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

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International Journal of Industrial Organization

2004
Purpose:
To investigate how institutional settings affect a network provider’s incentives to invest in infrastructure quality.

Defining the Network Industry:
A vertically organized industry where the intermediate good is an interconnected network necessary for the production of final goods.

Primary Concern:
Does vertical separation or vertical integration hinder investment?

Institutional Framework of Networked Industries:
1. Degree of Vertical Integration
2. Form of Network Access
3. Access Tariffs
A model of quality enhancing investment in a networked industry:

Assumptions:
1. A Networked Industry where one unit of the intermediate good is required to produce one unit of the final good.
2. Final Demand is of the form $D(p, \theta)$ where $p > 0$ is the price of the final good and $\theta > 0$ denotes quality of infrastructure.
3. $D(p, \theta)$ is non-increasing in $p$ and non-decreasing in $\theta$.
4. $\theta$ is non-verifiable.
5. $K(\theta)$ is a strictly increasing function of cost and $F$ is fixed cost.
6. Price of final good is not regulated, but access charge $a$ is determined by regulator.
7. Since $\theta$ is non-verifiable, regulator cannot enforce quality dependent access prices.

Production Model:

Stage 1: Quality Level $\theta$ is determined by a vertically integrated monopolist $I$ or a separated (“upstream”) network operator $U$.

Stage 2: For a given $a$ and $\theta$, the integrated monopolist $I$ or separated (“downstream”) service provider $D$ sets retail price $p^R(\theta, a)$ for the final product. For the price under integration, we will write $p^I(\theta) = p^R(\theta, 0)$. 
Profit of Firm Making Quality Decision:

$$\Pi(\theta, a) = p^U(\theta)D(p^R(\theta,a), \theta) - K(\theta) - F$$

Where $p^U(\theta)$ is the price per unit of demand received by firm making quality decision.

We will define $\pi(\theta, a)$ to be the revenue component for this function.

For vertical separation and constant linear access price, $p^U(\theta) = a$ and $p^R(\theta, a)$ is final retail price.

For vertical integration, $p^U(\theta) = p^R(\theta,0) = p^I$

Defining Investment Incentive: Suppose $\theta_H > \theta_L$. The Incentive to raise quality from $\theta_L$ to $\theta_H$ is given by the revenue increase:

$$\Delta \pi(\theta_L, \theta_H, a) = \pi(\theta_H, a) - \pi(\theta_L, a)$$

The Effect of Quality on Retail Price and Demand:

Given monopoly pricing and a revenue function that is concave and twice continuously differentiable, the shape of the demand curve will determine the shifts in retail price and demand due to an increase in quality to be one of the following:

1. $\left( p^* D^- \right)$
2. $\left( p^* D^+ \right)$
3. $\left( p^* D^+ \right)$
Fig. 1. An example of \((p^+D^-)\)

Fig. 2. An example of \((p^-D^+)\)
Investment Incentives in Vertical Integration vs. Vertical Segregation:

In the Integrated Case, the network provider determines both $a$ and $\theta$. Therefore by the envelope theorem:

$$\pi^I_\theta = p^I(\theta) \cdot D_\theta(p^I(\theta), \theta)$$

Under vertical segregation, the relevant prices are $p^R = p^R(\theta, a)$ and $p^U = a$. The marginal investment incentive is therefore:

$$\pi^U_\theta = a\hat{D}_\theta = a[D_p(p^R(\theta, a), \theta) \cdot p^R_\theta + D_\theta(p^R(\theta, a), \theta)]$$

Note that under vertical separation, the upstream monopolist will generally have an incentive to invest even if access charges are insensitive to quality, since greater profits will come from higher access revenue, given $\hat{D}_\theta > 0$.

Proposition (*Integration vs. Separation*): Assume $p^I(\theta) > a > 0$. Integration yields stronger investment incentives than separation if:

$$\pi^I_\theta > \pi^U_\theta$$

1. For $(p^+ D^-)$, the marginal investment incentive is stronger under vertical integration than under separation.
2. For $(p^+ D^+)$, the marginal investment incentive is stronger under vertical integration than under separation, except if $D_{p\theta}$ is positive and sufficiently large.
3. For $(p^- D^+)$, the marginal investment incentive may be stronger under vertical separation than under integration.
The authors contend that most well-behaved demand functions will imply a stronger marginal investment incentive under integration rather than separation.

To illustrate this, authors’ propose two contra-examples: linear demand functions with discontinuities.

![Graphs showing linear demand functions with discontinuities](image)

The authors contend that while it is possible to construct examples where investment incentives are higher under separation rather than integration, they are largely contrived and should therefore be discounted.
Means to Improve Investment Incentives: Introducing Competition in Downstream Market

The model is modified only in that after the quality is chosen and the access cost is known, the downstream monopoly is auctioned off and the winning bid is the firm with the lowest $p$.

In this game, the price $p$ is auctioned down to the average cost $a$. Anticipating this, the upstream monopolist maximizes utility by choosing marginal investment incentive such that:

$$\pi^u_\theta (\theta, a) = aD_\theta (\theta, a).$$

**Proposition (Competition vs. Integration):** Suppose $p^I(\theta) > a$. Then if $(p^+D^-)$ and $(p^+D^+)$ hold for $a = 0$ (*i.e. the integration assumption*), then the marginal investment incentive is weaker under vertical separation with competition than under integration. For $(p^-D^+)$, incentives are higher under separation with competition.
Given that competition does not solve the underinvestment problem, but does it affect it?

Proposition (Effects of Competition):

1. For \((p^+D^-)\), the marginal investment incentive under vertical separation is stronger with competition than without.
2. For \((p^+D^+)\), the marginal investment incentive under vertical separation is stronger with competition than without, except if \(D_{p\rho}\) is positive and sufficiently large.
3. For \((p^-D^+)\), the marginal investment incentive under vertical separation may be weaker with competition than without.

While the introduction of competition eliminates the downstream firm profit externality, the overall effect of competition on incentives is ambiguous.

Authors’ Conclusions:

The authors state that the common presumption that investment incentives are higher under vertical integration is generally correct and that the price effect dominates only in peculiar demand functions.
Additional Comments:

The \((p^{-} D^{+})\) demand may be more widespread than first realized: consider the case of any market that is characterized by increasing technology which commoditizes a good.

For instance long-distance telecom, local telecom in large metro areas, cable and fiber-optic communications, and large airlines.

The authors also only consider the case where \(p'(\theta) > a\). What about the case where regulators may price access to a network for less than the average cost of use. Case in point: the complaint against the FCC from local telecoms complaining about the cost of providing services to new entrants.