Network Quality and Social Welfare under Different Access Pricing Methods

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Abstract

We consider an industry with a vertical structure and Bertrand competition with heterogeneous goods at the downstream market. There are two different firms, the *network provider* and a *competitor*. The network provider determines in a first stage the quality level of the infrastructure. In a second stage he competes with his rival at the downstream market. Thereby the network access is an essential input for serving the downstream market. According to `Dixit and Stiglitz (1977)` we assume that downstream demand shows itself as quality sensitive. In this context, we introduce and analyze different access pricing rules (ECPR and cost based access tariffs). Furthermore we examine cases of complete integration and liberalization without access price regulation. Following `Buehler et al (2004)` we compare investment incentives. In addition we investigate the social welfare generated in the different scenarios in a numerical example. As an interesting result we discover that a high level of quality does not necessarily induce a high level of social welfare. This is due to the different grades of competition under the various access pricing rules. Further, we show that a higher restriction on setting the access tariff leads to a smaller infrastructure quality.

Keywords: Access Pricing, Investment Incentives, Infrastructure Quality.

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1 Introduction

Since the big blackouts of electricity networks, for example in Italy, USA and Canada in 2003 and Germany in 2005, infrastructure quality of electricity networks has become an important topic in industrial organization literature.[1] Is the liberalization of such network-based industries responsible for this critical development? How is infrastructure quality influenced by access pricing rules? We try to answer these questions for appropriate access pricing tariffs.

Access tariffs can be based on the costs of the network provider (cost based tariffs), or they can be based on market prices (market based tariffs). The focus of this paper lies on the comparison of investment incentives of a network providers under complete integration and under liberalization with cost based and market based access prices. Further we investigate the case of liberalization with no restriction on setting the access price. In order to do so, we develop a two stage game. In the first stage the integrated firm sets the quality level, and in the second stage he competes with an other separated firm in a Bertrand competition at the downstream market. Thereby we relax the the strong assumption of homogeneous products.

The aim of this paper is to get a better understanding of factors influencing the investment incentives generated under different access pricing methods. We start in chapter 2 with the general setting of the model and we introduce the different access pricing methods. In chapter 3 we determine the investment incentives for the case of complete integration and the different cases of liberalization and we investigate these incentives by doing comparative statics. Also, we study and compare the scenarios in an numerical example. Besides the quality of the network infrastructure, we focus on social welfare. Chapter 4 concludes.

2 The basic set-up

This section develops a simple network industry model of quality-enhancing investment. In addition the formal structure of the different access pricing methods is introduced.

[1] See for example `Buehler et al (2004)`, `Buehler et al (2006)`.

2.1 Setting of the Market Structure

We consider an industry with a vertical structure. Suppose that in order to deliver the final product (e.g. electricity, water, telecommunications services), the producers need access to an intermediate good (the network), which is provided by an upstream firm. For simplification, assume that one unit of the intermediate good is required to produce one unit of the final product. Further assume that at the downstream market two heterogeneous final products are offered.[2] The heterogeneity is expressed by the parameter $\gamma \in [0,1]$. For $\gamma = 1$ we have perfect substitutes, $\gamma = 0$ products are in no way substitutes. According to `Buehler et al (2004)` the demand for the final product i ($i = 1,2$) depends on the quality of the network infrastructure $(\Delta + \theta)$, where Δ is the initial level of the network quality and θ is the quality-enhancement, chosen by the network provider.[3] Since we are analyzing network providers investment incentives, we are interested in the choice of θ. Suppose that the costs of an quality-enhancement are reflected by $K(\theta)$, with $K'(\theta) > 0$, $K''(\theta) > 0$, and $K'''(\theta) > 0$. Without loss of generality assume that there are no fixed costs. In addition to network quality the demand for the final product i depends on both final product prices p_i ($p_i > 0$, for $i = 1,2$) for $\gamma > 0$. Finally the demand for the two products on the downstream market takes the form[4]

$$q_i(\theta, p_i, p_j) = \frac{\Delta + \theta}{1 + \gamma} + \frac{-p_i + \gamma p_j}{1 - \gamma^2} \quad i, j \in \{1,2\}; i \neq j. \tag{1}$$

Equation (1) shows that quality-enhanced investments are leading to an increase of the demand of both final products ($\partial q_i(\theta, \cdot)/\partial\theta > 0$, $i = 1,2$).

Apart from the costs of quality-enhancement, the network provider bears marginal-transmission costs of c_0 and the two downstream firms bear marginal-delivering costs, denoted by c_1, c_2. In case of two integrated downstream entities, it is needless to say that there is no competition. This

[2]There are a lot of reasons for assuming heterogeneous products. One example is different advertising strategies of the two firms. Furthermore, the products can be generated by different sources.

[3]Following `Buehler et al (2004)`, $(\Delta+\theta)$ should be interpreted as an easily measurable quantity; an aggregate of all aspects of infrastructure that have positive effects on demand. For a visualization of the market structure see figure 1.

[4]This demand structure can be derived from a standard utility optimization of a representative consumer with a utility function $U(q_1, q_2; \gamma) = (\Delta + \theta)(q_1 + q_2) - (q_1^2 + 2\gamma q_1 q_2 + q_2^2)/2 + m$, where m is a numeraire good, see `Spence (1977)`, `Dixit and Stiglitz (1977)`.

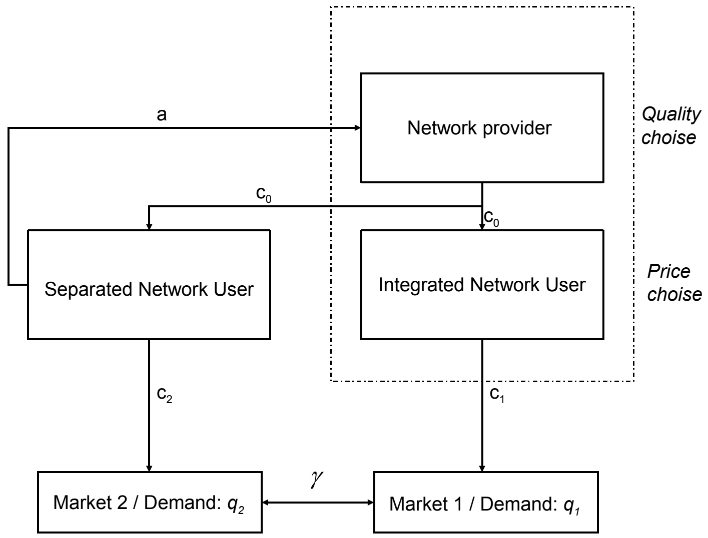

Figure 1: Market Setting under Liberalization.

is unlike the case of liberalization, where we assume Bertrand competition at the downstream market. If we further assume that the choice of the quality-enhancement is longer termed[5] than the choice of prices, we can model the interaction of the integrated network provider and the separated downstream firm in the following two stage game

- *Stage 1*: the quality-enhancement level of the infrastructure θ is determined by the network provider.
- *Stage 2*: for a given θ the downstream service providers set the retail prices for the final product.[6]

Putting all these ingredients together, we obtain under complete integration of the downstream market the following network providers profit function

$$\pi_I^{int}(\theta, p_1, p_2) = [p_1 - c_1 - c_0] \cdot q_1(\theta, p_1, p_2) + [p_2 - c_2 - c_0] \cdot q_2(\theta, p_1, p_2) - K(\theta). \qquad (2)$$

In case of liberalization, the network provider receives a payment a (access price) from the separated downstream service provider for the transmission of one unit (e.g. megawatt, hectoliter,

[5]Since quality choices usually involve technological decisions, it is natural to assume that quality is less flexible and less frequently changed than price.

[6]We do require $\Delta + \theta$ to be verifiable for both downstream firms.

telephone connection) on the network. So we obtain the following profit functions

$$\pi_I^{lib}(\theta, p_1, p_2) = [p_1 - c_1 - c_0] \cdot q_1(\theta, p_1, p_2) + [a - c_0] \cdot q_2(\theta, p_1, p_2) - K(\theta) \tag{3}$$

$$\pi_S^{lib}(\theta, p_1, p_2) = [p_2 - c_2 - a] \cdot q_2(\theta, p_1, p_2), \tag{4}$$

whereby π_I^{lib} is the profit of the integrated network provider and π_S^{lib} is the profit of the separated firm.

2.2 Access Pricing Methods

In accordance to the European Union legislation[7] we introduce different access pricing methods in this chapter. Thereby, we distinguish between cost based and market based access prices. Furthermore, we focus on liberalization without access price regulation.

In line with the cost based access price method, costs of running the network determines the calculation basis for the access tariff. In addition, a mark-up (μ) on these costs is warranted. By using the marginal cost of transportation as calculation basis, we get

$$a_c = (1 + \mu)c_0. \tag{5}$$

In contrast to the cost based methods the notion of market based methods is the determination of tariffs based on market prices. A well-established method in this context is the efficient component pricing rule (ECPR).[8] According to ECPR the tariff is calculated in a way that the network provider is indifferent between giving the separated downstream firm access to the network and selling one unit through the integrated division on the downstream market. The effect of this pricing method is that only efficient firms enter the market and that inefficient firms exit the market. Efficiency here is based on the marginal costs of the integrated downstream firm (c_1). Putting all this together, we can formalize the access tariff under ECPR as

$$a_m = p_1 - c_1. \tag{6}$$

[7]See European Commission (2002) for on overview.

[8]See Baumol and Sidak (1995).

Besides the cost and market based methods, we also investigate the case where the network provider is free to choose any access charge. In this scenario the network provider will set the access tariff in order to maximize his profit (π_I^{Lib}).

3 Investment incentives under different access pricing methods

In this chapter we determine and analyze the network providers investment incentive according to `Buehler et al (2004)`. We investigate therefore the profit derivation of the network provider in dependency on a change of the network quality. Hence the focus is on the partial derivative of (2), respectively (3), with respect to θ. However, without loss of generality we concentrate in the following on the marginal revenue of a quality enhancement $\partial\tilde{\pi}_I(\cdot)/\partial\theta$, which excludes the costs of an enhancement of infrastructure quality[9]

$$\tilde{\pi}_I(\cdot) = \pi_I(\cdot) + K(\theta). \tag{7}$$

3.1 Determination of Investment Incentives

In case of complete integration of the two downstream firms there is no competition on the final product market. The maximization of the network provider's modified profits

$$\max_{p_1,p_2} \tilde{\pi}(\cdot)_I^{int} = [p_1 - c_1 - c_0] \cdot q_1(\cdot) + [p_2 - c_2 - c_0] \cdot q_2(\cdot) \tag{8}$$

with respect to prices, leads to optimal prices

$$p_1^{int} = \frac{\Delta + \theta + c_0 + c_1}{2} \;\; ; \;\; p_2^{int} = \frac{\Delta + \theta + c_0 + c_2}{2}. \tag{9}$$

By substituting p_1 and p_2 by p_1^{int} and p_2^{int} in (8), we obtain the marginal investment incentive through the differentiation with respect to θ

$$\frac{\partial\tilde{\pi}_I^{*int}(\cdot)}{\partial\theta} = \frac{2\Delta + 2\theta - 2c_0 - c_1 - c_2}{2(\gamma+1)}. \tag{10}$$

In the case of liberalization there is competition on the final product market for $\gamma > 0$. For $lib = \{ecpr, cost, no\}$, where *ecpr* indicates access pricing after ECPR, *cost* indicates cost based

[9] For a proof see appendix.

access pricing, and *no* stands for the case without access price regulation, we derive in the following the corresponding investment incentives.

In the case of market based access prices we obtain the following profit functions

$$\tilde{\pi}_I^{ecpr}(\cdot) = [p_1 - c_1 - c_0] \cdot q_1(\cdot) + [a_m - c_0] \cdot q_2(\cdot) = [p_1 - c_1 - c_0] \cdot [q_1(\cdot) + q_2(\cdot)] \tag{11}$$

$$\pi_S^{ecpr}(\cdot) = [p_2 - c_2 - a_m] \cdot q_2(\cdot) = [p_2 - (p_1 - c_1) - c_2] \cdot q_2(\cdot). \tag{12}$$

Maximization by the integrated and separated divisions with respect to prices leads to the following best response functions

$$p_1^{ecpr}(p_2) = \frac{2(\Delta + \theta) + c_1 + c_2 - p_2}{2} \tag{13}$$

$$p_2^{ecpr}(p_1) = \frac{(1-\gamma)(\Delta + \theta) + (1-\gamma)p_1 + c_2 - c_1}{2}. \tag{14}$$

By solving (13) and (14) with respect to p_1 and p_2 and plugging in these Nash-Equilibrium prices into (11), we obtain by a derivation with respect to θ

$$\frac{\tilde{\pi}_I^{*ecpr}(\cdot)}{\partial \theta} = \frac{2(\gamma(\Delta + \theta) + 3(\Delta + \theta) - c_2 - 3c_0 - 2c_1 - \gamma(c_0 + c_1))(\gamma + 3)}{(1+\gamma)(\gamma + 5)^2}. \tag{15}$$

In case of cost based access pricing we obtain the following profit functions

$$\tilde{\pi}_I^{cost}(\cdot) = [p_1 - c_1 - c_0] \cdot q_1(\cdot) + [a_c - c_0] \cdot q_2(\cdot) = [p_1 - c_1 - c_0] \cdot q_1(\cdot) + ((\mu - 1)c_0) \cdot q_2(\cdot) \tag{16}$$

$$\pi_S^{cost} = [p_2 - c_2 - a_c] \cdot q_2(\cdot) = [p_2 - c_2 - \mu c_0] \cdot q_2(\cdot). \tag{17}$$

The maximization of (16) and (17) with respect to p_1, respectively p_2, leads to the following reaction functions

$$p_1^{cost}(p_2) = \frac{(1-\gamma)(\Delta + \theta) + \gamma p_2 + c_0(\gamma\mu - 1) + c_0 + c_1}{2} \tag{18}$$

$$p_2^{cost}(p_1) = \frac{(1-\gamma)(\Delta + \theta) + \gamma p_1 + \mu c_0 + c_2}{2}. \tag{19}$$

By putting these optimal prices into the profit function of the network provider (16) we obtain the investment incentive by derivation with respect to θ[10]

$$\frac{\tilde{\pi}_I^{*cost}(\cdot)}{\partial\theta} = -\frac{\gamma^3 c_o(1-\mu) - 2c_1\gamma^2 + (\Delta+\theta)2\gamma(1+\gamma) - 3c_0\gamma^2 + c_0\gamma^2\mu - 4(\Delta+\theta) + A}{(\gamma-2)(\gamma^2-4)(1+\gamma)}. \quad (20)$$

In the case of liberalization without access price regulation, the network provider sets a in order to maximize profits ($\tilde{\pi}_I^{no}$). Starting point in this scenario are the modified profit functions

$$\tilde{\pi}_I^{no}(\cdot) = [p_1 - c_1 - c_0] \cdot q_1(\cdot) + [a - c_0] \cdot q_2(\cdot) \quad (21)$$

$$\pi_S^{no}(\cdot) = [p_2 - c_2 - a] \cdot q_2(\cdot) \quad (22)$$

leading to the best response functions of the downstream firms

$$p_1^{no}(p_2) = \frac{(1-\gamma)(\Delta+\theta) + \gamma p_2 + c_0(1-\gamma) + c_1 + a\gamma}{2} \quad (23)$$

$$p_2^{no}(p_1) = \frac{(1-\gamma)(\Delta+\theta) + \gamma p_1 + a + c_2}{2}. \quad (24)$$

By replacing prices by the Nash prices, given by the solution of (23), (24), the maximization of (21) with respect to a leads to the optimal access tariff

$$a_{No}^*(\theta) = \frac{-c_0\gamma^3 + \gamma^3(\theta+\Delta) - c_1\gamma^3 + 2c_0\gamma^2 + 8(\theta+\Delta) + 8c_0 - 8c_2}{2(\gamma^2+8)}. \quad (25)$$

By replacing a with a_{No}^* in (21) we obtain the investment incentive through differentiating with respect to θ by using the optimal prices (23), (24)[11]

$$\frac{\tilde{\pi}_I^{*no}(\cdot)}{\partial\theta} = \frac{(\Delta+\theta)(\gamma^3+\gamma^2+4\gamma+12) + B}{2(\gamma^2+8)(1+\gamma)} \quad (26)$$

3.2 Analyzing the Investment Incentives

The investment incentives (10), (15), (20), (26) can be split into the two final product markets. Besides the integrated network provider, the separated downstream firm always benefits from a network quality increase in the cases of liberalization. But these benefits are not internalized by the network provider. Therefore liberalization tends to result in a lower investment incentive.

[10] Where $A = 2\gamma(-2c_2 - 2c_0\mu) - 4\mu c_0 + 4c_1 + 8c_0$.

[11] Where $B = (1+\gamma)(-c_0\gamma^3 - c_1\gamma^3) - (4\gamma)(c_0 + c_1) - 12c_0 - 8c_1 - 4c_2$.

Furthermore the investment incentive depends strongly on the degree of influence on the access tariff by the network provider.[12]

The aim of this chapter is a comparison of the investment incentives in the different scenarios. This chapter is structured as follows. First, we compare the different settings qualitatively. Second, we focus on the influence of parameter variations. In this context we analyze the effect of the initial level of quality on the investment incentive. We also investigate investment incentives for a variation of the degree of substitution.

3.2.1 Liberalization versus Complete Integration

The comparison of liberalization and complete integration of the downstream market by the network provider shows well known insights of vertical externalities.[13] A quality-enhancement leads to a parallel shift of the demand on both final product markets resulting in higher profits generated on market 1, but also to higher profits on market 2 ($\partial\pi_S^{Lib}(\cdot)/\partial\theta > 0$). In absence of non-linear tariffs these additional profits on market 2 cannot be reaped up completely by the setting of the access price.

In the case of complete integration there is only one decision maker in the supply chains. Accordingly, there is no double marginalization. In this scenario the network provider benefits fully (by higher prices and quantities) from the quality enhancement on both markets. There are no vertical externalities, furthermore there is no competition on the downstream market. Consequently prices are not pushed down. A quality increase in this scenario leads to a high profit increase, since prices are set in a way that marginal revenues equals marginal costs.

In the event of cost based access tariffs, the network provider has no influence on the access tariff (5). Furthermore the access price does not depend on the network quality. Hence, based on

[12]In case of cost based tariffs the network provider has no influence on a. This approach different from the market based tariffs, where the network provider has an influence on a through the price setting (p_1). In the case of no access price regulation the network provider can set an arbitrary a. Therefore the influence on a is highest in this scenario.

[13]See Tirole (1988), Chapter 4.

market 2 the network provider profits from a higher demand in market 2 only, not from higher charges. Moreover the structure of the tariff can yield a high degree of competition, e.g. for a low mark up (μ) and a high substitutability (γ) profits become vanishingly small.[14]

For liberalization with market based access tariffs, the network provider can influence the access price (6) by setting the price on market 1. In other words, the network provider can determine the marginal costs of his competitor on the downstream market. Therefore the integrated network provider has a strategic advantage on the downstream market. But, the optimal choice of p_1 is characterized by a trade-off. The network provider has to optimize profits on market 1 on one hand, one other hand (through (6)) profits on market 2.

Considering the case of liberalization without regulation, the network provider can adjust the price on market 1 and the access tariff (25) with respect to the network quality. Thus, there are two instruments for two objectives in this case. The trade-off of choosing p_1 has vanished.

3.2.2 Comparative Statics and Analysis of the Equilibria

Besides the comparison of different scenarios, we are also interested in a "intra-scenario"-comparison of different parameter constellations. In the following we therefore focus on the derivations of the different investment incentives with respect to the initial quality level (Δ) and the degree of substitution (γ).

The derivation of the different investment incentives ((10), (15), (20), (26)) with respect to Δ is leading to the following expressions:

$$\frac{\partial^2 \tilde{\pi}_I^{*int}(\cdot)}{\partial\theta\partial\Delta} = \frac{1}{1+\gamma} \tag{27}$$

$$\frac{\partial^2 \tilde{\pi}_I^{*ecpr}(\cdot)}{\partial\theta\partial\Delta} = \frac{2(-\gamma-3)^2}{(1+\gamma)(5+\gamma)^2)} \tag{28}$$

[14]Assume for example: $c_1 = c_2$, $\mu = 1$, $\gamma = 1$. In this case the benefits of both market participant equals independently of θ zero , therefore there is no incentive to invest in infrastructure.

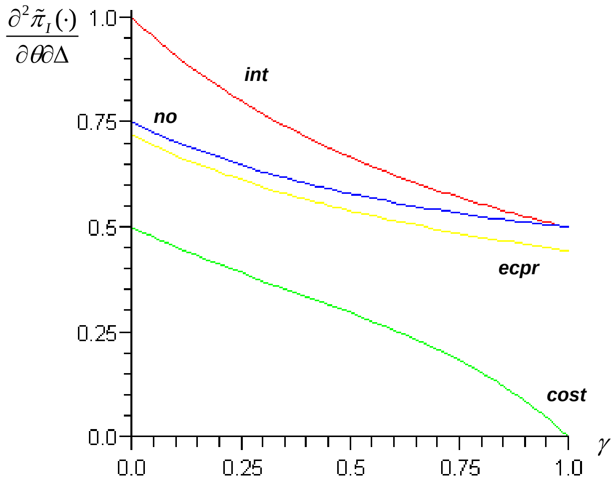

Figure 2: Influence of the Initial Value on Investment Incentives.

$$\frac{\partial^2 \tilde{\pi}_I^{*cost}(\cdot)}{\partial\theta\partial\Delta} = \frac{2(1-\gamma)}{(1+\gamma)(\gamma-2)^2} \tag{29}$$

$$\frac{\partial^2 \tilde{\pi}_I^{*no}(\cdot)}{\partial\theta\partial\Delta} = \frac{\gamma^3+\gamma^2+4\gamma+12}{2(\gamma+8)(1+\gamma)}. \tag{30}$$

It is easy to see that all expressions are always strictly positive.[15] The reason for this is, that a higher initial quality level comes along with a higher demand (see (1)). We can say that in this case, more consumers absorb the downstream market products. When the network provider increases network quality in this situation, all consumers will react by an extension of their demand. It follows directly that a higher initial quality level leads to a higher investment incentive. Furthermore, is it easy to see that the degree of substitution has a negative effect on the effect of the initial level on the investment incentive; since markets become closer connected and aggregate demand decreases.[16] For complete integration of the downstream markets the change of the investment incentive is the highest. This outcome is based on the non-existence of vertical externalities. So when $\gamma = 0$, markets are not connected, (31) equals one. This means that an increase of the initial level leads to the same increase of the investment incentive.

[15] See figure 2. An exception are cost based tariffs and homogeneous products ($\gamma = 1$). In this case Bertrand-competition leads to prices that equals marginal costs. In this case profits are independently from Δ always zero.

[16] See figure 2.

Focusing on ECPR and the case of non regulated access tariffs, we can see that the graphs show similarities.[17] The reason for this can be seen in the possibility of increasing rival's costs. The gap between these two approaches can be explained by a higher degree of vertical externalities in the case of market based access tariffs; profits on market 2 can be better reaped up when there is no constraint on setting the access charge. Furthermore the gap becomes bigger for increasing γ. This can be explained by the increasing competition pressure, leading to a lower impact of the initial level on both investment incentives. Access price setting without regulation is then the better instrument for reaping up profits on the competitors downstream market.

Since the consequence of a quality-enhancement is an increase in demand in both final product markets (see (1)), this also leads to higher prices (see (18), (19)). Hence, cost based access prices tend to result in lower investment incentives. In the market served by the separated downstream firm the network provider benefits from a change in quantities only, the access tariff is fixed (see 5)). Therefore the derivation of the investment incentive with respect to Δ is lowest.

Focusing on the effect of the degree of substitution on the investment incentive, we get from (10), (15), (20), (26) the following expressions[18]

$$\frac{\partial^2 \tilde{\pi}_I^{int}(\cdot)}{\partial\theta\partial\gamma} = -\frac{11}{(1+\gamma)^2} \tag{31}$$

$$\frac{\partial^2 \tilde{\pi}_I^{ecpr}(\cdot)}{\partial\theta\partial\gamma} = -\frac{726+506\gamma+154\gamma^2+22\gamma^3}{(1+\gamma)^2(\gamma+5)^3} \tag{32}$$

$$\frac{\partial^2 \tilde{\pi}_I^{cost}(\cdot)}{\partial\theta\partial\gamma} = -\frac{176-4.8\gamma+128.1\gamma^3+35\gamma^2+44\gamma^4-0.3\gamma^5}{(\gamma-2)(4-\gamma)^2(1+\gamma)^2} \tag{33}$$

$$\frac{\partial^2 \tilde{\pi}_I^{no}(\cdot)}{\partial\theta\partial\gamma} = \frac{-352-44\gamma(1+\gamma-\gamma^2)}{(\gamma+1)^2(\gamma^2+8)^2}. \tag{34}$$

The variation of substitutability (γ) can be seen as a change in the interaction of the two downstream markets. For γ close to 1, products are almost homogeneous and we have a high

[17] See figure 2.

[18] For simplification, we assume: $\Delta = 10, \theta = 3, c_0 = c_1 = c_2 = 1$, $\mu = 1.3$.

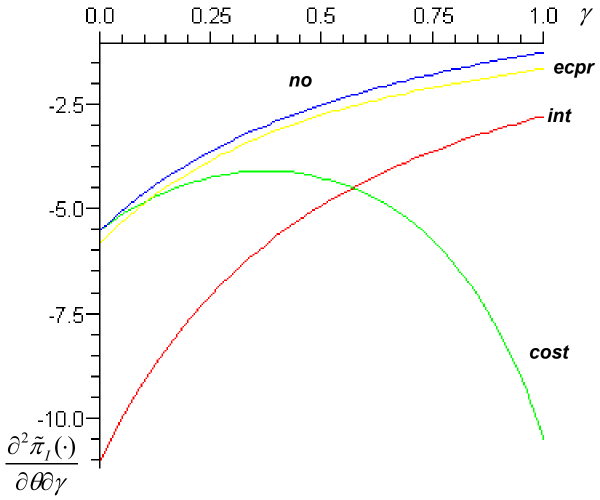

Figure 3: Influence of Degree of Substitutability on Investment Incentives.

degree of competition. The sum of the quantities demanded on both markets is therefore lower than in the case of a small γ. Further, it is easy to see that in the domain of γ ($\gamma \in [0,1]$) the expressions (31)-(34) are always negative.[19] This result is based on the assumed utility function of the consumers. The higher γ the lower is the marginal utility of the two products, and the lower the demand. Hence investment incentives of the network provider is lower, because consumers react relatively non-responsive on quality enhancements.

Comparing the different scenarios, it is obvious that the effect of a change in the level of γ has the strongest negative influence under complete integration. This can be explained by the complete internalization of both downstream markets. Increasing γ leads to losses on both markets, which lowers strongly the investment inventive. Under liberalization the network provider is affected directly by one market only, explaining a lower influence of the degree of substitution on the investment incentive.

Investigating the influence of the level of γ, we can state that a marginal change of γ has a lower influence on the investment incentive for a high level of γ.[20] Responsible for that fact is

[19]See figure 3.

[20]This does not hold under cost based access prices.

that the reduction of the quantities demanded is proportional to its absolute level. Under cost based access prices we also have a strong competition effect. This means that for a certain level of γ and an marginal increase of γ, the increase in the degree of competition becomes very strong and overcompensates the discussed impact of a high γ on the influence of a marginal change of γ on the investment incentive. As we know, the network provider does not have any tool to reduce the degree of competition in this scenario.

3.3 Social Welfare and Network quality: A Numerical Example

In order to get deeper insights and to have direct comparison of the different scenarios, we give a numerical example. We therefore assume the following values for the parameters $c_0 = 1$, $c_1 = 1$, $c_2 = 1$, $\mu = 1.3$, $\gamma = 0.8$, $\Delta = 10$. Further we assume $K(\theta) = 0.1 \cdot \theta^3$. For these values we can determine the generated network quality, quantities, prices, profits and social welfare, given in table 1.

First of all, the numerical example shows that complete integration yields the highest infrastructure quality. Then comes liberalization without access price regulation, then liberalization with ECPR. The lowest infrastructure quality level is the consequence of cost based access prices. Further, a high θ tends to result in high Nash-Equilibrium prices.[21]

Investigating the complete integration, we observe a symmetry of the two integrated downstream firms. This follows directly from the symmetry of the cost and demand structure. Accountable for the high quality level is the complete internalization of both downstream markets. Benefits of a quality enhancement are fully reaped up by the network provider.

Looking at the case of marked based access prices (ECPR), we obviously have, relative to the quality level, high prices on both downstream markets. By optimizing profits from both markets with p_1, the integrated network provider has an incentive to increase the rival's cost by increasing p_1. This "alleviated competition" results in low consumer surplus (CS).

[21] This is rooted in the structure of consumers utility function. The higher θ the higher is consumers reservation price.

θ^*	q_1^{NE}	q_2^{NE}	p_1^{NE}	p_2^{NE}	a^*	π_I^*	π_S^*	CS^*	W^*
4.06	3.35	3.35	8.03	8.03	/	38.94	/	40.41	79.35
2.65	4.86	4.75	3.99	4.01	1.30	9.23	8.14	48.14	65.51
3.84	3.17	1.13	9.75	10.16	8.75	27.76	0.46	24.76	52.98
3.98	4.14	2.03	8.63	8.21	6.90	31.41	1.49	35.60	68.50

Table 1: Network Quality and Social Welfare: A Numerical Example.

In the scenario of cost based access prices, the low level of network infrastructure is a consequence of high vertical externalities. Further, consumers have a low reservation price on grounds of the low quality level. On the other side, we have here a high degree of competition, leading to a relative high consumer surplus. This is based on the fact that the network provider cannot influence the marginal costs of his downstream competitor.

Under liberalization without regulation, the network provider is not restricted in setting the access tariff. In other words, the network provider can optimize the profits on market 2 by setting a. Therefore the network provider benefits highly from quality enhancements, explaining the high quality level.

Investigating social welfare (W), it is obvious that the order of the scenarios with respect to quality is different from the ordering with respect to W. The case of liberalization with ECPR yields a higher infrastructure quality, but not higher social welfare level than cost based access prices. The reason is the high degree of competition under cost based access prices which overcompensates the effect of the low infrastructure in this scenario. Prices are pushed down and the high consumer surplus leads to high social welfare.

Under complete integration we have the highest social welfare. One reason for that is the absence of vertical externalities, only the network provider profits from quality enhancement. Further marginal costs of the price setter on market 2 (given by $c_2 + c_0$) are low. Together with the absence of double marginalization this explains the high degree of social welfare.

4 Concluding Remarks

Comparing complete integration with liberalization of the downstream market it has been showed that under complete integration investment incentives tend to be higher. This is based on the fact that under liberalization network providers do not internalize benefits from a quality enhancement on market 2 completely. Comparing the scenarios of liberalization, the influence of the network provider on the access tariff seems to play an important role. Under liberalization without regulation of the access tariff, the network provider has a good instrument to reap up benefits from a quality enhancement on market 2, explaining the high investment incentive. By setting the price on market 1, the network provider can reap up benefits from an quality-enhancement on market 2. However, he has to maximize profits on market 1 with the price setting. Hence, under ECPR the network provider has only one instrument for two objectives. This trade off lowers the investment incentive compared to the case of liberalization without regulation. Under cost based access tariffs, network provider cannot influence the access price, which leads to a high degree of competition and explains the low investment incentive.

By investigating the social welfare of the scenarios, we find that network quality of access prices determined by ECPR do not yield a higher social welfare, although it leads to higher investment incentives. Here, the degree of competition under cost based tariffs pushes down prices and leads mostly to a higher social welfare.

The developed model can be extended in many ways. To fit the reality better, investment incentives can be analyzed in a dynamic approach. Further it would be interesting to assume a more general demand function on the downstream market.[22] Moreover we can implement regulation of the downstream prices, which should yield a lower infrastructure quality.

[22] For example we can think of the demand functions given in `Buehler et al (2004)`.

A Appendix

Parts of the analysis in chapter 3 are done without considering the costs of an infrastructure quality enhancement. We therefore have to show that the outcomes of the investigation still hold there. In other words, we have to show that a higher investment incentive leads to a higher infrastructure quality level.

First, we concentrate on a comparison of two different scenarios. Let $\tilde{\pi_I}(\theta, \cdot)$ be the revenues of the network provider. And let $K(\theta)$, with $K'(\theta) > 0$, $K''(\theta) > 0$, be the cost of a quality enhancement. The network provider has an optimization problem of the form

$$max_\theta \;\; \tilde{\pi_I}(\theta, \cdot) - K(\theta) = max_\theta \;\; \pi_I(\theta, \cdot).$$

Let θ^* denote the optimal quality level, solving $\tilde{\pi_I}'(\theta, \cdot) = K'(\theta)$. If we compare two different scenarios X and Y, and we have $\tilde{\pi_I}'(\theta, \cdot)^X > \tilde{\pi_I}'(\theta, \cdot)^Y$, we can say that scenario X leads to a higher infrastructure quality level, since $K(\theta)$ is an increasing, convex function in θ. Because of $\tilde{\pi_I}'(\theta, \cdot)^X > \tilde{\pi_I}'(\theta, \cdot)^Y \rightarrow \theta^{*X} > \theta^{*Y}$, we make a statement about the quality level just by comparing investment incentives.

Apart from the comparison of two different scenarios, we are also interested in "intra-scenario" comparison, which is done in chapter 3.2.2. Thus we have to show that a marginal change in a parameter leading to a higher investment incentive, also leads to a higher network quality. Let us therefore do a proof for the parameter γ.[23] The optimal quality level (θ^*) for all scenarios is characterized by

$$\tilde{\pi_I}'(\theta^*, \cdot) - K'(\theta^*) = 0. \tag{35}$$

By differentiation of (35) with respect to γ, we get by using the chain rule the following

$$\frac{\partial \tilde{\pi_I}'(\theta^*, \cdot)}{\partial \gamma} + \frac{\partial \tilde{\pi_I}'(\theta^*, \cdot)}{\partial \theta} \cdot \frac{\partial \theta^*}{\partial \gamma} - \frac{\partial K'(\theta^*)}{\partial \theta^*} \cdot \frac{\partial \theta^*}{\partial \gamma} = 0 \leftrightarrow \frac{\partial \theta}{\partial \gamma} = -\frac{\frac{\partial \tilde{\pi_I}'(\theta^*, \cdot)}{\partial \gamma}}{\frac{\partial \tilde{\pi_I}'(\theta^*, \cdot)}{\partial \theta} - \frac{\partial K'(\theta^*)}{\partial \theta}}.$$

With the condition of an inner maximum, given by $\frac{\partial \tilde{\pi_I}'(\theta^*, \cdot)}{\partial \theta} - \frac{\partial K'(\theta^*)}{\partial \theta} < 0$, it follows directly

$$sign \frac{\partial \theta^*}{\partial \gamma} = sign \frac{\partial \tilde{\pi_I}(\theta^*, \cdot)}{\partial \gamma}.$$

[23] The proof for the initial level Δ can be done analogously.

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