3c(\beta-\gamma)-2\alpha^2)}, z^D=\frac{2\alpha(A-\theta)}{3c(\beta-\gamma)-2\alpha^2},$$
$$X^D=Y^D=\frac{c(A-\theta)}{3c(\beta-\gamma)-2\alpha^2}$$

respectively. In case of two single-product firms, the upstream monopolist maximizes

$$2q\frac{A-q+\alpha z-\theta}{2\beta-\gamma}-\frac{cz^2}{2}$$

w.r.t. *q* and *z*. The Hessian is equal to $4(c(2\beta-\gamma)-\alpha^2)/(\beta-\gamma)^2$ and warrants $c(2\beta-\gamma)-\alpha^2>0$ as to guarantee concavity. The first order conditions imply a user price, a quality investment and aggregate outputs

$$q^S=\frac{c(2\beta-\gamma)(A-\theta)}{2(c(2\beta-\gamma)-\alpha^2)}, z^S=\frac{\alpha(A-\theta)}{c(2\beta-\gamma)-\alpha^2},$$
$$X^S=Y^S=\frac{c(A-\theta)}{2(c(2\beta-\gamma)-\alpha^2)},$$

respectively. Comparing these terms shows that quality, the user price and outputs with two multi-product firms are strictly larger than under a monopoly and weakly larger than with two single-product firms. They are only weakly larger as this includes the case $\gamma=-\beta$ for which both duopoly setups coincide. Furthermore, quality, the user price and outputs are larger (smaller) under a monopoly compared to two single-product firms if $\gamma>(<)0$. If a social planner could impose user prices and quality levels, the results would be

$$z^F=\frac{2(A-\theta)\alpha}{c(\beta-\gamma)-2\alpha^2},$$
$$X^F=Y^F=\frac{c(A-\theta)}{c(\beta-\gamma)-2\alpha^2}$$

where the superscript *F* denotes the first best in this institutional setup. Note that the first best requires $c(\beta-\gamma)-2\alpha^2>0$ for concavity. We will assume that a first best would lead to interior solution, and hence we assume that this condition is fulfilled.

Output and quality levels in the other three cases allow us to compute the welfare in the different setups, respectively:

$$W^M = \frac{c(5c(\beta-\gamma)-4\alpha^2)(A-\phi)^2}{4(2c(\beta-\gamma)-\alpha^2)^2},$$
$$W^D = \frac{c(7c(\beta-\gamma)-2\alpha^2)(A-\phi)^2}{(3c(\beta-\gamma)-2\alpha^2)^2},$$
$$W^S = \frac{c(7c\beta-3c\gamma-2\alpha^2)(A-\phi)^2}{4(c(2\beta-\gamma)-\alpha^2)^2}$$

Not surprisingly, a comparison of welfare levels shows that welfare is highest for the case of two multi-product firms, matched only by two single-product firms if $\gamma = -\beta$. The monopoly setup dominates (is dominated by) the case of two single-product firms if $\gamma > (<) 0$.

Let us now compare the best case of vertical separation, which is the case of two multi-product firms, with the case of a vertically integrated monopolist. The vertically integrated monopolist realizes economies of scope which does not happen in the case of two multi-product firms. Hence, the lowest welfare level for a vertically integrated monopolist is given by (4) for $\delta = 0$:

$$\frac{c(3c(\beta-\gamma)-2\alpha^2)(A-\theta)^2}{4(c(\beta-\gamma)-\alpha^2)^2}$$

We will do our proof by contradiction. W^D is larger than this term only if

$$4(c(\beta-\gamma)-\alpha^2)^2(5c(\beta-\gamma)-4\alpha^2)-(3c(\beta-\gamma)-2\alpha^2)^3$$

is positive. Note that the first derivative of this term with respect to $\beta - \gamma$ is equal to

$$c(16\alpha^4-4c\alpha^2(\beta-\gamma)-21c^2(\beta-\gamma)^2).$$

Since an interior solution for the first best in the case of separation requires $c(\beta-\gamma) > \alpha^2$, this derivative is clearly negative in the relevant range. Furthermore, the term is zero for $c(\beta-\gamma) = \alpha^2$, proving that any claim that vertical separation may welfare dominate a vertically integrated monopolist leads to a contradiction.

A.6 Welfare maximizing upstream SOE

Maximizing welfare subject to the output levels (12), (13) and (14) leads to user prices of

$$\begin{aligned} q^M &= -\frac{c(\beta-\gamma)(A-\theta)(1+\lambda)}{c(\beta-\gamma)(1+\lambda)-2\alpha^2}, \\ q^D &= -\frac{c(\beta-\gamma)(A-\theta)(1+\lambda)}{2c(\beta-\gamma)(1+\lambda)-2\alpha^2}, \\ q^S &= -\frac{c\beta(A-\theta)(1+\lambda)}{c(\beta-\gamma)(1+\lambda)-2\alpha^2}. \end{aligned}$$

respectively. The second-order conditions require $c(\beta - \gamma)(1 + \lambda) > 2\alpha^2$ such that all terms are negative, also demonstrating that $q^D \geq q^S$, $q^D > q^M$ and $q^M > (<) q^S$ if $\gamma > (<) 0$. The welfare level implied by a fully integrated SOE is at least equal to

$$W = \frac{c(1+\lambda)(A-(1+\lambda)\theta)^2(1+\lambda)}{c(\beta-\gamma)(1+\lambda)-2\alpha^2} - (1+\lambda)F$$

which is computed from (7) for $\delta = 0$. This level is lower than the level implied by a welfare-maximizing SOE in case of separation (see Lemma 6). However, it increases with δ and decreases more with λ than the welfare implied by a welfare-maximizing SOE in case of separation.

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BIOGRAPHICAL NOTE

Frank Stähler is Associated Professor at the Department of Economics, University of Otago, New Zealand.

Telephone:	+64 3 64 3 479 8645
Fax:	+49 421 218-8721
E-Mail:	email: fstaehler@business.otago.ac.nz
Address:	Department of Economics and CESifo, University of Otago, PO Box 56, Dunedin 9001, New Zealand

Stefan Traub holds the Chair of Economics, esp. Finance and is Projekt Director at the Collaborative Research Center 'Transformations of the State' at the University of Bremen.

Telephone:	+49 421 218 2765
Fax:	+49 421 218 3155
E-Mail:	traub@uni-bremen.de
Address:	Department of Economics and CRC 597, University of Bremen, Hochschulring 4, 28359 Bremen