Infrastructure Quality in Deregulated Industries: Is there an Underinvestment Problem?

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ABSTRACT: We investigate how various institutional settings affect a network provider's incentives to invest in infrastructure quality. Under reasonable assumptions on demand, investment incentives turn out to be smaller under vertical separation than under vertical integration, though we also provide counter-examples. The introduction of downstream competition for the market can sometimes improve incentives. With suitable non-linear access prices investment incentives under separation become identical to those under integration.

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1 Introduction

The privatization and deregulation of network industries in industrialized countries has generated a number of success stories. Nevertheless, there are also concerns about inadequate institutions. In particular, vertical separation of network industries is often seen as the main culprit for insufficient investment into network quality. In this paper, we shall analyze the effects of alternative institutional arrangements on the incentives to invest in network quality.[1]

There are various dimensions in which the institutions shaping deregulated network industries differ widely across countries and industries.

(i) *Degree of vertical integration.* The most radical form of restructuring is full vertical separation, as it was adopted, for example, in the U.S. telecommunications industry in 1984 (breakup of AT&T), and in the British railway industry in 1994 (breakup of British Rail).[2] At the other extreme is the full vertical integration approach, adopted e.g. in the Swiss railway industry.[3] Elsewhere, intermediate approaches were taken.

(ii) *Form of network access.* There may be exclusive access to segments of the network for local monopolists, as in the British railway industry, where the local monopolies were auctioned off by a franchising agency. In other countries, such as Germany or Switzerland, local monopolies for designated network segments are supplemented by services that are subject to open and non-discriminatory access. Thus, in principle several companies can use the same part of the network at different times, just as different telecommunications companies can use the same local loop to individual households to provide their services.

[1]Throughout the paper, we will compare different types of privatized industries, rather than privatized and state industries.

[2]See Shaw (2000) and the references therein for further details on the British railway reform. Our descriptions of the British railway system refer to the time before the restructuring since autumn 2001.

[3]See Federal Department of the Environment, Transport, Energy and Communications (1996).

(iii) *Access tariffs*. In some cases, access tariffs are set freely by the network provider, subject only to competition policy, in other cases there is access price regulation. Another important issue is whether access prices are strictly linear in the amount of network access demanded, or whether fixed components are used. In the British railway system tariffs were non-linear.[4] In Germany, providers of transportation services used to be allowed to opt for two-part access tariffs with a relatively low variable component rather than a linear tariff.[5] In the Swiss railway industry, in turn, access tariffs are linear and regulated. The same is true for the telecommunications industry in many countries.

To investigate the effects of such institutional differences, we model an industry in which an essential input—network infrastructure—can be provided at various quality levels. High network quality is costly to provide, but increases the value of the industry's final output to the consumer. Under vertical integration, a single firm decides on investment levels and output prices. Under vertical separation, the upstream firm decides on the quality of the network and sells the right to use the network to a downstream firm that provides the final product. The downstream firm, in turn, pays an access price which is determined according to the rules specified by the regulatory regime, but is independent of network quality.

Our main results are as follows. *First*, with linear access prices incentives to invest are generally smaller under vertical separation than under integration. This is partly due to the familiar vertical externality argument that a separated upstream monopolist ignores the positive effect on downstream profits. The result is non-trivial, however, because the move from separation to integration also affects retail prices, which generates subtle demand effects that may work against the standard argument. *Second*, introducing downstream competition has ambiguous effects on quality. *Third*, with non-linear access prices investment incentives are the same as in the integrated case, if

[4] Over 90% of access revenues were generated by the fixed component; see British Office of the Rail Regulator (1999, 1.17).

[5] The system had been introduced mainly because of expected positive effects on the number of trains provided by the transport operating companies (Knieps, 1998).

the network owner can set the fixed components so as to fully extract the downstream profit.

Unsurprisingly, the difference between integration and separation would vanish if access prices were allowed to depend on quality. However, access prices usually reflect network quality increases only to a very limited extent, presumably reflecting problems of verifiability.[6]

The plan of the paper is as follows. We first introduce our analytical framework (section 2). Then we compare the investment incentives under vertical integration and vertical separation with linear access prices in the absence of competition (section 3). In section 4, we consider competition for the market and non-linear access prices as potential means of improving investment incentives. Section 5 concludes.

2 The Basic Set-Up

This section develops a simple model of quality-enhancing investment in a network industry.

2.1 Assumptions

We consider an industry with a vertical structure. Suppose that in order to deliver the final product (e.g. electricity, telecommunications services, transportation), the producer of the final product needs access to an intermediate good (the network). One unit of the intermediate good is required to produce one unit of the industry's final product. Demand for the final good takes the form $D(p, \theta)$, where $p > 0$ is the price of the final output, and $\theta \geq 0$ denotes the quality of infrastructure. $D(p, \theta)$ is non-increasing in p and non-decreasing in θ. Here, θ should not be interpreted as an easily measurable variable, but as an aggregate of all aspects of infrastructure that have positive effects on demand.[7] Though some aspects of quality are usually

[6]For instance, in the German railway system, there are six classes of network qualities, which exclusively reflect the speed which is possible on the network. Other quality distinctions are absent (Berndt and Kunz, 1999).

[7]In the railway example, the quality of the tracks and signalling affect punctuality, speed, and safety; the accessibility and comfort of stations also affect demand.

verifiable, this will not be true for the aggregate measure. Thus, it is a useful first approximation to assume that θ is non-verifiable (Laffont and Tirole, 1993, ch. 4).[8] There is a strictly increasing function $K(\theta)$ measuring the minimal costs of reaching quality level θ. In addition, running the network involves fixed costs F.[9]

We assume that the price for the final good is not regulated. Except for section 4.2, there is a linear access charge a determined by a regulator. Consistent with the assumption that θ is unverifiable, the regulator is unable to enforce quality dependent access prices. Production is modelled as follows:

- Stage 1: The quality level θ of the network infrastructure is determined, either by a vertically integrated monopolist I or a separated ("upstream") network operator U.

- Stage 2: For given a and θ, the integrated monopolist I or a separated ("downstream") service provider D sets the retail price $p^R(\theta, a)$ for the final product.[10] For notational simplicity, we shall henceforth write $p^I(\theta) \equiv p^R(\theta, 0)$ for the retail price under integration.[11]

2.2 Defining Investment Incentives

We write the profit function of the firm taking the quality decision as

$$\Pi(\theta, a) = p^U(\theta) D\left(p^R(\theta, a), \theta\right) - K(\theta) - F. \tag{1}$$

Here $p^U(\theta)$ is the price per unit of demand obtained by the firm taking the quality decision: For separation with a constant linear access price $a > 0$, $p^U(\theta) = a$, and $p^R(\theta, a)$ is the retail price of a downstream monopolist who faces quality level θ and access price a. For vertical integration, $p^U(\theta) =$

[8] Even in cases where it is possible to measure some aspects of quality (e.g. punctuality), it is typically very costly to attribute this to the performance of the network owner or the downstream firm.

[9] W.l.o.g. we abstract from variable costs of running the network.

[10] We do not require θ to be verifiable by third parties, but it should be common knowledge between I and D.

[11] The price under integration corresponds to the price of a separated downstream firm with zero marginal costs.

$p^R(\theta,0) = p^I(\theta)$. We explicitly distinguish $\pi(\theta,a) = p^U(\theta)D\left(p^R(\theta,a),\theta\right)$, the firm's revenue, from $\Pi(\theta,a)$. We write $\pi^I(\theta) \equiv \pi(\theta,0)$ and $\Pi^I(\theta) \equiv \Pi(\theta,0)$ for the respective terms under integration.

Definition 1 (investment incentive) *Suppose $\theta_H > \theta_L$. The incentive to raise the quality level from θ_L to θ_H is given by the resulting revenue increase $\Delta\pi(\theta_L,\theta_H,a) \equiv \pi(\theta_H,a) - \pi(\theta_L,a)$.*

Observe that $\Delta\pi(\theta_L,\theta_H,a)$ is non-negative. Further, it not only depends on the demand function, but also on the institutional structure through its effect on $p^R(\theta,a)$ and $p^U(\theta)$. $K(\theta)$, on the other hand, is assumed to be independent of institutions. Thus, if for a given demand function $\Delta\pi(\theta_L,\theta_H,a)$ is higher under integration than under separation for arbitrary $\theta_H > \theta_L$, network quality will be higher under integration. Assuming that $\pi(\theta,a)$ is differentiable, this will be true, for instance, if the *marginal investment incentive* $\pi_\theta(\theta,a)$ is higher under integration for all $\theta \in [\theta_L,\theta_H]$.[12] Defining $\widehat{D}(\theta,a) \equiv D\left(p^R(\theta,a),\theta\right)$, the marginal investment incentive is given by

$$\pi_\theta = p^U(\theta)\widehat{D}_\theta + p^U_\theta\widehat{D}. \tag{2}$$

2.3 The Effect of Quality on Retail Prices and Demand

Much of the following will depend on how the quality improvement affects the equilibrium retail price p^R and the downstream demand. One might expect that higher quality will unequivocally lead to higher prices and higher demand. Yet, it is possible that either price or demand decreases as a result of a quality increase.[13] With $\Delta p^R(\theta_L,\theta_H,a) \equiv p^R(\theta_H,a) - p^R(\theta_L,a)$ and $\Delta\widehat{D}(\theta_L,\theta_H,a) \equiv \widehat{D}(\theta_H,a) - \widehat{D}(\theta_L,a)$, we can distinguish three different cases.

Definition 2 *A quality increase from θ_L to θ_H is of type*
(i) (p^+D^-) *if* $\Delta p^R(\theta_L,\theta_H,a) > 0, \Delta\widehat{D}(\theta_L,\theta_H,a) < 0$;
(ii) (p^+D^+) *if* $\Delta p^R(\theta_L,\theta_H,a) \geq 0, \Delta\widehat{D}(\theta_L,\theta_H,a) \geq 0$;
(iii) (p^-D^+) *if* $\Delta p^R(\theta_L,\theta_H,a) < 0, \Delta\widehat{D}(\theta_L,\theta_H,a) > 0$.

[12] Throughout the paper, subscripts denote partial derivatives.
[13] It is straightforward to show that prices and demand cannot both fall as a result of an increase in θ.

Lemma 1 demonstrates how the equilibrium effects of a marginal change in quality depend on the form of the demand function.

Lemma 1 *Assume that the downstream firm's revenue function π^D is concave and twice continuously differentiable. Then a marginal quality increase is of type*

(i) p^+D^- *if* $D_{p\theta} > \frac{D_\theta}{D_p}\left(\frac{D_p}{p^R-a} + D_{pp}\right)$;

(ii) p^+D^+ *if* $-\frac{D_\theta}{p^R-a} \leq D_{p\theta} \leq \frac{D_\theta}{D_p}\left(\frac{D_p}{p^R-a} + D_{pp}\right)$;

(iii) p^-D^+ *if* $D_{p\theta} < -\frac{D_\theta}{p^R-a}$.

Proof. See Appendix. ■

Note that (p^+D^-) implies $D_{p\theta} > 0$ whenever $p^R > a$, i.e., the effect of quality on demand is larger for higher prices,[14] and conversely, (p^-D^+) implies $D_{p\theta} < 0$. Thus (p^+D^+) holds for $D_{p\theta} = 0$, i.e., for quality increases leading to a parallel shift of demand.

Let us illustrate the different types of quality increases using specific demand functions. Most standard demand functions correspond to (p^+D^+). For instance, suppose $D(p,\theta) = \alpha - \beta p + \theta, \alpha > 0, \beta > 0, \theta > 0$, so that changes in θ correspond to parallel shifts of demand. In this case, $p^R(\theta, a) = (\alpha + \theta + \beta a)/2\beta$ and $\widehat{D}(\theta, a) = (\alpha + \theta - \beta a)/2$, thus $\Delta p^R > 0$ and $\Delta\widehat{D} > 0$. Another standard example is $D(p,\theta) = \alpha - \beta p/\theta, \alpha > 0, \beta > 0, \theta > 0$, where changes in θ correspond to changes of the slope of demand. Here, $p^R(\theta, a) = (\alpha\theta + \beta a)/2\beta$ and $\widehat{D}(\theta, a) = (\alpha\theta - \beta a)/2\theta$, with $\Delta p^R > 0, \Delta\widehat{D} > 0$. As a last example for (p^+D^+), consider any demand function $D(p,\theta) = f(\theta)\, g(p)$ such that f is increasing and g is decreasing. In this case, $\Delta p^R = 0, \Delta\widehat{D} > 0$.

Regimes (p^+D^-) and (p^-D^+) are usually associated with non-standard demand functions. For example, $D(p,\theta) = \theta p^{1/2\theta} + 1 - p, \theta > 0$, corresponds to (p^+D^-) for suitable θ. Figure 1 illustrates this finding for $a = 0$ and a selection of quality levels $\theta \in \{\frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}\}$. Any increase of θ within this set involves $\Delta\widehat{D} < 0$. This can be explained as follows. For definiteness, think of demand as arising from a population of heterogeneous customers, each with unit demand and the willingness to pay (WTP) depending positively

[14] If $D_{pp} \leq 0$, the r.h.s. of inequality (i) is obviously positive, if $D_{pp} > 0$, then $\Pi^D_{pp} < 0$ implies that the r.h.s. is positive.

on quality. In Figure 1, quality increases have a particularly strong positive effect on the WTP of customers who already have a high WTP. Thus, it becomes attractive to raise prices strongly so as to milk the customers with high WTP and sacrifice demand from low WTP customers.

<Figure 1 here>

A similar exercise demonstrates that the demand function $D(p, \theta) = (2-p)^{\theta}(1-p), \theta \geq 0, 0 \leq p \leq 1$ corresponds to $(p^{-}D^{+})$ for suitable θ. Figure 2 illustrates this for $a = 0$ and the quality levels $\theta = \{1, ..., 5\}$.

<Figure 2 here>

The intuition of Figure 2 is opposite to Figure 1.

3 Integration vs. Separation

We now compare investment incentives under vertical integration and vertical separation. In the integrated case, the same decision maker determines θ and p. Thus, using the envelope theorem,

$$\pi_{\theta}^{I} = p^{I}(\theta) \cdot D_{\theta}\left(p^{I}(\theta), \theta\right). \tag{3}$$

Under vertical separation, the relevant prices are $p^R = p^R(\theta, a)$ and $p^U = a$. The marginal investment incentive is thus given by

$$\pi_{\theta}^{U} = a\widehat{D}_{\theta} = a\left[D_p(p^R(\theta, a), \theta) \cdot p_{\theta}^{R} + D_{\theta}(p^R(\theta, a), \theta)\right]. \tag{4}$$

Therefore, under vertical separation, the upstream monopolist generally has an incentive to invest even if access charges are insensitive to quality, since she is rewarded for higher quality by higher access revenue, provided that $\widehat{D}_{\theta} > 0$. Note that, contrary to (3), (4) not only contains a direct effect D_{θ} of quality, but also a price-mediated effect $D_p \cdot p_{\theta}^{R}$: Quality affects downstream prices, which affect demand. The next result compares investment incentives.

Proposition 1 (integration vs. separation) *Suppose $p^I(\theta) > a > 0$. Integration yields stronger incentives than separation if:*

$$p^I(\theta) \cdot D_\theta \left(p^I(\theta), \theta\right) > a\widehat{D}_\theta = a\left[D_p(p^R(\theta, a), \theta) \cdot p^R_\theta + D_\theta(p^R(\theta, a), \theta)\right] \quad (5)$$

(*i*) *For (p^+D^-), the marginal investment incentive is stronger under vertical integration than under separation.*

(*ii*) *For (p^+D^+), the marginal investment incentive is stronger under vertical integration than under separation, except possibly if $D_{p\theta}$ is positive and sufficiently large.*

(*iii*) *For (p^-D^+), the marginal investment incentive may be stronger under vertical separation than under integration.*

Proof. See Appendix. ■

It may seem surprising that the only definite underinvestment results arise for (p^+D^-) and for those (p^+D^+)-cases where $D_{p\theta} \leq 0$. After all, a standard vertical externality argument would suggest that under separation the network owner invests less than under integration, as she does not take positive quality effects on downstream demand into account.[15] Such a vertical externality does indeed exist in our model, i.e. increasing upstream quality increases downstream profits ($\Pi^D_\theta = (p - a)\, D_\theta > 0$). Thus, under separation the network owner will always invest less than she would if she were to maximize total industry profits Π^T. However, vertical separation does not only mean that the investing party does not consider the effect of a quality increase on downstream profits. It also means that downstream prices rise from $p^I(\theta)$ to $p^R(\theta, a)$. Therefore, a vertically separated upstream firm might, in principle, have higher incentives to invest than an integrated firm if the quality increase enhances demand more strongly for higher retail prices ($D_{p\theta} > 0$). The latter effect may outweigh the standard vertical externality if it is sufficiently strong, explaining the ambiguity for (p^+D^+).

For (p^-D^+), the direct effect of quality on demand is lower for separation (because $D_{p\theta} < 0$), thus reinforcing the argument that investment incentives

[15] Compare e.g. Hart (1995) for similar arguments.

are stronger under integration. However, as the downstream firm decreases prices as a result of the quality increase, there is an additional incentive to increase quality under separation, which may lead to stronger investment incentives under separation.

The first row of Table 1 summarizes these ideas. The difference between the revenue of an integrated firm π^I and a vertically separated upstream firm π^U is the sum of $\pi^T - \pi^U = \pi^D$ and $\pi^I - \pi^T$. The derivative of the first expression ($\pi_\theta^D > 0$) reflects the familiar *vertical externality* of quality enhancement on downstream revenue. The derivative of the second expression $\partial(\pi^I - \pi^T)/\partial\theta$ reflects the *price effect* resulting because prices are usually not the same in the separated and integrated case.

<table 1>

Using Proposition 1, it can be shown that with the demand functions from section 2.3, investment incentives are higher under integration. However, we can provide other examples for (p^+D^+)- and (p^-D^+), where investment incentives are higher under separation. For simplicity, we shall work with piecewise linear functions with discontinuities. It will be obvious that these simplifications are not crucial for the results.

Our first example is illustrated in Figure 3a. It corresponds to (p^+D^+), where $D_\theta(p,\theta)$ is larger for higher prices. Assume that demand is given by[16]

$$D(p,\theta) = \begin{cases} 1-p & \text{if } p \leq 0.5 \\ \theta & \text{if } 0.5 < p \leq 1 \\ 0 & \text{if } p > 1 \end{cases} .$$

Now suppose the initial quality level is $\theta_L > 0$, but close to zero. Consider a quality increase to some $\theta_H > \theta_L$. Under integration $p^I(\theta_L) = 0.5$ and revenues are $\pi^I(\theta_L) = 0.25$. This remains true as long as $\theta_H \leq 0.25$.[17] Therefore, the investment incentive is $\Delta\pi^I(\theta_L, \theta_H) = 0$ for $\theta_H \leq 0.25$. For

[16] Intuitively, think of heterogeneous consumers with unit demand. Half the population has quality-independent reservation prices, the rest is quality-sensitive, willing to pay $p = 1$ if and only if a reservation quality-level is reached.

[17] For any level θ_H, the integrated firm must choose between charging $p = 1$, resulting in revenue θ_H, or continuing to charge $p = 0.5$, resulting in revenue 0.25 as before.

$\theta_H > 0.25$, $p^I(\theta_H) = 1$, and revenues are $\pi^I(\theta_H) = \theta_H$, so that investment incentives are $\Delta\pi^I(\theta_L, \theta_H) = \theta_H - 0.25$.

Now consider separation with $a = 0.5$. As $\theta_L > 0$, the downstream firm prefers to set $p = 1$ and obtain profits of $(p^R - a)D(p^R, \theta_L) = 0.5\theta_L$ rather than set $p = 0.5$ and obtain $(p^R - a)D(p^R, \theta_L) = 0 \cdot (1 - 0.5) = 0$. Access revenues are therefore $\pi^U(\theta_L, a) = 0.5 \cdot D(1, \theta_L) = 0.5\theta_L \approx 0$. For $\theta_H > 0$, the access revenues is $\pi^U(\theta_H, a) = 0.5\theta_H$. There is thus always a positive investment incentive $\Delta\pi^U(\theta_L, \theta_H, a) = 0.5(\theta_H - \theta_L) \approx 0.5\theta_H$ under separation, and it is higher than under integration as long as $0.5\theta_H > \theta_H - 0.25$, i.e. $\theta_H < 0.5$. Note the simple intuition of this result. At the original optimal price under integration and below, demand is insensitive to quality. To enter the quality-sensitive region, the integrated firm would have to raise the price. Because the price elasticity is infinite near $p^I(\theta_L)$, this would result in a huge loss of customers with low WTP. As long as θ_H is not much higher than θ_L, the quality increase is thus useless for the integrated firm. Under separation, prices are in the region where demand is quality sensitive to begin with—hence the positive incentive to invest.

<Figure 3 here>

Our second example corresponds to $(p^- D^+)$, where $D_\theta(p, \theta)$ is larger for lower prices. Suppose that, as in Figure 3b, demand is given by

$$D(p, \theta) = \begin{cases} 1 - p + \theta & \text{if } p \le 0.55 \\ 1 - p & \text{if } 0.55 < p \le 1 \end{cases}.$$

Consider the incentive to increase quality from $\theta_L = 0$ to $\theta_H = 1$. Under integration, $p^I(\theta_L) = D(p^I(\theta_L)) = 0.5$ and revenue is $\pi^I(\theta_L) = 0.25$ without investment. With investment, $\pi^I(\theta_H) = 0.7975$, since $p^I(\theta_H) = 0.55$ and $D(p^I(\theta_H)) = 1.45$. The investment incentive under integration is thus $\Delta\pi^I(\theta_L, \theta_H) = 0.5475$.

Under separation, with $a = 0.5$, the upstream firm's revenue is $\pi^U(\theta_L, a) = 0.125$, since $p^S(\theta_L, a) = 0.75$ and $D(p^R(\theta_L, a)) = 0.25$ without investment. With investment, the firm's revenue is $\pi^U(\theta_H) = 0.725$, since $p^R(\theta_H, a) = 0.55$ and $D(p^R(\theta_H, a)) = 1.45$. The investment incentive under separation is thus given by $\Delta\pi^U(\theta_L, \theta_H, a) = 0.6$, which is higher than that under integration. The intuition of this result is straightforward. To reap the benefits of the quality increase from θ_L to θ_H, the separated downstream monopolist must cut its retail price to enter the region where demand is quality sensitive, which reinforces the demand enhancing effect of the quality increase. The integrated monopolist, in turn, is in the quality sensitive region to begin with and further increases the retail price, thereby reducing the demand enhancing effect of the quality increase.

To sum up, it is possible to construct intuitive examples where investment incentives are higher under separation than under integration. Nevertheless, these examples are somewhat contrived. Thus, the intuition that vertical separation is negative for investment incentives is strengthened rather than weakened by our analysis.[18]

3.1 The Social Welfare Benchmark

Let us compare the investment incentives derived under vertical integration and separation with those in the welfare optimum. We briefly adapt Spence's (1975) approach to our setting.[19] Consider vertical integration. Let $S = \int_{p^R}^{\infty} D(\tilde{p}, \theta) d\tilde{p}$ be the consumer surplus, and

$$\Pi^I = p^R D(p^R, \theta) - K(\theta) - F \tag{6}$$

the integrated monopolist's profit for any given price p^R. Total surplus is then $W = S + \Pi^I$, and the following relation obtains

$$W_\theta = S_\theta + \Pi^I_\theta = \int_{p^R}^{\infty} D_\theta(\tilde{p}, \theta) d\tilde{p} + \Pi^I_\theta > \Pi^I_\theta. \tag{7}$$

Thus, for $\Pi^I_\theta = 0$, we must have $W_\theta > 0$. In other words, at any given price p^R, the vertically integrated monopolist underprovides quality relative

[18] If θ were assumed to be verifiable, the integration outcome could be duplicated in the case of separation, using quality-dependent access prices.

[19] Note that in Spence (1975) the costs of producing x output units with quality θ are given by $c(x, \theta)$. In our setup, the costs of attaining the quality level θ are given by $K(\theta)$ and are thus independent of output.

to the social optimum. Hence, in those cases where vertically separated firms provide less quality than integrated firms, vertical integration is preferable to vertical separation.

Clearly, this is a statement of *local* inefficiency in the sense that it holds for a fixed retail price p^R. It is well-known that if the retail price in the welfare optimum differs substantially from that under vertical integration, the integrated monopolist may actually provide more than the socially optimal level of quality (see e.g. Wolfstetter 1999). In such cases, our underinvestment result relative to integration does not automatically imply that there is underinvestment relative to the social welfare benchmark. In fact, by reducing investment incentives, separation might correct for overinvestment under integration.

4 Means to Improve Investment Incentives

4.1 Competition for the Downstream Market

We now analyze the effects of competition for the downstream market on quality.[20] We still suppose the industry is vertically separated and there is a designated private network owner. The downstream monopoly, however, is auctioned off.[21] There is a pool of n identical firms participating in the franchise bidding process for the separated downstream monopoly. Assume the course of events can be summarized as follows.

- Stage 1: Given the access charge a, the upstream firm U determines investment in quality θ.
- Stage 2: Observing a and θ, each competitor $i = 1, ..., n$ bids a price p^i at which they will provide downstream services. The firm with the

[20] This resembles the case of the British railway system—though many important institutional aspects of this case differ from our model.

[21] The standard idea that competition for the market à la Demsetz (1968) drives down quality (Viscusi et al., 2000, 403) is not applicable to our setting, as it requires that the bidding firms are also those responsible for quality decisions. Similarly, multidimensional auctions (Branco, 1997) for the downstream market cannot solve the problem.

lowest bid $\underline{p}$ wins the auction and has to charge the price of the second-lowest bid, $\underline{\underline{p}}$. The winner thus obtains profits $(\underline{\underline{p}} - a)D(\underline{\underline{p}}, \theta)$.

We apply the solution concept of subgame perfect equilibrium. In the equilibrium of the second stage, the price $\underline{\underline{p}}$ for services is driven down to average cost, i.e. $p^R = \underline{\underline{p}} = a$. Anticipating this result, the upstream firm U chooses quality so as to maximize $\Pi^U(\theta, a) = aD(\theta, a) - K(\theta) - F$ in the first stage of the game. The marginal investment incentive is thus

$$\pi_\theta^U(\theta, a) = aD_\theta(\theta, a). \tag{8}$$

As in the case of the integrated monopolist (see (3)), there is no price-mediated effect. However, there is a difference with respect to the direct effect. If $p^I(\theta) > a$, the price per unit of demand obtained by the investor is lower than in the integrated case. Yet, competition for the downstream market might overcompensate this disadvantage if the quality effect on demand is much stronger for lower prices, i.e. $D_\theta(\theta, a) \gg D_\theta(p^I(\theta), \theta)$, which would require $D_{p\theta} \ll 0$. The next Proposition makes this result more precise.

Proposition 2 (competition vs. integration) *Suppose $p^I(\theta) > a$. Then if (p^+D^-) and (p^+D^+) hold for $a = 0$, the marginal investment incentive is weaker under vertical separation with competition than under integration. For (p^-D^+), incentives are higher under separation with competition.*

Proof. See Appendix. ■

Hence, except for (p^-D^+), competition does not solve the underinvestment problem; but does it alleviate it? To answer this question, consider the investment incentives in a vertically separated industry with and without competition for the downstream market (see (8) and (4), respectively). In both cases, the price p^U per unit of demand obtained by the upstream firm is a. Since retail prices are driven down to $p^R = a$ by competition for the market, the downstream firm is restricted to zero profits. Consequently, there is no vertical externality: higher investment does not increase downstream profits. This might lead one to conclude that investment incentives are higher with competition. However, this is not always true. The demand effect of quality is $D_\theta(\theta, a)$ with competition, the corresponding term is $\widehat{D}_\theta(p^R(\theta,a),\theta) = D_p\left(p^R(\theta,a),\theta\right)\cdot p^R_\theta + D_\theta\left(p^R(\theta,a),\theta\right)$ in the absence of competition. For (p^+D^-) and (p^+D^+), i.e. for $D_{p\theta}$ positive or not too negative, there is a negative price-mediated effect of quality without competition. On the other hand, the positive direct effect is higher when there is no competition $\left(D_\theta\left(p^R(\theta,a),\theta\right) > D_\theta(\theta,a)\right)$ if $D_{p\theta} > 0$. Our next result summarizes the outcomes.

Proposition 3 (effects of competition) *Under separation, marginal investment incentives are stronger with competition than without if*

$$D_\theta(\theta,a) > D_p\left(p^R(\theta,a),\theta\right)\cdot p^R_\theta + D_\theta\left(p^R(\theta,a),\theta\right) = \widehat{D}_\theta. \tag{9}$$

(*i*) *For (p^+D^-), the marginal investment incentive under vertical separation is stronger with competition than without.*

(*ii*) *For (p^+D^+), the marginal investment incentive under vertical separation is stronger with competition than without competition, except possibly if $D_{p\theta}$ is positive and sufficiently large.*

(*iii*) *For (p^-D^+), the marginal investment incentive under vertical separation may be weaker with competition than without.*

Proof. See Appendix. ■

Thus, although downstream competition eliminates the vertical externality, the overall effect of competition on incentives is ambiguous.

4.2 Non-linear Access Prices

We now turn to the analysis of more general forms of access prices in the absence of competition. Assume that the upstream monopoly charges a two-part tariff of the form $T(\tilde{a}) = A + \tilde{a}D(\cdot)$; that is, the downstream monopolist pays a fixed premium A plus a variable access charge $\tilde{a}$. In addition, suppose that the upstream firm chooses $\tilde{a}$, A and θ. More specifically, assume that the upstream firm is free to choose a linear or non-linear pricing schedule, and that there are no regulatory restrictions imposed on the level of the access tariff components $\tilde{a}$ or A. Finally, suppose θ and $D(p,\theta)$ are common knowledge for the two firms.[22] In this setting, it is straightforward to derive the following result (see Table 1, row 3).

Proposition 4 (two-part access tariffs) *Suppose the industry is vertically separated and the network monopolist is allowed to set an arbitrary two-part tariff $T(\tilde{a}) = A + \tilde{a}D(\cdot)$. Then*
(i) *the variable access charge will be chosen as $\tilde{a} = 0$;*
(ii) *the incentive to invest in quality is the same as under integration;*
(iii) *the fixed premium is chosen as $A = \Pi^I(p^I(\theta), \theta)$.*

The intuition is straightforward. As a higher θ increases downstream profits, the upstream firm can choose a higher A. This allows the upstream firm to completely extract the profit of the downstream firm. Hence, she enjoys the full benefits of the investment and thus has the same incentive to invest as a vertically integrated firm.[23] Thus, as with competition for the downstream market the vertical externality is eliminated. In addition, however, unrestricted two-part access tariffs eliminate the price distortion introduced by the vertical separation of the industry. Competition for the downstream market *alone* is not sufficient to produce this result.[24]

5 Conclusion

We investigated how institutional settings affect investment incentives, where the latter are defined as the revenue increases resulting from raising quality. Our analysis highlighted the interplay of two effects associated with vertical

[22] We do not, however, require θ to be verifiable by third parties.

[23] Of course, this result requires that the downstream firm can be forced to zero profits. Aside from the strong informational requirements needed to achieve this, there is also some experimental evidence casting doubt on this possibility (Roth, 1995): In similar games, where two players divide some arbitrary resource (e.g. ultimatum games), players do not accept low profits, even when they are above the reservation value and, anticipating this, upstream players avoid attempting to extract all profits.

[24] Competition for the downstream market would have to be supplemented by access price regulations that impose $a = p^I(\theta^I)$, where θ^I is the profit maximizing quality level under integration. A second-price auction of the type described above then implements $p^R = \underline{\underline{p}} = a = p^I(\theta^I)$, and the upstream firm chooses θ^I.

separation: (i) the familiar vertical externality that tends to decrease investment incentives, and (ii) a price effect that may reinforce or weaken the vertical externality. Our main findings are the following:

First, the common presumption that investment incentives are higher under vertical integration turns out to be mostly correct. The price effect rarely dominates the vertical externality, and it does so only for peculiar demand functions. Second, both competition for the downstream market and unrestricted two-part access tariffs eliminate the vertical quality externality, because they lead to zero downstream profits. Third, unrestricted two-part access tariffs eliminate the price distortion of vertical separation, whereas competition for the downstream market alone does not. Adequate non-linear access pricing thus virtually replicates the situation under a vertically integrated monopoly.

There is ample scope for further research. First, we did not consider investment in the downstream market. Second, we restricted ourselves to the analysis of a chain of monopolies. Studying imperfect downstream competition would be instructive. Third, empirical studies could help to determine the characteristics of the demand for the final good, which in turn would inform policy decisions with respect to the institutional setting.

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Appendix

Proof of Lemma 1. Using the implicit function theorem,

$$p_\theta^R = -\frac{\pi_{p\theta}^D}{\pi_{pp}^D} = -\frac{[p^R - a]D_{p\theta} + D_\theta}{2D_p + [p^R - a]\, D_{pp}}.$$

Thus, $p_\theta^R \geq (\leq)\ 0$ if

$$\pi_{p\theta}^D = [p^R - a]D_{p\theta} + D_\theta \geq (\leq)\ 0 \text{ or } D_{p\theta} \geq (\leq) - \frac{D_\theta}{p^R - a}.$$

Substituting p_θ^R into $\widehat{D}_\theta = D_p \cdot p_\theta^R + D_\theta$ and rearranging terms yields $\widehat{D}_\theta \geq (\leq)$ 0 if

$$D_{p\theta} \leq (\geq) \frac{D_\theta}{D_p} \left(\frac{D_p}{p^R - a} + D_{pp} \right).$$

The results now follow immediately from $D_\theta > 0$, $D_p < 0$ and $\Pi_{pp}^D < 0$. ■

Proof of Proposition 1. (3) and (4) imply (5), which in turn implies (i)-(iii) as follows:

(i) For $(p^+ D^-)$, the r.h.s of (5) is negative, and the claim follows.

(ii) For $(p^+ D^+)$, $D_p(p^R(\theta, a), \theta) \cdot p_\theta^R < 0$. Hence, it suffices to show that $a > 0$ implies $p^I(\theta) D_\theta(p^I(\theta), \theta) > a D_\theta(p^R(\theta, a), \theta)$. As $p^I(\theta) > a$, this condition clearly holds if $D_\theta(p^I(\theta), \theta) > D_\theta(p^R(\theta, a), \theta)$. By Lemma 1, integration thus yields higher incentives provided $D_{p\theta} \leq 0$ or at least not very high.

(iii) For $(p^- D^+)$, the very negative values of $D_{p\theta}$ lead to $p_\theta^R(\theta, a) < 0$, which gives a positive first term in the brackets on the r.h.s of (5) that is absent under integration. However, D_θ is higher for integration case than for separation. It is unclear which effect dominates.

■

Proof of Proposition 2. Marginal investment incentives are $p^I(\theta) D_\theta(p^I(\theta), \theta)$ and $a D_\theta(\theta, a)$, respectively. As $a < p^I(\theta)$, incentives are higher under separation if $p \cdot D_\theta(p, \theta)$ is decreasing in p, that is $D_\theta + pD_{p\theta} < 0$. By Lemma 1, this coincides with $(p^- D^+)$. ∎

Proof of Proposition 3. (4) and (8) imply (9), leading to (i)-(iii) as follows.

(i) For $(p^+ D^-)$, $D_{p\theta}$ is positive and sufficiently large so that $\widehat{D}_\theta < 0$. Since $D_\theta > 0$ by definition, the claim follows immediately.

(ii) For $(p^+ D^+)$, $D_{p\theta}$ is sufficiently small in absolute value so that $p^R_\theta > 0$ and the indirect effect $D_p\left(p^R(\theta, a), \theta\right) \cdot p^R_\theta$ is negative. Incentives are thus higher with competition if $D_\theta(\theta, a) - D_\theta\left(p^R(\theta, a), \theta\right) \geq 0$ or at least $\left|D_\theta(\theta, a) - D_\theta\left(p^R(\theta, a), \theta\right)\right|$ sufficiently small. Because $p^R(\theta, a) > a$, this is true as long as $D_{p\theta}$ is negative or at least not too positive. Hence, the result follows.

(iii) For $(p^- D^+)$, $D_{p\theta}$ is negative with sufficiently large absolute value so that $\widehat{D}_\theta > 0$. Under these circumstances, $D_\theta(\theta, a)$ may be smaller than $\widehat{D}_\theta$, and hence it remains unclear in which case incentives are higher.

∎

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Table 1: Summary of results

Institutional Arrangements	$\pi^T - \pi^U = \pi^D$	$\pi^I - \pi^T$
Vertical Separation/ Linear Prices	$p^R(\theta,a)D(p^R(\theta,a),\theta)$ $-aD(p^R(\theta,a),\theta)$	$p^R(\theta,0)D(p^R(\theta,0),\theta)$ $-p^R(\theta,a)D(p^R(\theta,a),\theta)$
Vertical Separation/ Downstream Competition	$=0$	$p^R(\theta,0)D(p^R(\theta,0),\theta)$ $-aD(\theta,a)$
Vertical Separation/ Non-linear Access Tariffs	$=0$	$=0$

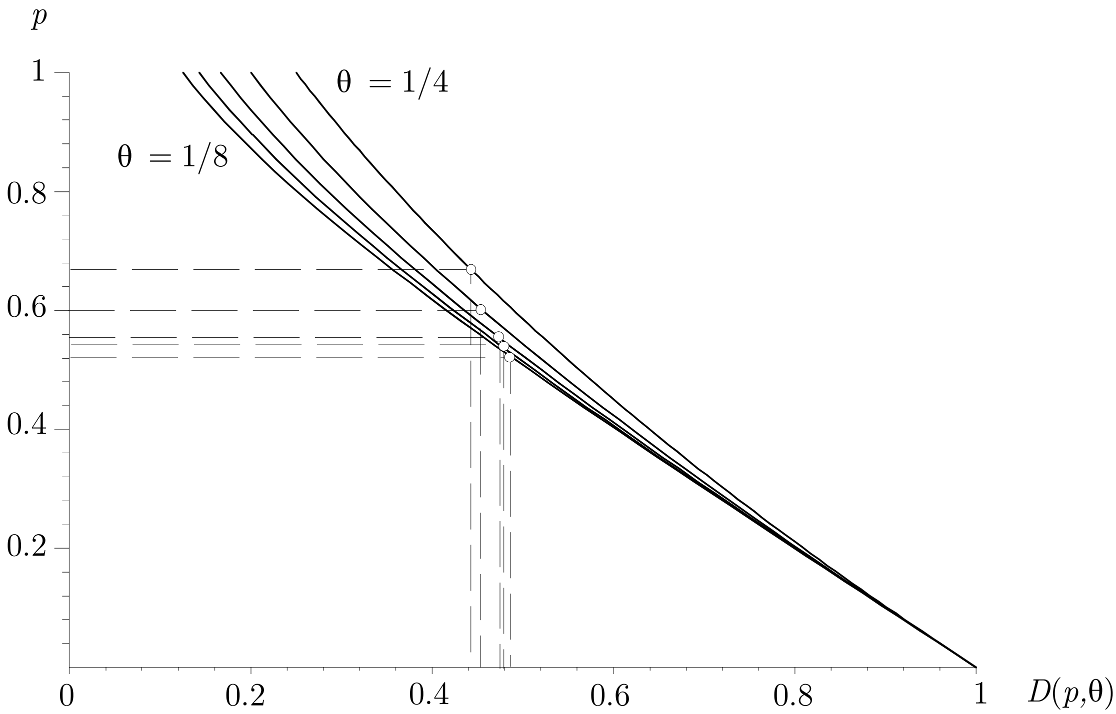

Figure 1: An example for (p^+D^-)-quality-increases

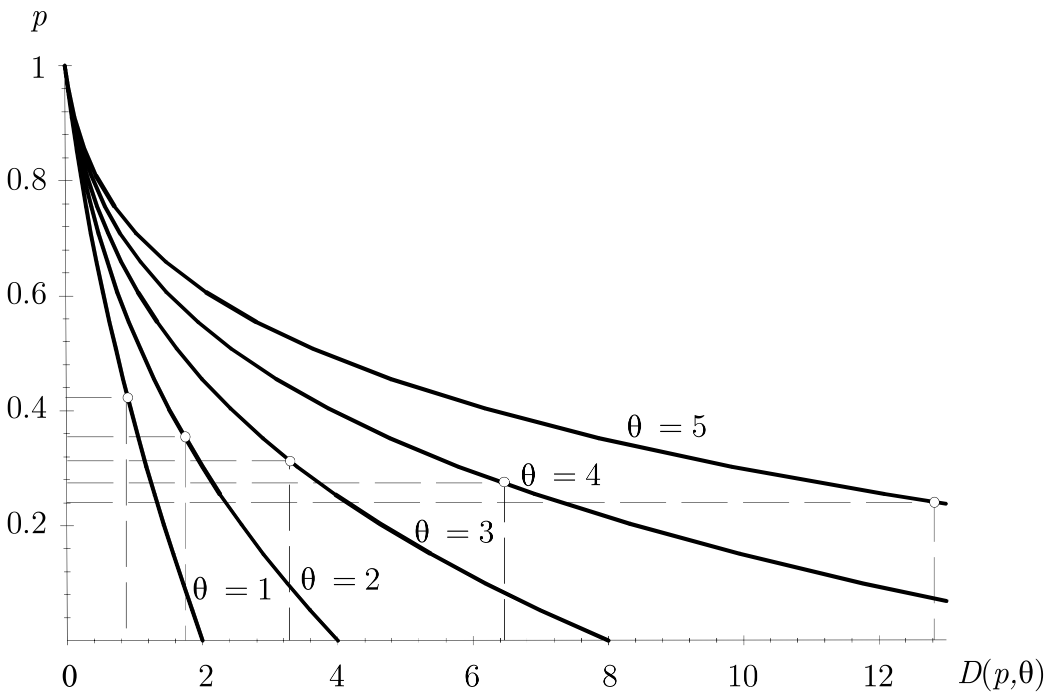

Figure 2: An example for $(p^- D^+)$-quality-increases

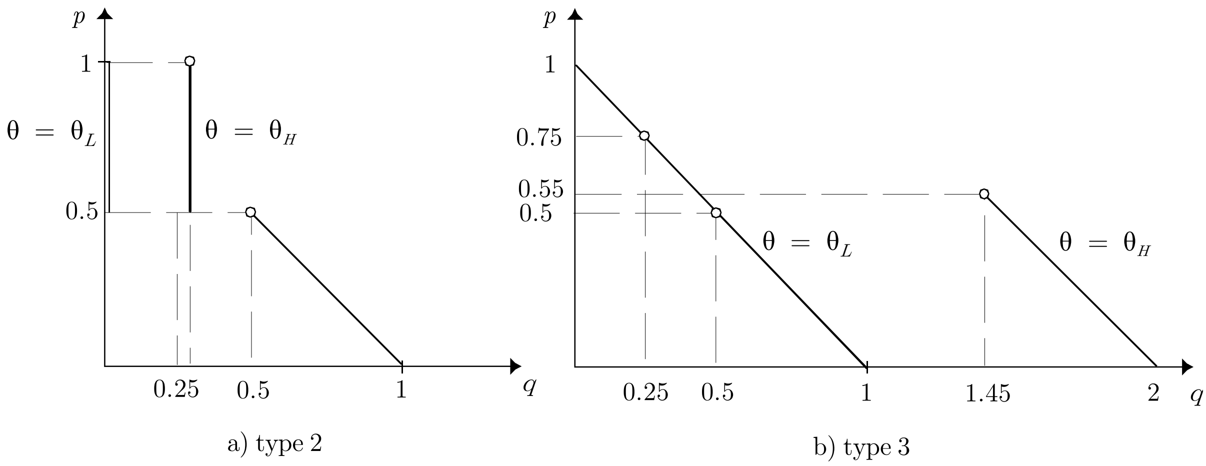

Figure 3: Two examples with higher incentives under separation