# Access Conditions, Investment and Welfare

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**Abstract**

We investigate the relationship between investment in new infrastructure by telecoms operators and the access conditions to such infrastructure. We consider two variations of the problem. In the first, there is one infrastructure company which invests in upgrading its network. A second non-infrastructure company needs to gain access to that infrastructure in order to offer the same higher quality services. We find that cost based access to the new infrastructure leads to a reduction in investment and also a fall in consumer welfare.

In the second variation, both companies invest, either non-cooperatively or co-operatively (joint venture). We find that investment and consumer welfare is higher than in the case that only one invests and is forced to give access at cost to the other.

To clarify the effects, we show that after an investment has been carried out, e.g. for legacy assets, the best regulatory policy is to give access at cost. Once companies can carry out autonomous investment decisions, then such regulation is no longer optimal. We conclude that a new regulatory policy is needed to allow for investments into the upgrading of infrastructures.

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# 1 Introduction

The telecommunications industry is currently in the midst of a disruptive technological development. Technology is now in place that will allow to increase data transmission speeds in fixed local networks from the current 16MBit/s to - at least - around 100MBit/s, and in wireless networks from the current 384kbit/s to a possible peak rate of around 10MBit/s. These increases in speed enable new innovative and higher quality services.

While the technology exists today, it is an entirely different question whether it will be deployed by operators. Deployment of both fixed and mobile networks requires very significant amounts of investment. As an illustrative example, Deutsche Telekom has announced to upgrade its local network to achieve the speeds mentioned above, in 50 cities or 6 million households across Germany, at a cost of Euro 3bn.[1] Similarly, in mobile technology, the upgrade to what is termed "Release 5" of the third generation technology means that networks need to carry out very significant infrastructure upgrades.

A heated debate has therefore started whether/under what conditions a company should give access to competitors when it upgrades its own infrastructure. The importance of the debate should not be underestimated. If the German investment figures are any guide for the EU and infrastructure costs for upgrading a household are as high as Euro 500, total investment costs could be as much as Euro 100bn. If this investment really does create value and increases welfare for European citizens, then regulation that does not hinder such investment is fundamental.

In this paper we analyse the 'investment-access' problem by considering a stylised market in which there are two active companies.[2] Companies can choose to invest in the quality of the product they offer. An investment leads to a vertical displacement of the firm's demand curve. Following the investment, firms play a Cournot game in the retail market. Our investigation is structured into two parts. In the first part, only one of the firms invests. The other firm needs access to the first firm's upgraded infrastructure in order

[1] http://www.telekom3.de/de-p/aktu/5-sp/inha/gedo/060706-vdsl-netz-ar.html

[2] We generalise some of the more important results to $n$ companies.

to sell the same high quality product. We are interested how its investment decision is influenced by what we call *access conditions,* namely (i) whether it needs to give access to the upgraded infrastructure (except for the "full monopoly" part, there is always access to the existing infrastructure) and (ii) at what price access is given. In particular we investigate the effects of a regulator who requires access to the upgraded infrastructure at cost.

In the second part both firms invest, either in competition to each other or cooperatively (in a Joint Venture). We evaluate investments and consumer welfare in that setting and compare results across all cases.

Our main results can be summarised as follows.

- Investment and consumer welfare are higher when two companies invest in infrastructure (non-cooperatively or in a JV) than in the case when only one company invests and gives infrastructure access to the other company at cost.
- If one company invests and the investment is particularly effective in creating quality, then a higher access price can increase consumer welfare.
- When two companies invest cooperatively in a joint venture, consumer welfare is higher than in any other case. However, this result depends on the particular formulation of the joint venture.

Given these results, we analyse further why a regulator may want to impose such access conditions if these are bad for consumers. We find that,

- *ex post*, i.e. once the investment is made, it is welfare maximising for the regulator to force access to the upgraded infrastructure at cost.

In other words, if the investment is already there, then cost based access is optimal, but if the infrastructure first needs to be deployed at high cost, such a policy is suboptimal. This may provide an explanation for regulatory policy: in the past, regulation was mostly on legacy assets which existed before regulation was introduced and, moreover, which were built by state owned monopolists. In such a setting, cost based regulation can be beneficial.

However, when investments need to be made, such a policy is no longer appropriate.

This insight contains the main message of the article. While cost based access regulation so far was beneficial for consumers, when new investments need to be made, this is no longer the case. New regulation or deregulation is required to capture the positive effects of investment induced quality improvement in products.

There are already a number of articles on the subject of access and investments. Our model is closest to Foros (2004). In contrast to us, Foros introduces the possibility that an entrant is more efficient than an incumbent, and shows that the entrant can operate without a regulated price in this setting. We derive similar results to Foros. We add the case in which two firms can invest in competition or cooperatively. Our formulation closely follows d'Aspremont and Jacquemain (2001).

# 2 Structure of the model

We consider a stylised telecommunications industry structure with two firms that we call an incumbent, $I$, and an entrant, $E$. There are two main parts. In the first part, only the incumbent invests in infrastructure. This investment leads to an increase in the quality of the product it sells. The focus of that part of the model is to understand the relationship between investment by the incumbent and the conditions for access negotiated between the incumbent and the entrant or set exogenously by a regulator. Initially in the status quo the incumbent operates infrastructure. The incumbent then carries out an investment in infrastructure which makes the services provided over it more desirable. This investment is intended to represent an upgrade of a fixed line local loop from ADSL to VDSL or fibre capability, or of a (single) mobile network to UMTS Release 5 (HSDPA). The incumbent can give the entrant *wholesale* access to its network. The entrant gets either no access, access only to the existing network, or access to the new improved network. Retail competition depends on what type of access is given. Both incumbent and entrant compete against each other in the retail market, but the entrant can only offer advanced services if it has access to the new infrastructure, and without any access at all the incumbent retains a monopoly in the retail market. We compare several market solutions to the investment / access problem with scenarios in which a regulator intervenes and sets the access price.

In the second part of the article, both the incumbent and the entrant invest. We look both at cases in which they invest competitively and those in which they invest cooperativel. In the competitive case, we consider subcases in which they do / do not give each other access to the upgraded infrastructure at cost.

Our model is set up as a three stage game. We model (i) an investment stage, (ii) a regulation stage and (iii) a retail stage. In the investment stage the incumbent can invest in upgrading its network. This upgraded network enables services that are more desirable: they increase consumers' willingness to pay and induce a demand shift to the right, meaning that for a given price the quantity sold by the incumbent is higher. In the second stage the regulator determines access conditions alongside two dimensions. First it can set the access (wholesale) price and, secondly, it can determine if the entrant has access to the incumbent's upgraded network. In the retail stage the incumbent and the entrant compete a la Cournot.

Below we list all cases:

- *Monopoly for both old and upgraded infrastructure (for reference only):* As a benchmark and in order to restrict the access prices that the incumbent would want to charge to the entrant, we compute the foreclosing access price and a monopolist's investment levels. We take the foreclosing access price to be the maximum access price for the remainder of our analysis.

- *Investments for given access price and access conditions*: This is our basic setting with one company investing in infrastrcuture in the first stage. In the second stage the incumbent and the entrant compete a la Cournot. This version of the model outlines the general framework and will provide some benchmark results for the analysis to follow.

- *Access to upgraded infrastructure regulated at cost*:
  In a variation on the above setting, the regulator gives access to the incumbent's upgraded infrastructure at cost. The incumbent understands this and conditions its investment on the regulation. In the third stage the incumbent and the entrant compete a la Cournot.

- *Investments by both incumbent and entrant.*
  In the first stage, both companies invest. In the second stage, we consider mutual access to the upgraded infrastructure at cost, or no access. In the third stage, the two companies compete a la Cournot.

- *Investments under joint venture*:
  The incumbent and the entrant form an upgrade joint venture in the first stage, i.e. both firms contribute to infrastructure upgrading as to maximise joint profits. In the second stage access is given at cost and in the third stage firms compete a la Cournot.

## 2.1 Demand

Infrastructure investments increase the quality, e.g. the speed, of the network. This enables new or faster services which, in turn, increase consumers' willingness to pay. The demand side is similar to Katz and Shapiro (1985). Formally, the inverse demand function facing the incumbent is

$$p_I(q_I, q_E) = (A + x_I) - q_I - q_E \tag{1}$$

where the constant $A$ represents the reserve price given the old technology, the variable $x_I$ captures the incumbent's investment in infrastructure upgrading and $q_I, q_E$ the incumbent's and the entrants retail quantity respectively. The entrant's inverse demand function is similar.

$$p_E(q_I, q_E) = (A + \alpha x_I) - q_I - q_E, \tag{2}$$

where$\alpha$ is the parameter indicating whether the entrant gains access to the incumbent's upgraded infrastructure or not and therefore takes values $\alpha = 0$ (no access) or $\alpha = 1$ (access). In the latter case, (1) equals (2) and the incumbent and the entrant face identical demands demands. In contrast if the entrant is denied access to the incumbent's upgraded infrastructure, $\alpha = 0$, the entrant experiences a lower willingness to pay as it can only offer services based on the old technology.

## 2.2 Costs and profits

We assume that there are constant and identical marginal costs $c$ for both entrant and incumbent. In addition, the incumbent faces an investment cost with decreasing returns to scale, $\tau(x_i) = \frac{\gamma}{2}x_I^2$, where $\gamma > 0$ is a parameter which determines the effectiveness of the investment. If $\gamma$ is very low, then a large increase in market demand can be achieved with little effort. If $\gamma$is high, then more effort is required to achieve the same shift in market demand. Decreasing returns to scale in upgrading the network ensures an interior solution to the incumbent's first stage maximisation problem. It can be justified, for instance, if consumers have a decreasing additional willingness to pay for additional network speed. Alternatively one may think of different regional areas to be potentially upgraded. Then the incumbent will first upgrade the most promising areas, before it moves on to less promising ones[3].The wholesale price which the incumbent charges the entrant is denominated by $w \geq c$. If $w = c$ then access is given at cost.

With (1) at hand we can write the incumbent's profit function as

$$\pi_I = (p_I - c)q_I + (w - c)q_E - \frac{\gamma}{2}x_I^2 \tag{3}$$

The first term of (3) represents the incumbent's retail profits while the second term captures its wholesale profits. The last term reflects the cost of investment of upgrading the network.

Given the inverse demand function facing the entrant (2) we can write the entrant's profit function

$$\pi_E = (p_E - w)q_E. \tag{4}$$

According to (4) the entrant has no direct cost of using infrastructure but has to purchase infrastructure access proportional to its output quantity at the

[3]We note that Deutsche Telekom has announced to upgrade its network to VDSL in 10 cities first, before potentially expanding it to an additional 40 cities.

wholesale price $w$. Furthermore (4) implies that the entrant has no option and no cost of upgrading infrastructure. In section 2.3 below we will relax this assumption in the context joint quality improvements, i.e. under quality joint ventures. Finally we assume that apart from the costs of using the infrastructure there are no further additional costs of providing services for either the entrant or the incumbent.

# 3 Investment by the incumbent only[4]

For comparison purposes it will be useful to derive results for the case in which the incumbent *forecloses* its rival from the retail market. The incumbent can foreclose by setting the access price sufficiently high. A sufficient condition for this is that the incumbent sets the wholesale price to the monopoly retail price $p^m$. As a monopolist, the incumbent would face inverse demand curve

$$q_i^m = A + x_i - p^m \tag{5}$$

and it would maximise monopoly profits

$$\Pi_i^m = (p^m - c)[A + x_i - p^m] - \frac{\gamma}{2}x_I^2 \tag{6}$$

which yields a monopoly quantity and price of

$$q^{m*} = \frac{1}{2}[A + x_i - c] \quad \text{and} \quad p^{m*} = \frac{1}{2}[A + x_i + c] \tag{7}$$

$p^{m*}$is the highest price the incumbent would charge the entrant. As will be clear later, we actually need to assume a slightly stricter condition on the access price for our results. The above equations lead to a first stage maximisation problem of

$$\Pi^m = (q^{m*})^2 - \frac{\gamma}{2}x_i^2 \tag{8}$$

Using these values in the profit function of the monopolist gives a monopoly investment level of

[4]This section is based on a model by Foros (2004).

$$x_i^{m*} = \frac{A - c}{2\gamma - 1} \tag{9}$$

Since $A > c$ for a positive quantity in equilibrium, this expression is positive as long as $\gamma > \frac{1}{2}$. We do note that, as expected, investment is decreasing in $\gamma$. If investment is not very effective for the creation of a new market ($\gamma$ is large), then investment itself is going to be lower.

## 3.1 Investment and access conditions in a two-stage Cournot model

In the basic Cournot competition setting we analyse the incumbent's and the entrant's decisions for exogenously given access price, $w$, and access quality, $\alpha$. This requires a two stage model. In the first stage the incumbent decides on its infrastructure investment, $x_I$, as a function of access price and quality. In the second stage the entrant and the incumbent compete in quantities, $q_I$ and $q_E$ respectively. We proceed via backwards induction.

In the second stage the incumbent and the entrant maximise (3) and (4) with respect to $q_I$ and $q_E$, respectively. This yields equilibrium output quantities

$$q_I^* = \frac{1}{3}(A + (2 - \alpha)x_I + w - 2c) \tag{10}$$

and

$$q_E^* = \frac{1}{3}(A + (2\alpha - 1)x_I - 2w + c). \tag{11}$$

To solve the incumbent's first stage maximisation problem, we substitute (10) and (11) into (3), and maximise the resulting first-stage profit function with respect to $x_I$. We obtain the incumbent's equilibrium investments for given access price and access quality. Under the two parameter values of $\alpha = 0$ and $\alpha = 1$, we arrive at:

$$\alpha = 0 \Rightarrow x* = \frac{4A - 5c + w}{-8 + 9\gamma} \quad \text{and} \quad \alpha = 1 \Rightarrow x* = \frac{2A - 7c + 5w}{-2 + 9\gamma} \tag{12}$$

Note that the second-order condition, $\partial^2 \pi_I / x_I^2 < 0$, requires $\gamma > \frac{8}{9}$ when there is no access to the upgraded infrastructure, and $\gamma > \frac{2}{9}$ when there is access. Throughout the paper we assume that the latter inequality holds. We derive the following results:

**Claim 1** *(i) The incumbent's investment in infrastructure upgrade,* $x_I^*$*, is increasing in the access price,* $\partial x_I^*/\partial w > 0$*,*
*(ii) for values of* $\gamma$ *for which equilibria exist with access and no-access to the upgraded infrastructure, the incumbent invests less when the entrant is given access (*$\alpha = 1$*) than when it is not (*$\alpha = 0$*), and*
*(iii) consumer surplus,* $CS$*, increases for higher access prices,* $w$*, if the cost of upgrading infrastructure,* $\gamma$*, is low.*

**Proof.** (i) can be easily shown, since $\frac{\partial x_I^*}{\partial w}$ is positive for both values of $\alpha$under the conditions necessary for equilibrium.

For (ii) we need to compare (12) substituted with the possible values of $\alpha$. Since $A > w \geq c$, $\gamma > \frac{8}{9}$and with the additional stricter condition on the access price than (7), namely that $\frac{1}{2}(A+c) > w$, investment to the upgraded infrastructure under no access,

$$\alpha = 0 \Rightarrow x* = \frac{4A - 5c + w}{-8 + 9\gamma}$$

is higher than investment under access

$$\alpha = 1 \Rightarrow x* = \frac{2A - 7c + 5w}{-2 + 9\gamma}$$

For (iii), note that the linearity of the inverse demand functions means that, in equilibrium, consumer surplus is just

$$CS^* = \frac{(q_I^*(x_I^*) + q_E^*(x_I^*))^2}{2} \tag{13}$$

Note that $\partial CS/\partial w = (q_I^* + q_E^*)(\partial q_I^*/\partial w + \partial q_E^*/\partial w)$ and thus $sign\, \partial CS/\partial w = sign\ \partial(q_I^* + q_E^*)/\partial w$. We have that

$$\frac{\partial(q_I^* + q_E^*)}{\partial w} = \frac{3 - \alpha + 2\alpha^2 - 3\gamma}{9\gamma - 8(1-\alpha) - 2\alpha^2},$$

where the denominator is negative as $9\gamma > 8$ and the numerator is positive iff $\gamma < 1 + \frac{\alpha(2\alpha-1)}{3}$. ■

The intuition behind Claim 1 is straightforward. The incumbent has higher investment incentives the higher the entrant's access price to the incumbent's network for two reasons. Firstly, it directly increases the incumbent's market share, since $w$ enters positively into the optimal quantity for the incumbent (10), but negatively for the entrant (11). A higher market share means that investments into upgrading infrastructure can be spread over a larger customer base. Secondly, a higher access price softens competition between the two firms in the retail market.

By the same token access to the new infrastructure by the entrant reduces the incumbent's incentives to invest in infrastructure upgrading since the entrant can free-ride on its efforts. If the entrant gets access to the better infrastructure, then it will increase competition at the retail stage, since now both demand curves shift and consumers can choose between equally attractive offers. Since competition is imperfect at the retail stage, the incumbent's decrease of retail profits is never completely compensated through an increase in wholesale profits. The extra condition on $\gamma$ means that the profit function must be sufficiently convex. If it is not, then no equilibrium can be found, since investment is so effective that it would always pay to invest another unit. We note that the condition on $\gamma$ is lower for full access. This is due to the fact that when the incumbet loses profits earlier than when it is not required to give access.[5]More surprisingly, consumer surplus increases when the wholesale access price increases, if the investment in upgrading the infrastructure is very effective. The access price, $w$, affects consumer surplus in two ways. On the one hand a lower access price increases the entrant's ability to compete vigorously at the retail stage and hence increases competitive intensity and consumer surplus (*competition effect*). On the other hand a lower access price discourages the incumbent's incentives to upgrade infrastructure quality which harms consumers (*investment effect*). Now, if investments are relatively expensive, the incumbent would not incur much investments anyway and hence the competition effect outweighs the investment effect: a higher access price decreases consumer welfare. On the contrary, if investments are relatively cheap, the potential increase in infrastructure quality at stake is significant. In this case the competition effect is dominated by the investment effect: consumer surplus is higher the higher the access price.

[5]That is due to double marginalisation, the Chicago argument does not apply and the incumbent is not indifferent of selling capacity through its own retail channel or through the entrant's retail channel.

This result can be interpreted in the context of the discussion on whether there should be regulated access (see also below). From a consumer welfare perspective, a higher access price is beneficial when the investment is particularly effective. Effective investment could be interpreted as the creation of a "new market[6]". If a new market is created by the investment, then it is indeed beneficial from a social policy point of view to charge an access price which exceeds costs.

### 3.1.1 Regulator's incentives and consumer surplus

Thus far we have not explicitly modelled a regulator's decision regarding entrant access. Since the pre-dominant form of access regulation is to give access at cost, we analyse the impact on consumer welfare of such access regulation. Crucially, the regulator can determine access conditions, but it cannot influence the investment decision of the incumbent. We model the game in the following way: In the first stage the incumbent carries out investments to upgrade its infrastructure. In the second stage the regulator determines access conditions: it gives full access to the upgraded infrastructure, $\alpha = 1$, and it does so at cost, $w = c$. In the third stage the incumbent and the entrant compete a la Cournot. Again we solve by backwards induction.

Since the third stage set-up is similar to the previous section, we can use equilibrium output quantities, $q_I^*$ and $q_E^*$, as given by (10) and (11).

In the second stage, the regulator sets $\alpha = 1$and $w = c$, i.e. full access to the upgraded infrastructure is given at cost.

In the first stage the incumbent maximises (3) with respect to $x_I$, anticipating (10) and (11) as well as $w = c$ and $\alpha = 1$. The incumbent's optimal investment level is then

$$x_I^R = \frac{2(A-c)}{9\gamma - 2}. \tag{14}$$

We establish the following results:

[6] The model is not one of 'vertical' product differentiation, where consumers put different values at the same product, in the sense that, following the investment, one product has more quality. In this sense, a new market would be defined as one where products have significantly superior quality.

**Claim 2** *Consumer surplus, $CS$,*
*(i) is always suboptimal for cost functions that have equilibria ($\gamma > 8/9$) if access is both high quality, $\alpha = 1$, and cost-based, $w = c$.*
*(ii) under the scenario of (i), investment is also less than under no access, and*
*(iii) investment is actually lower than under full monopoly.*

**Proof.** For the first claim we use the consumer surplus equation (13). Note that setting $w = c$ in 12 will lead to

$$q_I^* + q_E^* = \frac{2}{3}(A-c) + \frac{4}{3}\frac{A-c}{-8+9\gamma} \quad for \quad \alpha = 0 \tag{15}$$

and

$$q_I^* + q_E^* = \frac{2}{3}(A-c) + \frac{2}{3}\frac{A-c}{-2+9\gamma} \quad for \quad \alpha = 1 \tag{16}$$

For cost functions that are sufficiently convex to guarantee an equilibrium for both solutions, $\gamma > 8/9$, we find that (15) is larger than (16). For (ii) see Claim 1. For (iii) compare equations (14) with (9) for allowable parameters of $\gamma$, i.e. $\gamma > 1/2$. ■

We therefore show that full access to the the upgraded infrastructure at cost is bad for investment incentives to an extent where no access to the upgraded infrastructure would lead to more consumer surplus, and no access at all to any infrastructure would still lead to more investment.

One may think that a regulator should therefore have no incentives to set a cost based access price for new technologies. In order to understand why a regulator may be tempted to do so, we analyse consumer welfare *after the investment has taken place.* Following an investment, a regulator maximises

$$CS^R = \frac{(q_I^*(x_I) + q_E^*(x_I))^2}{2} \tag{17}$$

with respect to $w$ and $\alpha$. Note that, in contrast to (13), (17) does not include the incumbent's equilibrium investment levels but any given $x_I$. This is because the regulator determines the regulatory regime post investment, i.e. the incumbent's investment is made and not affected through the regulator's decision anymore. In this case the regulator decides as follows:

**Claim 3** *If a regulator intends to maximise consumer welfare post-investment, it sets*
*(i) access prices according to marginal costs, i.e.* $w = c$*,*
*(ii) gives full access, i.e.* $\alpha = 1$*.*

**Proof.** As for the first claim, note that

$$\frac{\partial CS^R}{\partial w} = -\frac{1}{9}(2A - c - w + x_I(1+\alpha)) < 0,$$

and hence (17) is maximised for minimum access price, $w = c$.

For the second claim we have that

$$q_I^* + q_E^* = \frac{2}{3}(A - c) + \frac{1}{3}x_I \quad for \quad \alpha = 0$$

which, for positive $x_I$ is always smaller than

$$q_I^* + q_E^* = \frac{2}{3}(A - c) + \frac{2}{3}x_I \quad for \quad \alpha = 1$$

and thereby (17) is maximised for maximum access quality, $\alpha = 1$. ■

Clearly, once investments are made there is no negative incentive anymore of giving a low access price. The regulator's decision is only influenced by the access effect, not the investment effect. According to the latter, consumers unambiguously benefit if the entrant has better access conditions, both in terms of price and quality, since these stimulate retail competition and hence increase consumer surplus.

However, given Claim 2 above shows that in fact, giving full access to upgraded infrastructure at cost is always suboptimal for consumer welfare, since the incumbent will invest less and therefore the consumer welfare gain from such investment is reduced.

This analysis may explain regulators' behaviour. When regulation was introduced originally, large investments in infrastructure (the local loop) had been made long ago. At the time when those investments were made, telecoms companies were usually state-owned monopolies. Therefore, regulators did not need to worry about negatively affecting incentives to invest. From a consumer welfare point of view, they maximised consumer welfare by forcing access at cost.

However, with new technologies and infrastructure upgrading that need to be introduced at a high cost for the incumbent, regulation concenred with consumer welfare will need to take into account both competition in the retail market and investment incentives of infrastructure providers. Our analysis argues that cost based regulation does not do so and is therefore suboptimal to maximise consumer welfare.

# 4 Investments by incumbent and entrant

## 4.1 Investments under competition

Thus far we have considered investments by the incumbent only. We now relax this assumption and analyse investment levels if both the incumbent and the entrant may invest in infrastructure up-grading. This requires a slightly modified set-up. Given that either firm invests and $w = c$, the incumbent and the entrant face demand

$$p_i^D = A + x_i + \alpha x_j - q_i - q_j, \quad i = I, E, \quad i \neq j, \tag{18}$$

where $x_E$ refers to the investment made by the entrant. Profit functions are

$$\pi_i = (p_i^D - c)q_i - \frac{\gamma}{2}x_i^2, \quad i = I, E, \tag{19}$$

where now both the incumbent and the entrant have costs of infrastructure upgrading. The solution process is, again, backward induction.

In the second stage the incumbent and the entrant maximise (19) with respect to $q_I$ and $q_E$ respectively, yielding

$$q_i^D = \frac{1}{3}(A - c + (2-\alpha)x_i + (2\alpha - 1)x_j), \quad i = I, E, \quad i \neq j. \tag{20}$$

### 4.1.1 Subcase 1: no access to upgraded network

Our first subcase regards a regulatory regime in which no (reciprocal) high speed network access is granted by the regulator, i.e. $\alpha = 0$. Firms' maximisation problem can then be written as

$$\max_{x_i} \ \pi_i^D\big|_{\alpha=0} = (p_i^J - c)q_i - \frac{\gamma}{2}x_i^2, \quad i = I, E, \ i \neq j. \tag{21}$$

The solution to (21) implies equilibrium investments of

$$x_i^D\big|_{\alpha=0} = \frac{4(A-c)}{9\gamma-4}, \quad i = I, E, \quad i \neq j.$$

#### 4.1.2 Subcase 2: reciprocal high speed network access

This case proposes a regulatory regime that proposes reciprocal access, that is both the incumbent and the entrant are forced to grant access to their high speed netwroks once investments are made and the new technology is available. The maximisation problem then is

$$\max_{x_i} \ \pi_i^D\big|_{\alpha=1} = (p_i^J - c)q_i - \frac{\gamma}{2}x_i^2, \quad i = I, E, \quad i \neq j.$$

The solution is

$$x_i^D\big|_{\alpha=1} = \frac{2(A-c)}{9\gamma-4}, \quad i = I, E, \quad i \neq j.$$

### 4.2 Investments under joint venture[7]

We have established that the presence of regulation creates an investment dilemma in which the incumbent invests too less in infrastructure upgrading. Consumer welfare is suboptimal and could be increased through less restrictive access conditions. However post-investment the regulator cannot do better than allowing cost based access, $w = c$, and ensuring high speed network access for the entrant, $\alpha = 1$.

Given this regulatory regime, we explore whether an upgrade or quality joint venture between the incumbent and the entrant might (i) induce more investments and increase consumer welfare and (ii) is incentive compatible such that the incumbent and the entrant would both like to set-up such a joint venture. In so doing we consider that the incumbent and the entrant agree upon a certain amount of infrastructure investment undertaken by both the incumbent and the entrant. In particular we determine the amount of infrastructure investment through the incumbent and the entrant that maximises both firms' joint profits at the first (investment) stage. We know from the previous section that the regulator will set full and cost based access

[7] This section is based on a model by D'Aspremont, Jacquemin (1988).

in the second stage. The incumbent and the entrant remain competitors at the third (retail) stage.

In the first stage the incumbent and the entrant form a joint-venture to upgrade infrastructure. Firms recognise the positive externality their investments have on each other and reciprocally internalise it rather than cutting back for the purpose of not benefitting one's rival. Formally firms choose investments as to maximise joint first stage profits,

$$\max_{x_i} \; (\pi_i^D + \pi_j^D) = (p_i^D - c)q_i + (p_j^D - c)q_j - \frac{\gamma}{2}x_i^2 - \frac{\gamma}{2}x_j^2, \quad i = I, E, \quad i \neq j. \tag{22}$$

We differentiate (22) with respect to $x_I$ and $x_E$ simultaneously and solve first-order conditions for

$$x_i^D = \frac{4(A-c)}{9\gamma - 8}, \quad i = 1, 2. \tag{23}$$

In our formulation of the joint venture we follow d'Aspremont and Jacquemin (2001). In their investment cost function, companies are treated separately. This formulation naturally gives an advantage over a rival specification in which the investment cost is the square of the sum of individual investments, rather than the sum of the squares. Our results depend on this formulation and should therefore be treated with caution.

Also, we do not consider bargaining in the model. The threat of regulation in case of a failure to establish a joint venture can lead to asymmetric bargaining. The profits are therefore unlikely to be distributed evenly and it remains unclear whether the JV can be established. In this sense, more work is required in transferring the research JV framework to the communications industry.

For these reasons, we cannot deduce sustainable policy recommendations regarding infrastructure joint ventures.

# 5 Comparison of cases

With (23) we can conclude the following:

**Claim 4** *Equilibrium investment levels satisfy*

$$x_I^R = x_i^D\big|_{\alpha=1} < x_i^D\big|_{\alpha=0} < x_i^J, \quad i = I, E.$$

**Proof.** For the first claim compare (14) and (23) and note that

$$\begin{aligned} x_I^R = x_i^D\big|_{\alpha=1} = \frac{2(A-c)}{9\gamma-2} &< \frac{4(A-c)}{9\gamma-4} = x_i^D\big|_{\alpha=0} \\ &< \frac{4(A-c)}{9\gamma-8} = x_i^J, \quad i = I, E. \end{aligned}$$

The first inequality follows because the numerator of the left hand side is strictly smaller than the numerator of the right hand side and the denominator of the left hand side is strictly greater than the denominator of the right hand side. The second inequality follows because denominator of the second row fraction is smaller than the denominator of the first row fraction. ■

Quality joint ventures stimulate infrastructure investments. This is due to the public good characteristic of infrastructure upgrades. For instance the incumbent may upgrade infrastructure in a certain region and can provide superior services to its customers. However, usage by the incumbent's customers still allows usage by the entrant's customers at no or negligible extra costs. The same holds for regions upgraded by the entrant. With perfect access hence either firm's investment imposes a positive externality on the other firm. The quality joint venture allows firms to internalise these positive externalities. This means that either firm incurs investments beyond the level that would be optimal from its isolated point of view.

Practically this may take the form of side–payments, i.e. the entrant does not physically upgrade any part network itself but reimburses the incumbent for some of its investments. Alternatively the incumbent and the entrant could agree on each upgrading a certain region whilst reciprocal access is allowed subsequently (or might, in fact, be regulated anyway).

**Claim 5** *Equilibrium consumer surplus levels satisfy,*

$$\begin{aligned} CS^R(x_I^R) < CS^D(x_i^D\big|_{\alpha=0}, x_j^D\big|_{\alpha=0}) &= CS^D(x_i^D\big|_{\alpha=1}, x_j^D\big|_{\alpha=1}) \\ &< CS^J(x_i^J, x_j^J), \quad i = I, E. \end{aligned}$$

**Proof.** Compare first $CS^R(x_I^R)$ and $CS^D(x_i^D\big|_{\alpha=0}, x_j^D\big|_{\alpha=0})$. Note that $CS^R(x_I^R) < CS^D(x_i^D\big|_{\alpha=0}, x_j^D\big|_{\alpha=0}) \iff (q_I^R + q_E^R) < (q_i^D(x_i^D\big|_{\alpha=0}) + q_j^D(x_j^D\big|_{\alpha=0}))$. Substituting the equilibrium values we obtain

$$q_I^R + q_E^R = \frac{6(A-c)\gamma}{9\gamma - 2} < \frac{6(A-c)\gamma}{9\gamma - 4} = q_i^D(x_i^D\big|_{\alpha=0}) + q_j^D(x_j^D\big|_{\alpha=0}).$$

Next we have $CS^D(x_i^D\big|_{\alpha=0}, x_j^D\big|_{\alpha=0})$ and $CS^D(x_i^D\big|_{\alpha=1}, x_j^D\big|_{\alpha=1})$. Again, $CS^D(x_i^D\big|_{\alpha=0}, x_j^D\big|_{\alpha=0}) = CS^D(x_i^D\big|_{\alpha=1}, x_j^D\big|_{\alpha=1}) \iff (q_i^D(x_i^D\big|_{\alpha=0}) + q_j^D(x_j^D\big|_{\alpha=0})) = (q_i^D(x_i^D\big|_{\alpha=1}) + q_j^D(x_j^D\big|_{\alpha=1}))$, where we substitute for equilibrium values.

$$q_i^D(x_i^D\big|_{\alpha=0}) + q_j^D(x_j^D\big|_{\alpha=0}) = \frac{6(A-c)\gamma}{9\gamma - 4} = q_i^D(x_i^D\big|_{\alpha=0}) + q_j^D(x_j^D\big|_{\alpha=0}).$$

Finally we have $CS^D(x_i^D\big|_{\alpha=1}, x_j^D\big|_{\alpha=1})$ and $CS^J(x_I^J, x_E^J)$. Following basic substitution of equilibrium investment values we obtain

$$q_i^D(x_i^D\big|_{\alpha=1}) + q_j^D(x_j^D\big|_{\alpha=1}) = \frac{6(A-c)\gamma}{9\gamma - 4} < \frac{6(A-c)\gamma}{9\gamma - 8} = q_I^J + q_E^J.$$

as the denominator of the left hand side of the inequality is greater than the denominator of the right hand side whilst the numerators are equal. ■

Infrastructure quality joint ventures are good for consumers. Next we are interested whether joint ventures are also desirable from the firms' point of view. In particular it is questionable whether the entrant has an incentive to contribute, given that he would be granted high quality and costless access anyway. A comparison of firms' profits under regulation with incumbent investment only and with joint quality investments reveals the following:

**Claim 6** *Under quality joint ventures*
*(i) the incumbent earns higher profits than under regulation with incumbent investment only,*

$$\pi_I^D(x_i^D\big|_{\alpha=0}) < \pi_I^R < \pi_I^D(x_j^D\big|_{\alpha=1}) < \pi_I^J,$$

*(ii) the entrant earns higher profits than under regulation with incumbent investment only,*

$$\pi_E^R < \pi_I^D(x_i^D\big|_{\alpha=0}) < \pi_I^D(x_j^D\big|_{\alpha=1}) < \pi_E^J.$$

**Proof.** First claim. Consider first $\pi_I^D(x_i^D\big|_{\alpha=0})$ and $\pi_I^R$. Substitution of equilibrium investments and retail Cournot quantities yields

$$\pi_I^D(x_i^D\big|_{\alpha=0}) = \frac{(A-c)^2\gamma(9\gamma-8)}{(4-9\gamma)^2} < \frac{(A-c)^2\gamma}{9\gamma-2} = \pi_I^R$$

because $(9\gamma-8)(9\gamma-2) < (4-9\gamma)^2$.

Next we have $\pi_I^R$ and $\pi_I^D(x_j^D\big|_{\alpha=1})$. Following substitution we obtain

$$\pi_I^R = \frac{(A-c)^2\gamma}{9\gamma-2} < \frac{(A-c)^2\gamma(9\gamma-2)}{(4-9\gamma)^2} = \pi_I^D(x_j^D\big|_{\alpha=1})$$

since $(4-9\gamma)^2 < (9\gamma-2)^2$.

Finally, $\pi_I^D(x_j^D\big|_{\alpha=1})$ and $\pi_I^J$. We derive

$$\pi_I^D(x_j^D\big|_{\alpha=1}) = \frac{(A-c)^2\gamma(9\gamma-2)}{(4-9\gamma)^2} < \frac{(A-c)^2\gamma}{9\gamma-8} = \pi_I^J$$

since $(9\gamma-2)(9\gamma-8) < (4-9\gamma)^2$.

Second claim. First we have $\pi_E^R$ and $\pi_I^D(x_i^D\big|_{\alpha=0})$. From above,

$$\frac{(A-c)^2\gamma(9\gamma-8)}{(4-9\gamma)^2} > \frac{9(A-c)^2\gamma^2}{(2-9\gamma)^2}$$

Next $\pi_I^D(x_i^D\big|_{\alpha=0})$ and $\pi_I^D(x_j^D\big|_{\alpha=1})$. We have that

$$\frac{(A-c)^2\gamma(9\gamma-8)}{(4-9\gamma)^2} < \frac{(A-c)^2\gamma(9\gamma-2)}{(4-9\gamma)^2}.$$

Finally , the comparison of$\pi_I^D(x_j^D\big|_{\alpha=1})$ and $\pi_E^J$ have already been established in the first claim. ■

The fact that the entrant has an incentive to contribute to infrastructure upgrading may appear counter-intuitive at first glance, given that regulation would grant him full and cost-based access anyway. However it is the latter regulation that discourages infrastructure upgrading through the incumbent and forecloses additional profit streams for both the incumbent *and* the entrant. Realising this the entrant is better off to contribute, thereby ensuring that upgrades will actually be realised.

# 6 Policy implications

While our model is simple and stylised, it nevertheless provides insights into possible regulatory policies. First of all, we clarify the distinction between regulatory policy after an investment has been made, and regulatory policy before such an investment. We show that, after an investment has been made (and hence this would apply to legacy assets), regulators can maximise welfare by forcing access at cost. However, when the incumbent can decide on whether to invest or not, then access at cost will mean that it cannot recoup its outlays sufficiently and investment will become suboptimal. We show that both investment will be lower and that consumer welfare will be hit compared with giving less access or, in many cases, increasing the wholesale price. Therefore the main regulatory message is that, when investments play a role in creating welfare for consumers through a higher quality of a good, then access regulation can be harmful.

The positive effect on welfare of an increased wholesale price only arises when the investment is particularly effective. This would suggest that there is a qualitative difference between investments that truly create higher quality and those that do not. Put differently, access at cost is particularly harmful if the investment is effective at creating much improved services and products. It would point to a regulatory policy which is more lenient in the case in which a company can demonstrate that its products are of a truly higher quality.

We also consider infrastructure competition scenarios, in which there is no forced access at cost. When both entrant and incumbent invest in competition to each other, we get superior results to the case in which only the incumbent invests and the entrant gets access at cost. This case can be interpreted as a deregulation case. It is effectively an argument for infrastructure competition rather than cost based access. The fact that such competition can lead not just to higher investment but also increased consumer welfare implies that the onus is on regulators to demonstrate that access regulation is beneficial when investments play a significant role. The case also highlights that the market structure in the mobile market provide a reasonable trade-off between incentives to invest and competition at the retail stage, under the condition that the mobile markets represent an investment intensive industry.

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