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**Strategic Investments with Spillovers, Vertical Integration  
and Foreclosure in the Broadband Access Market**

by

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# Strategic Investments with Spillovers, Vertical Integration and Foreclosure in the Broadband Access Market\*

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Telenor R&D

## Abstract

We analyze competition between two firms (ISPs) in the retail market for broadband internet connectivity. One of the firms is vertically integrated and controls the input market for local broadband access. The vertically integrated firm may undertake an investment that increases the quality of the input (upgrading to broadband). The retailers' ability to offer value-added services (broadband services) when the input quality is improved differs. We analyze the effect of a price cap on the input offered by the vertically integrated firm. The total effect on consumer surplus and welfare critically depends on which firm that has the highest ability to offer value-added services. A price cap may have negative effects on the investment incentives. However, if the vertically integrated firm has much higher ability to offer value-added services, an access price cap may increase investment incentives.

JEL Classification: L13, L22, L43, L51, L96

Keywords: Broadband, strategic investment, vertical integration

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## **Non-technical summary**

We analyze competition between a vertically integrated firm with monopoly in the input segment and a rival in the retail market for internet connectivity. The vertically integrated firm may undertake an investment that increases the quality of the input (upgrading to broadband). The retailers' ability to offer value-added services (broadband services) when the input quality is improved differs. We analyze the effect of an access price regulation that sets access price to marginal cost, which has been the dominating regulatory paradigm both in the EU and the US. The total effect on consumer surplus and welfare critically depends on which firm that has the highest ability to offer value-added services. Obviously such regulation may have negative effects on the investment incentives. But we show that if the vertically integrated firm has much higher ability to offer value-added services, an access price cap may increase investment incentives.

Both firms will be present in the market without access price regulation as long as the rival has higher ability to transform input to output. However, we show that as long as the cost of investment is not too convex, an access price regulation lowers consumer surplus in this case.

If the vertically integrated firm's retail subsidiary has the highest ability to offer value-added services when the input quality is improved, the rival will always be foreclosed by a high access price without access price regulation. First, if we assume that the difference in the two firms ability to offer value-added services is not too high, then the rival's quantity increases when the investment increases for a given access price. We show that similar to above, as long as the cost of investment is not too high, the access regulation lowers consumer surplus. Hence, with not too convex cost downstream monopoly gives higher consumer surplus than a regulated duopoly. Second, if we assume that the vertically integrated firm's ability to offer value-added services is significantly higher than the rival's ability to use the improved quality of the input, then, for a given access price, the rival's quantity decreases when the investment increases. Hence, if an access price regulation eliminated the vertically integrated firm's ability to use the access price as a foreclosure tool, there exists an alternative tool. The vertically integrated firm may use overinvestment as a mechanism to drive the rival out of the market.

## 1 Introduction

The purpose of this paper is to examine the interplay between a facility-based vertically integrated firm and an independent downstream competitor in the market for broadband internet connectivity. The latter firm buys local access as an input from the former firm. The vertically integrated firm undertakes an investment (broadband upgrades) that increases the quality of the input. The retailers (ISPs) ability to offer value-added services (broadband services such as interactive video) when the input quality is improved differs. The main message of this paper is that the total welfare effect of a price cap regulation of the local access input – which has been the dominating paradigm both in Europe and the US – critically depends on which firm that has the highest ability to transform input to output. Moreover, when the vertically integrated firm's own subsidiary has the highest ability to use the quality improvement, a strong price cap regulation may even increase the investment incentives. The independent firm may be anything from the geeks in the garage to AOL/Time Warner. Compared to the facility-based vertically integrated firm, those firms ability to offer value-added services will obviously vary a lot.

Today the majority of residential consumers use their telephone lines for the last mile of Internet connectivity. The capacity in the conventional telephone lines in the last mile, or the local loop is, however, limited to give access to services as email and web-browsing. Hence, connectivity through the conventional telephone lines is often called narrowband Internet access. In order to access services such as interactive video the consumers need high-speed Internet access (broadband Internet access). The high up-front investments of new wire line facilities, and the possibility of increasing the capacity and quality of existing local telephony and cable-TV networks, indicate that telephone companies and the cable-tv-companies that already have installed wires to homes, will control the segment for broadband local access to residential consumers (Clark, 1999a, 1999b, Mackie-Mason, 1999).<sup>1</sup> By upgrading their local

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<sup>1</sup> PC Computing, January 1998, states that "There are only two viable plans for bandwidth freedom in works: Cable and DSL". DSL (Digital Subscriber Line) is the technology used by telecommunication providers to increase the speed of communication of existing copper-lines. See also *The Economist* (May 1, 1999) and *PC Magazine* (April 20, 1999). Some wireless technology with enough bandwidth seems to be one of the more promising technological innovations that may alter the picture. Another alternative may be some kind of combination of different technologies, or what often called hybrid technologies. For a further discussion of these issues, see Clark (1999a, 1999b), Medin and Rolls (1999), Hawley (1999), Shumate (1999), Norcross (1999), Skoro (1999), Mackie-Mason (1999), Ims (1999), and Speta (2000a).

network, they are able to increase the speed of communication.<sup>2</sup> The telecommunication incumbent has access to every potential consumer, since almost all private homes have a telephony subscription from this incumbent.<sup>3</sup>

The investment in higher speed of communication may be seen as a quality improvement of the local access component. First, an increase in speed of communication gives access to new broadband services (e.g. interactive audio and video).<sup>4</sup> Second, consumers' value from conventional Internet services like web-browsing and e-mail increase when the downloading speed increases. Third, today's dial-up internet connectivity is only connected when the user makes a phone call to her Internet Service Provider (ISP). The broadband internet connectivity systems are designed to be available all the time ("always on").<sup>5</sup>

With focus on the US market several analysts have argued that the cable-tv-providers have an advantage over the local telephone providers in supplying broadband Internet access (see e.g. Speta, 2000a,b, Mackie-Mason, 1999, Faulhaber and Hogendorn, 2000). The situation seems to be different in Europe.<sup>6</sup> In Sweden, for instance, Telia wants to sell its' cable-tv-company

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<sup>2</sup> Measured by bits per second (bps). A conventional voice telephone call needs approximately 10 kilo-bps, while high-quality television needs at least 10 mega-bps. The bandwidth requirements will vary a lot for new services. Furthermore, the transmission speed would vary between incoming and outgoing capacity. Current standard modem technology in the US gives access speed of 56 kbps, while the modem standard in Europe gives lower speed. In Europe, however, the penetration of ISDN is higher. ISDN access speed is no more than 128kbps. The upgrading technologies both for cable-tv and telephone lines should give access speed from a few hundred kbps to 10-20 mbps.

<sup>3</sup> While analysts agree that the cable-tv and the telephone providers will be the dominant provider of the broadband local access component, they disagree upon which one of these two that will have an advantage. See e.g. Telephony (October 19, 1998), Wired News (12/1998), Hawley (1999), and Medin and Rolls (1999).

<sup>4</sup> What broadband services and applications that will be offered are not discussed in this paper. The majority of analysts see the local access component as the bottleneck, and that the services will emerge as soon as this bottleneck is eliminated. Forrester Research (1999) estimates that one third of Internet subscribers in the US will have broadband access over cable or telephone lines in 2003. However, some analysts have also raised the question whether broadband services and application will emerge as soon as expected, and more important, whether consumers have willingness to pay for the new services. Hal Varian (2000) asks: "What if you build broadband and no one comes?"

<sup>5</sup> The development of the third generation mobile system (UMTS in Europe) has an analogous cost structure, and the main improvement compared to the second generation systems (e.g. GSM) is to increase speed of communication and offer always on functionality. However, the third generation system is hardly a substitute to the local broadband access alternatives discussed here for several reasons. The UMTS -system will not give a speed of communication in the range that the upgraded cable-tv and telephone networks do. Furthermore, unlike mobile telephone calls, internet users are most often stationary (Clark, 1999b).

<sup>6</sup> There may be several reasons for this difference. First this is due to the high penetration of cable-tv in the US compared to many European countries. Cable-tv networks cover 90% of the homes in the US (Hawley, 1999), while in Norway, for instance, approximately one third of the households have cable-tv. Furthermore, 50% of the cable subscribers in the US have two-way capabilities needed to Internet access, while the same portion is lower in Europe (Medin and Rolls, 1999). Second, and probably more important, this is due to the historical separation between local providers and long distance providers of telephony in the US between 1984 and 1996

(com hem). Telia is developing a separate broadband network using new fiber cables and its ordinary telephone lines in the local loop.<sup>7</sup> For our purpose, another important difference is that today only the telephone access provider is obligated by regulation to supply local access as an input to non-facility based rivals in the retail market for telephony and Internet connectivity. Therefore, the telephony incumbent has been the only provider of local access as an input to independent ISPs. Regardless of whether the cable-tv-provider or the telephone provider have an advantage over the other, the competitive pressure in the input segment for local broadband access seems limited.

When upgrading the existing network, the cable-tv provider or the telephone provider builds a fiber-optic line that serves a cluster of homes. From the end of the fiber-optic line to homes, existing local lines are used.<sup>8</sup> Compared to building a fiber-optic line into every home this solution is much cheaper (Clark 1999b, Ims, 1999). However, the longer the distance from the fiber-optic line to the homes, the lower is capacity or speed of communication. Put differently, there is a tradeoff between the distance the existing local lines are used and capacity (speed of communication). Since the number of consumers living in an area with radius 500 meter, for instance, is lower than in an area with radius 5 kilometers, the upgrading costs are convex in speed of communication.<sup>9</sup>

The service Internet connectivity, sold to end-users, may be seen as a composite good that consists of the complementary inputs local and global access. The ISPs act as a portal that gives the subscriber access to information around the globe (often called the Internet Backbone). In addition to the local access input, all regional ISPs need to buy access to the core global Internet Backbone located in the US. European ISPs also need transatlantic transmission capacity. The regional ISPs usually have long-term contract with the providers

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(the AT&T breakup in 1984). Since 1996 firms like AT&T are again allowed to vertically integrate into the local access segment. However, they have vertically integrated with cable-tv-companies rather than local telephone providers. AT&T is the largest cable-tv provider in the US through the acquisition of TCI and Media One. The situation is different in many European countries. The telephone network has higher coverage than the cable-tv networks, and the telephone providers are vertically integrated.

<sup>7</sup> Telia initially decided to sell its cable operations as a condition of its planned merger with Norway's Telenor. Although the merger collapsed, Telia said it will sell its cable-tv subsidiary. The value of the cable-tv-network lies in its ability to be upgraded into high-speed internet access.

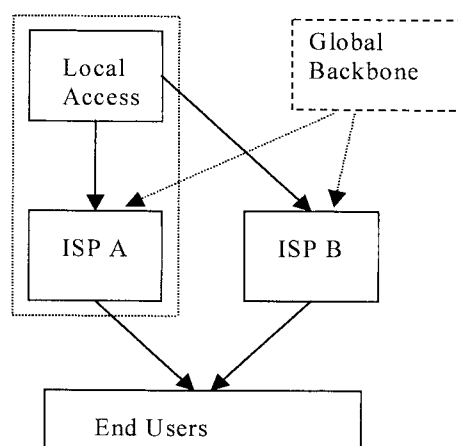
<sup>8</sup> In the cable-tv network cable modems can be used (see Medin and Rolls, 1999), while the capacity in the telephone copper lines can be increased by DSL-technology (see Hawley, 1999).

<sup>9</sup> Note that the investment costs also is convex in the coverage dimension. In a given area, it is a higher number of homes in urban areas compared to rural areas. This dimension is not covered in this paper. It may be realistic to assume that the firm chooses coverage before it chooses speed of communication. See Faulhaber and

of transatlantic-lines and access to the global Internet backbone. To some extent, this will give capacity constraints in the end-user market. If sufficient transatlantic-lines are not available, for instance, then congestion will reduce the response time even if the local access has high capacity. The interplay between local downstream ISP and the upstream providers of global access will not be addressed in this paper.<sup>10</sup>

The market context is illustrated in figure 1.

*Figure 1: The market structure*



In the retail market for Internet connectivity there is competition between vertical integrated firm's subsidiary and an independent ISP, ISP A and ISP B, respectively. Hence, we assume that there is a fixed number of firms in the downstream market. The retail market for Internet connectivity is unregulated.<sup>11</sup>

We assume that broadband internet connectivity is sold by the two ISPs to end-users at a fixed subscription fee independent of actual usage (the number of packet actual sent and received) and time connected. This also corresponds with what we see in the market place for

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Hogendorn (2000) for an analysis of the entry decision of a broadband access provider in a given are. The focus on whether one or more cable-provider will enter in a metropolitan area in the US.

<sup>10</sup> For a description and analysis of the interplay between the downstream ISPs and the local and global access providers, see Foros, Kind and Sørsgard (2000). An overview of the vertical structure in the Internet is given by Cremer, Rey and Tirole (2000). For a comprehensive description of the interconnection arrangements in the backbone market see Kende (2000).

<sup>11</sup> See Laffont and Tirole (2000) for a discussion.

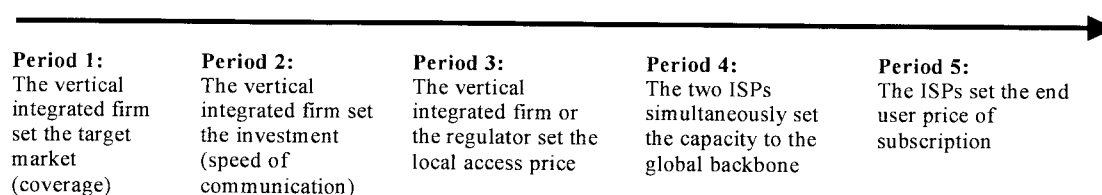


broadband Internet connectivity.<sup>12</sup> Hence, the ISPs face a downward sloping demand curve. When the subscription fee is reduced (for given quality), more consumers would subscribe. The usage by the inframarginal consumers is, however, not affected.<sup>13</sup> Absent the investment we assume that the services offered by the firms are identical. Furthermore, in the model, we assume that the investment may lead to vertical differentiation but no horizontal differentiation. There may be horizontal differentiation in this market (see Foros and Hansen (1999) and Dogan (2000)). However, we make this assumption in order to strengthen the foreclosure incentives of the vertically integrated firm absent price cap regulation.

The access input price charged by the facility-based firm will be a fee for each broadband subscriber the rival ISP (ISP B) serves over the vertical integrated firm's local network facilities.<sup>14</sup>

The timing structure is as in figure 2.

*Figure 2: The timing structure*



**Period 1:** Prior to the game we model, we assume that the vertically integrated firm sets target market - which area (coverage) is to be upgraded to broadband.

<sup>12</sup> This is in contrast to the current narrowband internet connectivity through modem where the user pay a time-dependent price while he is connected. However, the current billing systems do not charge the users for their actual usage of bandwidth.

<sup>13</sup> Implicit this implies that the direct networks effects are insignificant. In other words, for a given speed of communication in the local loop, the willingness to pay is not affected of how many other consumers subscribing to broadband in the same area. This assumption seems realistic if the user mostly is downloading information from the US. However, if the user mainly use of broadband Internet connectivity is to have video-conferences with neighbours this assumption is rarely fulfilled.

<sup>14</sup> We often observe an alternative business model where the facility-based firm is supplying the local access component directly to the consumers, and, furthermore, forward a part of the fee for local access to the ISPs (see also Mackie-Mason, 1999). This may be seen as an explanation of the "free internet subscriptions" offered by several ISPs. They do not earn their profit from the sale of internet subscription (that here only consists of access to the global Internet and not local access), but indirectly from the telephone providers sale of local access. However, for us the important feature is that the ISP pay for local facilities to the access provider either directly or indirectly.

**Period 2:** The only endogenously determined investment in the model is the choice of investment in speed of communication by the vertical integrated firm. The investment increases the speed of the network, and the subscriptions for internet connectivity sold from the ISPs could be more attractive since they can access new bandwidth demanding services such as interactive real time services. Hence, the investment increases the quality of the end-user service sold by both downstream firms.

**Period 3:** The vertical integrated firm sets the input price of local access in the unregulated regime, while the regulator sets this price under access price regulation.

**Period 4:** The ISPs simultaneously must choose how much regional and global backbone capacity to rent.<sup>15</sup> For simplicity we assume that the two ISPs have identical costs for the global access input, and we assume that the capacity constraint due to global access is exogenously given.

**Period 5:** Both the coverage constraint (period 1) and the capacity constraint of global access (period 4), imply that we have a capacity-constraint price game in the downstream market.

Absent of investment in quality improvement (broadband upgrades), we know that the vertically integrated firm may have incentives to use the access price to practice foreclosure towards the downstream rival. Due to this we see that the input price for local access is most often subject to price regulation. When the regulator chooses an access price lower than the monopoly price, the cost advantage for the vertically integrated firm is reduced.

In section 2 we present the model. In contrast to the existing literature on access price regulation in telecommunications, we allow the vertically integrated firm to undertake a strategic investment prior to competition. Moreover, we assume that the ability to use the investment to increase the consumers' willingness to pay may differ between the downstream firms. We analyze the facility-based vertically integrated firm's incentives to practice foreclosure towards the downstream competitor, and furthermore, we analyse whether the regulator can increase welfare by access price regulation. In section 3 we conclude.

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<sup>15</sup> It is realistic to assume that the ISPs sign a long-term contract and pay a fixed fee for a given capacity to the global backbone providers. It is often argued that the marginal cost of sending one packet in the Internet is zero.

## 1.1 Related literature

Access pricing in telecommunication have been examined by several studies. Since the independent firm needs access to the vertically integrated firm's network, but the reverse does not hold, we assume a one-way access problem. See Laffont and Tirole (2000) for a comprehensive overview. Recent analyzes of Laffont, Rey, and Tirole (1998a, 1998b), Armstrong (1998) and Armstrong, Doyle and Vickers (1996), among others, are analyzing two-way access.

Spence (1977), Dixit (1980), and Fudenberg and Tirole (1984) assume that one firm may have a first-mover advantage to make a strategic investment prior to competition. In these papers there are no spillovers from the investment to the rivals, and they do not focus on the effects of an access price that the rival must pay to the firm that makes the investment. Spence (1984) model spillovers from the investment, but he assumes that the firms are symmetric in their ability to invest. Brander and Spencer (1984) and Katz (1986) also pioneered the analysis of strategic investments and spillovers. Strategic investments and spillovers have been analyzed in the R&D-literature by D'Aspremont and Jacquemin (1988) and Kamien, Muller and Zang (1992), among others. In these papers there is no opportunity for access price charged by the investing firms, and the firms are assumed to be symmetric both with respect to their ability to make investment and to the level of the spillover. We assume that only one of the firms makes a strategic investment, and that the ability to use the improved quality may differ between the firms. DeBondt and Henriques (1995) investigate the implications of asymmetric spillovers from R&D investments in an oligopoly. DeBondt (1997) gives an overview over the literature for R&D investments.

Rey and Tirole (1996) analyze the incentives for foreclosure by a vertically integrated firm that controls an input bottleneck in an unregulated market, while Laffont and Tirole (2000) discuss the incentives for non-price discrimination under access price regulation. Recent technical papers analyzing non-price foreclosure in telecommunications and the Internet are Economides (1998a, 1998b), Cremer, Rey and Tirole (2000), Foros, Kind and Sørsgard (2000) and Sand (2000).

Since the Internet is relatively new, there are not many Industrial Organization analysis of this particular industry. A recent analyse of the broadband market is given by Faulhaber and

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This is true if there is excess global backbone capacity. Otherwise, the marginal cost of sending a packet is positive, since the ISP must rent more capacity in the spot market or the packet will cause congestion and delays.

Hogendorn (2000). They develop a model of competition among several facility-based broadband access providers, while we analyse the interplay between facility-based providers and non-facility-based rivals. A few papers have analysed the incentives for horizontal interconnection agreements between competing ISPs, see DangNguyen and Penard (1999), and Baake and Wichmann (1998), and Foros and Hansen (1999). The vertical interplay between the Internet Backbone Providers (IBPs), controlling the global infrastructure and routing structure, and downstream ISPs are analysed by Cremer, Rey, and Tirole (2000) and Milgrom et al (2000). Dogan (2000) models incentives to vertical integration between backbone providers and downstream ISPs.

## 2 The model

### *Demand side*

The investment at stage 1 is given by  $x$ . We see this investment as a quality improvement of the local access input that increases the willingness to pay in the retail market for broadband internet connectivity. How much the input quality improvement increases consumers' willingness to pay for internet connectivity depends on the downstream firms' ability to transform input to output.

Hence, we have a demand side spillover from the facility-based input provider to the retailers:

$$a_1 = a + \beta_1 x \quad \text{and} \quad a_2 = a + \beta_2 x$$

Subscript 1 and 2 indicate facility-based and non-facility-based firm respectively. The parameters  $\beta_1$  and  $\beta_2$  are the demand side spillover from the facility-based firm to its own subsidiary and the independent ISP, respectively.<sup>16</sup> If  $\beta_1 > \beta_2$ , the vertically integrated firm has higher ability to offer a value-added services from the investment than the non-facility

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<sup>16</sup> The spillover is analogous to the spillover effect from R&D investment in Kamien et al (1992) and D'Aspremont and Jacquemin (1988), among others. They assume process innovation, while we assume product innovation.

based firm. In contrast, if  $\beta_2 > \beta_1$ , the non-facility based firm has the highest ability to increase consumers' willingness to pay. We assume that  $\beta_1, \beta_2 \in [0, 1]$ .

The inverse demand function faced by the firms:

$$p_1 = a_1 - q_1 - q_2$$

$$p_2 = a_2 - q_1 - q_2$$

We see that if  $\beta_2 \neq \beta_1$  there will be vertical differentiation between the ISPs. Introducing horizontal differentiation will not alter the qualitative results in the model. Total downstream production is  $Q = q_1 + q_2$  and net consumer surplus is:

$$CS = 0,5(a_1 - p_1)q_1 + 0,5(a_2 - p_2)q_2$$

### *Supply side*

There are several kinds of costs related to Internet connectivity. We differentiate between costs related to the local access connection and costs related to access to the global backbone. We have assumed that the choice of target market, i.e. where to upgrade to broadband, is made prior to the game we analyze. Furthermore, we assume that the cost related to global access capacity is exogenously given, and for simplicity we normalized these cost to zero.

Regarding the vertical integrated firm's cost structure in the upstream segment for local access, we assume that cost per user is a constant marginal cost  $c$ . This cost is the same whether it's own downstream subsidiary or the rival are serving the end-user. We assume that the infrastructure quality, i.e. the investment level, does not have any effect on the marginal cost  $c$ . The facility-based firm faces a quadratic network investment cost regarding investment in higher speed (bandwidth) in the local loop, given by  $C_1(x) = \varphi x^2 / 2$ . The investment cost  $x$  is not related to each user, the investment is for every potential user in the target market (the area upgraded to broadband).

For simplicity, we assume that the marginal costs for the ISPs in the competitive segment (i.e. billing costs) are zero.

We assume that the choice of target market (where to upgrade to broadband) and the exogenously given capacity of global access, imply that there is a capacity-constrained price

game in the downstream market. Thus, we assume Cournot competition between the two ISPs.<sup>17</sup>

Hence we model the following game:

- Stage 0: The vertically integrated firm chooses the investment level  $x$ .
- Stage 1: The vertically integrated firm or the regulator choose the access price  $w$  to the downstream rival.
- Stage 2: The two downstream firms compete à la Cournot.

The profit functions for the firms are given by:

$$\pi_1 = (p_1 - c)q_1 + (w - c)q_2 - \varphi x^2 / 2$$

$$\pi_2 = (p_2 - w)q_2$$

The vertically integrated firm is active in both the upstream and the downstream segment, while the non-facility based firm earns profit only in the downstream segment.  $w$  is the access price charged by the facility-based firm in the upstream segment.

Throughout we make the following assumption

**Assumption 1:**  $\pi_2 \geq 0, \pi_1 \geq 0, w \geq c, x \geq 0$

The first two constraints state that each firm should have a non-negative profit. The third term says that the vertically integrated firm must have a non-negative price cost margin on its sale to the independent downstream firm. The last term states that the investment must be non-negative.

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<sup>17</sup> The result of Kreps and Sheinkman (1983) that a two stage game of capacity choice and then prices is the same as a one-stage Cournot game rests on very strong assumptions that rarely are fulfilled in our setting. However, since there exists rigid capacity constraints we assume that the Cournot competition assumption seems more realistic than a Bertrand game in the downstream market. See the discussion in Tirole (1988, chapter 5).

## *Welfare*

The welfare function:

$$W = CS + \pi_1 + \pi_2$$

## *A benchmark*

Let us consider a market context absent the investment in quality improvement ( $x=0$ ). In an unregulated market the facility-based firm chooses the access price in the upstream market at stage 1. In a regulated market the regulator chooses the access price at stage 1. At stage 2 the downstream market is unregulated, and the firms compete à la Cournot. In this context the results can be summarized in the following lemma (see Foros, Kind and Sørøgard (2000)):

**Lemma 1:** *If the vertical integrated firm has no ability to invest into quality improvement ( $x=0$ ), the regulator sets the access price to marginal cost. If the access price is unregulated, the vertically integrated firm sets an access price that forecloses the rival from the market. The consumer surplus and total welfare level is higher under the access regulation regime compared to the unregulated regime ,i.e. that  $W^r > W^*$ .*

Superscripts r and \* indicate access price regulation and market equilibrium, respectively.

## **2.1 Downstream market competition**

We solve the model by backwards induction and assume Cournot competition between the two firms (the ISPs) in the downstream market for broadband internet connectivity.

Equilibrium quantities in the competitive segment are:

$$q_1^* = [(a - c) + (w - c) + x(2\beta_1 - \beta_2)] / 3$$

$$q_2^* = [(a - c) - 2(w - c) + x(2\beta_2 - \beta_1)] / 3$$

From the equilibrium quantities we see that  $dq_1 / dw = 1/3 > 0$  and  $dq_2 / dw = -2/3 < 0$ .

Until stated otherwise we make the following assumption:

**Assumption 2:**  $2\beta_i - \beta_j \geq 0$  where  $i, j = 1, 2, i \neq j$

Assumption 2 ensures that the difference in ability to offer value-added services between the downstream firms is not too high. When  $2\beta_1 - \beta_2 \geq 0$ , the rival's quantity is non-decreasing by the investment in  $x$  for given access price  $w$ . Hence, the vertically integrated firm cannot use the investment as an alternative foreclosure under access price regulation. In section 2.5 we modify this assumption and assume  $2\beta_2 - \beta_1 < 0$ . Then the vertically integrated firm may use over-investment as an alternative foreclosure tool under access price regulation.

## 2.2 Unregulated access price

The vertically integrated firm sets the access price at stage 1, and stage 2 is as above.

### 2.2.1 Stage 1:

The objective function for the facility-based firm at stage 1 is

$$\pi_1 = q_1^2 + (w - c)q_2 - \varphi x^2 / 2$$

The first order condition with respect of  $w$  is

$$d\pi_1 / dw = 2q_1 (dq_1 / dw) + q_2 + (w - c)(dq_2 / dw) = 0$$

Insert from the equilibrium quantities at stage 2 gives the equilibrium access price at stage 1:

$$w^* = (a + c) / 2 + x(4\beta_2 + \beta_1) / 10$$

We have  $dw / dx = (4\beta_2 + \beta_1) / 10 > 0$ .

If we insert for  $w^*$  into the equilibrium quantities:

$$q_1^* = [5(a - c) + x(7\beta_1 - 2\beta_2)] / 10$$

$$q_2^* = x(\beta_2 - \beta_1) / 5$$



**Proposition 1:** *Let us assume no regulation of access price. The condition  $\beta_2 > \beta_1$  is necessary and sufficient to ensure that the downstream rival is active in the market.*

From *lemma 1* we know that absent the investment ( $x=0$ ) the independent firm is foreclosed from the market.<sup>18</sup> In contrast, we see that under investment in quality improvement ( $x>0$ ) the independent downstream firm will be active in the market if it has higher ability to use the improved input quality such that  $\beta_2 > \beta_1$ .

**Remark 1:** There may be some evidence for this result in the market place, since facility-based incumbents seem to give a more hostile response for small new entrants compared to firms with a strong position as e.g. a content provider. In the mobile market, where the context between facility-based and non-facility based firm is analogous, we have for instance seen that a firm like Virgin in the UK has met a more friendly strategy from the facility-based firm than the smaller entrant Sense in the Scandinavian countries.

### 2.2.2 Stage 0:

*Foreclosure:*

From *proposition 1* it follows that as long as  $\beta_1 \geq \beta_2$  the vertically integrated will use the access price in the next stage to practice foreclosure towards the rival (firm 2). Hence, in the case where it is optimal to practice foreclosure it chooses the investment level as a downstream monopoly. Downstream monopoly quantity is  $q_1^m = 0,5[a - c + \beta_1 x]$ , and the objective function for the facility-based firm when it sets  $x$  as a downstream monopolist is  $\pi_1^m = (q_1^m)^2 - 0,5\phi x^2$ . Superscript  $m$  indicates downstream monopoly.

First order condition with respect of  $x$  gives the following investment level:

$$\frac{\partial \pi_1}{\partial x} = 0 \Rightarrow x_m^* = (a - c)\beta_1 / A_m^* \quad \text{where } A_m^* = 2\phi - \beta_1^2$$

The second order condition is fulfilled as long as  $A_m^* > 0$ .

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<sup>18</sup> If we introduce horizontal differentiation in the model, the restriction in proposition 1 will be less restrictive.

*Market sharing:*

From *proposition 1* we know that both downstream firms are active as long as  $\beta_2 > \beta_1$ . The objective function for the facility-based firm when it sets  $x$  is:

$$\max_x \pi_1 = (q_1)^2 + (w - c)q_2 - 0,5\varphi x^2$$

We insert for  $w^*$  and the first order condition with respect of  $x$  gives the following investment level:

$$\frac{\partial \pi_1}{\partial x} = 0 \Rightarrow x^* = 5\beta_1(a - c) / A^* \quad \text{where } A^* = [10\varphi - 9\beta_1^2 + 8\beta_1\beta_2 - 4\beta_2^2]$$

The second order condition is fulfilled as long as  $A^* > 0$ . Comparing the investment level under foreclosure (i.e.  $\beta_1 \geq \beta_2$ ) with the market sharing equilibrium ( $\beta_2 > \beta_1$ ), we find the following (see appendix):

**Lemma 2:** *Let us assume no regulation of the access price. For a given level of  $\beta_1$  the investment will be higher under market sharing,  $\beta_2 > \beta_1$ , than foreclosure,  $\beta_1 \geq \beta_2$ , i.e. that  $x^* > x_m^*$ , as long as the second order conditions are fulfilled. Moreover, the investment and the rivals quantity increase with the rival's ability to use the quality improvement when  $\beta_2 > \beta_1$ , i.e. that  $dx^* / d\beta_2 > 0$  and  $dq_2^* / d\beta_2 > 0$ .*

Without access price regulation, the vertically integrated firm may imitate the strategy in the foreclosure case also in the market sharing case. Hence, when the vertically integrated firm chooses to serve the rival, this means that the profit by doing so is higher than the monopoly outcome. When the rival is more effective in order to use the improved quality of local access,  $\beta_2 > \beta_1$ , the consumers have higher willingness to pay for the service from ISP 2 than that of ISP 1. Hence, it will be optimal to let the rival be active in the market in order to capture some of the rent from ISP 2. The access price will, however, be set such that the quantity offered by ISP 2 will be low in order to reduce the competition. The reason why the vertically integrated firm does not outsource the retail market to the more effective rival is the assumption of uniform access price. In contrast, if the vertically integrated firm can use a two-

part tariff for access, it will set a unit access price equal to the marginal cost  $c$ , and then capture the monopoly profit of the more effective rival (ISP 2) through the fixed fee.<sup>19</sup>

### 2.3 Access price regulation

The government may regulate  $w$  to maximize the welfare. In principle, the regulator can act as a first mover and set  $w$  before the facility-based firm sets  $x$ . Such a commitment to *ex ante* regulation may, however, not be credible. We assume that the regulator has no ability to regulate the access price *ex ante* of the investment, and, hence, the only difference in the game from the complete unregulated regime is that the regulator decides the access price at stage 1 instead of the vertical integrated firm.

#### 2.3.1 Stage 1:

The welfare function may be written as

$$W = 0,5(q_1 + q_2)^2 + q_2^2 + q_1^2 + (w - c)q_2 - 0,5\phi x^2$$

The first term is the consumer surplus. The second term is the profit by the independent firm. The last three terms are the profit by the vertical integrated firm.

The regulator sets the price cap for  $w$  after the investment in  $x$  has taken place. The first order condition with respect of  $w$  gives the optimal regulated access price margin:<sup>20</sup>

$$w - c = -(a - c) + x(4\beta_1 - 5\beta_2)$$

The first term on the right hand side is always negative. Hence, a sufficient condition for  $(w - c) < 0$  is that the second term is non-positive, i.e.  $4\beta_1 - 5\beta_2 \leq 0$ . When  $(w - c) < 0$ , it is a violation of the constraint that  $w \geq c$ . Then we have the following result:

**Proposition 2:** *Let us assume regulation of access price. A sufficient condition to ensure that it is optimal for the regulator to set access price equal to marginal cost, ( $w^r = c$ ), is that*

$$\beta_2 / \beta_1 \geq 4 / 5.$$

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<sup>19</sup> The reason why we assume a linear access price per consumer the rival serves, is that this seems to be the business model the majority of the telecommunications incumbents use in their wholesale service for broadband. Up to now we have seen that for narrowband wholesale the dominating business model has been a per consumer time-dependent usage fee, i.e. the rival has paid a access price per minute the consumer has been logged on to the ISP (called originating). For broadband we see that the time-dependent usage fee is eliminating both in the retail and wholesale service, such the rival ISP pays a fixed fee per consumer (per month) for the local access input (see Petkovic and De Coster, 2000).

In this section we assume that  $\beta_2 / \beta_1 \geq 4 / 5$  holds, such that optimal regulated access price will be set to marginal cost ( $w^r = c$ ) at stage 1. Superscript r indicates regulated access price.

Insert for  $w=c$  into the equilibrium quantities from stage 2 gives:

$$q_1^r = [(a - c) + x(2\beta_1 - \beta_2)] / 3$$

$$q_2^r = [(a - c) + x(2\beta_2 - \beta_1)] / 3$$

### 2.3.2 Stage 0:

Now the facility-based firm has no revenue from the upstream market, and the objective function for the facility-based firm is:

$$\max_x \pi_1 = [(a - c) + x(2\beta_1 - \beta_2)] / 3]^2 - 0,5\phi x^2$$

First order condition with respect of  $x$  gives the following investment level:

$$\frac{\partial \pi_1}{\partial x} = 0 \Rightarrow x^r = 2(a - c)(2\beta_1 - \beta_2) / A^r \text{ where } A^r = 9\phi - 2(2\beta_1 - \beta_2)^2$$

From *lemma 2* we know that under market sharing in the unregulated case the investment level increases when  $\beta_2$  increases. In contrast to the unregulated case, we now see that the investment level decreases with the rival's ability to offer value-added services as the input quality is improved, since  $dx^r / d\beta_2 < 0$  (see proof of proposition 3 in appendix). Since the facility-based firm has no revenue from its upstream sale, the facility-based firm sees the advantage to the non-facility-based firm from the investment as a pure spillover. The higher the non-facility based firm's ability to use the investment, the higher is the spillover from the investment to the rival. Not surprisingly, the higher the spillover, the lower the incentives to make an investment.

Moreover, from *lemma 2* we know that without regulation the rival's quantity increases with  $\beta_2$  under market sharing. Under access price regulation we find that

$$dq_2^r / d\beta_2 = [2x^r + (dx^r / d\beta_2)(2\beta_2 - \beta_1)]$$

---

<sup>20</sup> The second order condition is fulfilled.

The first term is positive and indicates that for a given investment level, the rival's quantity increases when  $\beta_2$  increases. The second term indicates that an increase in  $\beta_2$  will have an effect on the investment level and that this in turn effects the quantity offered by the rival. We know that  $dx^r / d\beta_2 < 0$  and in this section we assume that  $(2\beta_2 - \beta_1) > 0$ . Hence, the second term is negative. This is due to the fact that for the vertically integrated firm the parameter  $\beta_2$  is now seen as a pure spillover. And therefore, when the spillover increases, the incentives to invest will be reduced. The total effect on the rival's quantity is then ambiguous.

The higher the spillover, the lower the downstream quantity sold from the facility-based firm, such that  $dq_1^r / d\beta_2 < 0$ . There are two effects leading to this result. First, the higher the spillover, the lower the investment. When the investment is reduced, the facility-based firm reduces its downstream quantity. Second, since the quantity offered by the two rivals are strategic substitutes, the facility-based reacts to an increase in the quantity from the rival, by reducing its own quantity (Bulow, Geanakoplos, and Klemperer, 1985). The last effect may be positive or negative (see above), but the total effect on the vertically integrated firm's quantity from an increase of  $\beta_2$  is negative.

## 2.4 Comparison of results with and without access price regulation

In order to compare the welfare levels with and without regulation we must make a distinction between the case of foreclosure and the case of market sharing in the unregulated market.

### *Foreclosure without regulation*

For simplicity we now make the following assumption:

$$\beta_2 \leq \beta_1 \equiv 1$$

In the access price regulation equilibrium, the vertical integrated firm has no profit from the input segment. From assumption 2 we have that  $\beta_2 \geq 0.5$ . Moreover, we assume that the cost parameter  $\varphi$  is so high that the second order conditions are fulfilled, i.e.  $\varphi > \underline{\varphi}^{crit} = 0.5$  in this case.

In the case without regulation, firm 2 is foreclosed, and, hence, profit and consumer surplus are independent of the level of firm 2's ability to offer value-added services as long as  $\beta_2 \in [0.5, 1]$ .

In the case with access price regulation and  $\beta_2 \leq \beta \equiv 1$ , we have the following effects from an increase in firm 2's ability to offer value-added services (see appendix):

**Lemma 3:** *In the case with access price regulation and  $\beta_2 \leq \beta \equiv 1$ ,*

- i. *The profit of firm 1 decreases with  $\beta_2$ , i.e. that  $\partial \pi_1' / \partial \beta_2 < 0$ .*
- ii. *The profit of firm 2 increases with  $\beta_2$ , i.e. that  $\partial \pi_2' / \partial \beta_2 > 0$ .*
- iii. *The consumer surplus decreases with  $\beta_2$ .*

The profit of firm 1 decreases due to two effects. First, an increase in  $\beta_2$  increases the rival's quantity. Second, an increase in  $\beta_2$  increases the spillover from the investment, and, hence, firm 1 lowers the investment, which also decreases its own quantity and profit. This is due to the fact that the vertically integrated firm gains a competitive advantage in the retail market from the investment. Hence, it will invest more the higher the difference in ability to use the quality improvement is between the firms. Put differently, when  $\beta_2$  is low, the spillover from the investment to the rival is low.

An increase in  $\beta_2$  also have two effects on firm 2' profit. First, for given investment level, an increase in it's ability to offer value added serviced compared to firm 1 will increase quantity and profit to firm 2 (given assumption 2). Second, since an increase in  $\beta_2$  reduces the investment, this will have an negative effect on firm 2's profit as long as  $\beta_2 > 0.5$ . However, the first effect dominates the second in this case.

Even if the consumer surplus is reduced, the total welfare may increase from an increase in  $\beta_2$ . Hence, when the regulator intervenes and sets a access price regulation in order to prevent foreclosure, it is not clear-cut that the welfare is higher when the rival's ability to offer value-added services is close to firm 1' ability to offer value-added services than when the rival has a significantly lower ability to offer such services compared to firm 1. Put differently, when  $\beta_2$  is close to  $\beta_1$ , firm 2 will be a vital rival for firm 2, but it will also increase the spillover from the investment. This will in turn reduce the investment level more than if  $\beta$  where low compared to  $\beta_1$ .

So let us compare the situation with and without access price regulation. The motivation behind an access price regulation is to prevent foreclosure and increase competition such that the consumer surplus increases. Hence, a necessary, but not sufficient, condition to intervene with an access price regulation is that the consumer surplus increases compared to the case without regulation.

Then we have the following results (see appendix):

**Proposition 3:** *In the case where  $\beta \leq \beta_1 \equiv 1$  we have the following results regarding investment and consumer surplus:*

- i. *the investment level is lower with than without access price regulation, i.e. that  $x^r - x_m^* < 0$ .*
- ii. *the consumer surplus, total quantity offered, is lower with than without regulation as long as the investment cost is not too convex, such that  $q_1^r + q_2^r < q_m^*$  when the parameter  $\varphi$  is not too high.*

Similar, we find that the total welfare is lower with than without regulation when the investment cost is not too convex.

In this case the vertically integrated firm has higher ability to transform input to output than the rival. Then, if it is allowed to do so, it will prevent the rival from entering the market through the access price. The regulator may then impose an access price regulation that prevents the vertically integrated firm from practicing foreclosure. The regulator faces a classical tradeoff between stimulating competition and reducing investment incentives. Moreover, this tradeoff implies that it may be better if the rival has significantly lower ability to offer value-added serviced than the vertically integrated firm since this will reduce the spillover from the investment.

*Market sharing without regulation*

We now make the following assumption:

$$\beta_1 \leq \beta_2 \equiv 1$$

Both firms are active in the market, also in the market equilibrium, and the investment and welfare is now given by  $x^*$  and  $W^*$  (in contrast to  $x_m^*$  and  $W_m^*$  above). As long as assumption 2 holds, we have that  $\beta_1 \geq 0.5$ .

In the case without access price regulation and  $\beta_1 \leq \beta \equiv 1$ , we have the following effects of an increase of firm 1's ability to offer value-added services (see appendix):

**Lemma 4:** *In the case without access price regulation and  $\beta_1 \leq \beta \equiv 1$ ,*

- i. *The profit of firm 1 increases with  $\beta_1$ , i.e. that  $\partial \pi_1^* / \partial \beta_1 > 0$ .*
- ii. *The profit of firm 2 increases with  $\beta_1$ , i.e. that  $\partial \pi^* / \partial \beta_1 > 0$ , as long as the cost is not to convex.*
- iii. *The consumer surplus increases with  $\beta_1$ .*

As long as the profit of firm 2 increases with  $\beta_1$  it follows from (i)-(iii) that the total effect on welfare from an increase in  $\beta_1$  is positive.

It is obvious that the vertically integrated firm's profit increases when it's ability to offer value-added services increases. At first glance, it is more surprisingly that the rival's profit increases when  $\beta_1$  increases. An increase in  $\beta_1$ , increases the quantity offered by firm 1, and for a given investment this will reduce the quantity and profit of firm 2. However, when  $\beta_1$  increases, the investment increases, and this will in turn increases profit for firm 2. As long as  $\beta_2 > \beta$  the latter effect dominates the former.

In the case with access price regulation and  $\beta_2 \leq \beta \equiv 1$ , we have the following effects of an increase of firm 1's ability to offer value-added services (see appendix):

**Lemma 5:** *In the case with access price regulation and  $\beta \leq \beta_2 \equiv 1$ ,*

- i. *The profit of firm 1 increases with  $\beta$ , i.e. that  $\partial \pi_1 / \partial \beta > 0$ .*
- ii. *The profit of firm 2 increases with  $\beta$ , i.e. that  $\partial \pi / \partial \beta > 0$ .*
- iii. *The consumer surplus increases with  $\beta$ .*

From (i)-(iii) it follows that the total effect on welfare from an increase in  $\beta$  is positive. We see that the effect of an increase in the vertically integrated firm's ability to offer value-added



services have the same qualitative effects on consumer surplus with and without regulation, such that:

**Proposition 4:** *An increase in the vertically integrated firm's ability to offer value-added services will increase consumer surplus both with and without access price regulation (lemma 4 and lemma 5). In contrast, combined with an access price regulation an increase in the rival's ability to offer value-added services is detrimental to consumer surplus since it reduces investment incentives (lemma 3).*

Now we compare the results with and without regulation when the rival has the highest ability to transform the input to output. Then we have the following results (see appendix):

**Proposition 5:** *In the case where  $\beta \leq \beta_2 \equiv 1$  we have the following results regarding investment and consumer surplus:*

- i. *the investment level is lower with than without access price regulation, i.e. that*  

$$x^r - x^* < 0$$
- iii. *the consumer surplus, total quantity offered, is lower with than without regulation as long as the investment cost is not too convex, such that  $q_1 + q < q_1^* + q^*$  when the parameter  $\varphi$  is not too high.*

For  $\beta$  close to 0.5 the loss from reduced competition in the case without access price regulation will be high. The loss from reduced competition, for a given investment level, in the unregulated regime may be separated into two effects. First, there will be a loss due to the fact that total quantity is reduced when the rival pays an access price higher than the marginal cost. This loss is higher the lower  $\beta$  is compared to  $\beta_2$  (which is equal one). Second, there will be a loss due to fact that the less effective firm 1 will serve the most of the market. For a given investment level, these two competition effects will imply that the welfare may be enhanced by access price regulation. However, access price regulation will reduce the investment incentives by the vertically integrated firm. For  $\beta = 0.5$  the investment incentives are absent under access price regulation, such that the investment is zero. However, for  $\beta$  close to 0.5 the positive competition effects from regulation dominate the negative investment incentives effect even if the cost parameter  $\varphi$  is low.

## 2.5 Access price regulation and non-price foreclosure

The purpose of this section is to analyse the situation where the vertically integrated firm in charge of the local network has a significant higher ability to offer value-added services compared to the rival. Until now we have assumed that the rival firm's quantity increases when the investment increases for given access price (assumption 2). We know that when  $\beta > \beta_2$  the vertically integrated firm wants to set an access price that forecloses the independent firm from the market. However, under access price regulation the vertically integrated firm's opportunity to use the access price as a foreclosure tool is eliminated. In this section, we see whether an overinvestment into input quality improvement may be used as an alternative foreclosure tool when assumption 2 is altered such that  $2\beta_2 - \beta < 0$ . Then the rival will reduce its quantity when the investment increases for a given access price, since in stage 2 we have that  $dq_2^* / dx < 0$ . For simplicity we make the following assumption:

**Assumption 3:**  $\beta \equiv 1 > 2\beta_2 > 0$

Then it follows that  $\beta_2 < 0.5$ , and the investment in  $x$  can be used as an alternative foreclosure tool under access price regulation. We know that for low values of  $\beta_2$ , it may be optimal for the regulator to set the access price above marginal cost (see above). For the sake of simplicity, we do not calculate the optimal access price set by the regulator. We simply assume that there exists a binding price cap such that  $\bar{w} \geq c$ , and we analyze the effect of a more or less stringent price cap. The timing is now as follows. At stage 1 the vertically integrated firm set  $x$ , knowing  $\bar{w}$ , and at stage 2 the firms compete à la Cournot when both firms are active in the market.

The strategic investment game has the timing structure analyzed by Fudenberg and Tirole (1984), Dixit (1980) and Spence (1977). We want to focus on the effect of the spillover from the investment and, in particular, the effect of the price cap on the vertically integrated firm's incentive to foreclosure through overinvestment.

The stage 2 quantities given that  $\bar{w} \geq c$  are  $q^* = (a - 2c + \bar{w} + x(2 - \beta_2)) / 3$  and  $q_2^* = (a + c - 2\bar{w} + x(2\beta_2 - 1)) / 3$ . We follow Fudenberg and Tirole (1984) and analyze whether the vertically integrated firm (the first-mover) chooses to invest to foreclose the rival or to share the market with the rival.

*Blocked entry*

The monopoly investment given assumption 3 is  $x_m^* = (a - c) / (2\varphi - 1)$ . If we insert  $x_m^*$  into  $q_2^*$  we find that entry is blocked with the monopoly investment when

$\beta_2 \leq \underline{\beta}^c \leq (1 - \varphi) + (\bar{w} - c)(2\varphi - 1) / (a - c)$ . The question is whether the vertically integrated firm will overinvest in  $x$  when  $\underline{\beta}^c < \beta_2 \leq 0.5$ .

*Non-price foreclosure by overinvestment:*

The effect of the investment  $x$  on the rival's profit is

$$\frac{d\pi_2}{dx} = \underbrace{\beta_2 q_2}_{\frac{\partial \pi_2}{\partial x}} + \underbrace{(-q_2)}_{\frac{\partial \pi_2}{\partial q_1}} \underbrace{((2 - \beta_2) / 3)}_{\frac{dq_2}{dx}} = 2q_2(2\beta_2 - 1) / 3$$

The first term is the direct effect of  $x$  on the rival's profit, and it is positive. The second term is the strategic effect, and will be negative. An increase in  $x$  increases the second stage choice of  $q$ . Since the quantities offered by the two firms are strategic substitutes, will an increase in  $q$  lowers  $q_2$  (see Bulow, Geanakoplos and Klemperer (1985)). Obviously,  $\pi_2$  is reduced when  $q_2$  is reduced.

When assumption 3 is fulfilled ( $2\beta_2 - 1 < 0$ ), the strategic effect dominates the direct effect. In Fudenberg and Tirole's taxonomy this means that investment makes tough. To foreclose the rival the vertically integrated firm should overinvest such that  $q_2^f = 0$  (superscript  $f$  indicates foreclosure by overinvestment):<sup>21</sup>

$$q_2^f = 0 \Rightarrow x^f = \frac{-a + 2\bar{w} - c}{2\beta_2 - 1}$$

For  $x=0$  we assume that both firms are active in the market, such that  $a - 2\bar{w} + c > 0$ . Then it follows that for  $\beta_2 < 0.5$ :

$$\frac{dx^f}{d\bar{w}} = \frac{2}{2\beta_2 - 1} < 0$$

<sup>21</sup> Using a "top-dog-strategy" in the Fudenberg-Tirole taxonomy.

and

$$\frac{dx^f}{d\beta_2} = \frac{-2(-a + 2\bar{w} - c)}{(2\beta_2 - 1)^2} > 0$$

For a lower local access price, the vertically integrated firm's response is to increase the investment if it wants to practice non-price foreclosure. The higher  $\beta_2$  (but lower than 0.5), the higher the investment must be to enhance a given reduction in the rival's quantity.

When the rival is foreclosed, the vertically integrated firm sets the monopoly quantity in stage 2. Insert for  $x^f$  we find that  $q^f = [(a - c)(\beta_2 - 1) + (\bar{w} - c)] / (2\beta_2 - 1)$ . For  $\beta_2 < 0.5$  we see that

$$\frac{dq_1^f}{d\bar{w}} = \frac{1}{2\beta_2 - 1} < 0$$

Hence, a strong price cap may be effective even if no inputs are sold to the rival. When the access price increases, the vertically integrated firm needs to overinvest less compared to the monopoly investment level. If we insert for investment level and quantity offered by the vertically integrated firm we find the profit and the welfare functions under foreclosure:

$$\pi_1^f = (q_1^f)^2 - 0.5\varphi(x^f)^2$$

$$W^f = \pi_1^f + 0.5(q_1^f)^2$$

Here we assume that  $\underline{\beta} < \beta_2 < 0.5$ , such that the rival is not blocked from the market by the investment level of a pure monopolist. Now it can be shown that:

$$\frac{dW^f}{d\bar{w}} = \frac{(a - c)(3\beta_2 - 3 + 2\varphi) + (\bar{w} - c)(3 - 4\varphi)}{(2\beta_2 - 1)^2}$$

When this is negative we see that an access price regulation may be effective even if the rival still is foreclosed from the market. The reason is that the regulator through a price cap forces the vertically integrated firm to increase the investment if it wants to foreclose the rival. The investment is an investment in quality, and we know that a monopolist may have too high or too low incentives to offer quality seen from the social planner point of view (Spence, 1975).

We now check that in this particular setting the monopolist offer to low quality (investment) seen from the regulator's point of view. Under non-price foreclosure  $q_2^f = q_2 = 0$ , and the vertically integrated firm chooses the monopoly quantity in stage 2  $q_1^m = (a - c + x) / 2$ . As long as  $q_2 = 0$  the welfare level will be given by  $W = (3q_1^2 - \varphi x^2) / 2$ . Thus we have  $dW / dx = (3q_1 (dq_1 / dx) - \varphi x)$ . We know that without access price regulation  $x_m^* = (a - c) / (2\varphi - 1)$ . Insert for  $x_m^*$  we find that  $dW / dx_{x=x_m^*} = (a - c)\varphi / (2(2\varphi - 1)) > 0$ .

Even if  $q = q^* = 0$ , the welfare will increase if the regulator through a binding price cap, gives the vertically integrated firm an incentive to increase the investment compared to  $x_m^*$ .

**Proposition 6:** *Let us assume that  $\beta_1 \equiv 1 > 2\beta_2 > 0$  and that there is a restrictive price cap on the local access. Then we have the following results:*

- i. *The vertically integrated firm overinvests compared to the monopoly equilibrium without access price regulation, i.e. that  $x^f - x_m^* > 0$*
- ii. *When the unconstrained monopoly underinvests seen from the regulator's point of view, the access price regulation may increase the welfare since it forces the vertically integrated firm to invest more, i.e. that  $W^f - W_m^* > 0$*
- iii. *If the rival has low ability to offer value-added services compared to the vertically integrated firm, the rival will be foreclosed from the market both with and without access price regulation, i.e. that  $q^f = q^* = 0$*

We have not checked whether the vertically integrated firm will prefer to overinvest into  $x$  in order to foreclose the rival. If the vertically integrated firm chooses not to foreclose the rival it will set  $x$  to maximize its own profit. We show in appendix that there will be an interval of low values of  $\beta_2$  where it is optimal for the vertically integrated firm to overinvest in order to foreclose the rival. We interpret  $\bar{\beta}^c$  as the critical value for whether foreclosure is optimal or not. Hence we have three intervals analogous to Fudenberg and Tirole (1984):

- i.  $\beta_2 \leq \underline{\beta}^c$ : The rival is blocked from entry by the monopoly investment level  $x$ .
- ii.  $\underline{\beta}^c < \beta_2 < \bar{\beta}^c$ : The vertically integrated firm overinvests to foreclose the rival.
- iii.  $\beta_2 \geq \bar{\beta}^c$ : Then it is more profitable for the vertically integrated firm to set  $x$  that maximize its own profit, even if the rival is now active in the market.

We see that the outcome may be foreclosure even if the access price is regulated. This is in contrast to the previous sections where both firms were active in the market under access price regulation.

We have focused on a market context where a vertically integrated firm with control over an essential input for the downstream market where the integrated firm meets competition from independent rivals. Access price regulation may in such context induce foreclosure through non-price discrimination (see Laffont and Tirole, 2000). When the facility-based firm meets a price cap on  $w$  it may engage into non-price discrimination by reducing the quality of the input sold to the downstream rival. As shown in Economides (1998a, 1998b) and Foros, Kind and Sørsgard (2000), it can be profitable to do so, and thereby put its rival in a disadvantageous position.

In contrast, in our context, the facility-based firm's response to a price cap may be to invest more into quality improvement if its own downstream subsidiary has superior ability to transform the input to output. It is often seen as detrimental for the welfare level when a price cap that prevents the vertically integrated firm from revenue in the access input segment gives incentives to extend the untapped market power by non-price methods. In contrast, in our context, it may increase welfare. By limiting the vertically integrated firm's ability to practice foreclosure by price discrimination, it gives the vertically integrated firm an incentive to invest more into quality. And as we have seen, such overinvestment into quality compared to the unconstrained monopoly level increases welfare if the unconstrained monopoly underinvests into quality seen from the social planner point of view (Spence, 1975).

### **3 Some concluding remarks**

In this paper we analyze a market structure where a vertically integrated firm controls the input segment for access that constitutes an essential input for downstream providers for internet connectivity. The vertically integrated firm may undertake an investment that increases the quality of the input (upgrading to broadband). In the downstream market the vertically integrated firm competes towards an independent firm that needs to buy access as an input. We analyze the effect of an access price regulation that sets access price to marginal cost, which has been the dominating regulatory paradigm both in the EU and the US.

Obviously such regulation may have negative effects on the investment incentives. The total effect on consumer surplus and welfare critically depend on whether the vertically integrated

firm or the rival firm has highest ability to offer value-added services (broadband services). Put differently, which firm has highest ability to transform input to output.

When the rival has higher ability to offer value-added services when the input quality is improved, both firms will be present in the market also without access price regulation. A binding price cap on access, will, however, reduce the cost of the most effective firm, the rival. For a given investment this will obviously increase consumer surplus, since the firm with highest ability to offer value-added services will increase its quantity. However, the vertically integrated firm's investment incentive is reduced, and a lower investment will hurt both firms. As long as the cost of investment is not too convex, an access price regulation lowers consumer surplus. Note that this result requires that the vertically integrated firm use a uniform access price. If the vertically integrated firm has the ability to use a non-uniform access price, it will prefer to outsource the retail market to the more effective rival in the unregulated case.

If the vertically integrated firm's retail subsidiary has the highest ability to offer value-added services when the input quality is improved, the rival will always be foreclosed by a high access price without access price regulation. We analyze two cases. First, we assume that the difference in the two firms ability to offer value-added services is not too high. Then the rival's quantity increases when the investment increases for a given access price. The conventional tradeoff between stimulating competition between the firms and investment incentives is still present, and we show that similar to above, as long as the cost of investment is not too high, the access regulation lowers consumer surplus. Hence, with not too convex cost downstream monopoly gives higher consumer surplus than a regulated duopoly.

Second, we assume that the vertically integrated firm's ability to offer value-added services is significantly higher than the rival's ability to use the improved quality of the input. Then, for a given access price, the rival's quantity decreases when the investment increases. Hence, if an access price regulation eliminates the vertically integrated firm's ability to use the access price as a foreclosure tool, there exists an alternative tool. The vertically integrated firm may use overinvestment as a mechanism to drive the rival out of the market. In this case the regulators incentives to use an access price regulation may change fundamentally. A strong price cap regulation, gives the rival low input costs, and, hence, the vertically integrated firm must invest more to induce the rival to exit. The regulator can then increase the investment with a strong access price regulation. If the vertically firm's investment in an unregulated

monopoly is too low seen from the regulator's point of view, it will also be optimal to do so. Moreover, an access price regulation may be optimal even if it does not stimulate to competition.



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## 5 Appendix

*Proof of Lemma 2:*

A necessary and sufficient condition for market sharing is now that  $\beta_2 > \beta_1$ .

$$x^* - x_m^* = [4(a-c)\beta_1(\beta_2 - \beta_1)^2] / (A^* A_m^*) > 0$$

$$dx^* / d\beta_2 = 40(a-c)\beta_1(\beta_2 - \beta_1) / (A^*)^2 > 0 \text{ if } \beta_2 > \beta_1$$

$$dq_2^* / d\beta_2 > 0 \text{ if } \beta_2 > \beta_1. \text{ QED.}$$

*Proof of lemma 3:*

*In the case with access price regulation and  $\beta_2 \leq \beta_1 = 1$  we have*

$$q_1^r = 3\varphi(a-c) / A^r, \quad q_2^r = (a-c)[3\varphi - 2(2-\beta_2)(1-\beta_2)] / A^r, \quad Q^r = q_1^r + q_2^r,$$

$$x^r = 2(a-c)(2-\beta_2) / A^r, \text{ and } A^r = [9\varphi - 2(2-\beta_2)^2].$$

Hence we have

- i.  $\pi_1^r = \varphi(a-c)^2 / A^r \Rightarrow \partial \pi_1^r / \partial \beta_2 = -4\varphi(a-c)(2-\beta_2) / (A^r)^2 < 0.$
- ii.  $\partial \pi_2^r / \partial \beta_2 > 0$  if  $= \partial q_2^r / \partial \beta_2 > 0. \partial q_2^r / \partial \beta_2 = 2(a-c)(A^r - 6\varphi(2\beta_2 - 1)) / (A^r)^2 > 0$  since  $(A^r - 6\varphi(2\beta_2 - 1)) > 0$  for  $\beta_2 \in [0.5, 1]$  and  $\varphi > 0.5.$
- iii.  $dQ^r / d\beta_2 = -2(a-c)[3\varphi(2\beta_2 - 1) + 8(1-\beta_2) + 2\beta_2^2] / (A^r)^2 < 0$  for  $\beta_2 \in [0.5, 1].$  QED.

*Proof of Proposition 3:*

The higher ability the non-facility-based firm has to use the investment, the lower is the investment level with access price regulation:

$$\frac{dx^r}{d\beta_2} = -\frac{2(a-c)}{(A^r)^2} [A^r + 4(2\beta_1 - \beta_2)^2] < 0$$

- i. We have  $dx^r / d\beta_2 < 0.$  Hence, it is sufficient to ensure  $x^r - x_m^* < 0$  for  $\beta_2 = 0.5.$  For that  $\beta_2 = 0.5$  we have  $x^r - x_m^* = -(a-c) / 3A_m^* < 0.$

- ii. We have  $dQ^r / d\beta_2 < 0$  for  $\beta_2 \in [0.5, 1]$  (see lemma 3). Hence, let us insert for  $\beta_2 = 0.5$ . Then we have  $Q^r - q_m^* = (a - c)[3\varphi^2 - 4.5\varphi + 1.5] / A^r A_m^*$  which is negative for  $\varphi^{crit} < \varphi < 1$  and positive for  $\varphi > 1$ . QED

*Proof of lemma 4:*

*In the case without access price regulation and  $\beta_1 \leq \beta_2 \equiv 1$  we have*

$$q_1^* = (a - c)[5\varphi - (1 - \beta_1)(2 - \beta_1)] / A^*, \quad q_2^* = (a - c)[\beta_1(1 - \beta_1)] / A^*, \quad Q^* = q_1^* + q_2^*,$$

$$x^* = 5\beta_1(a - c) / A^*, \quad \text{and } A^* = [10\varphi - 9\beta_1^2 + 8\beta_1 - 4].$$

*Hence*

- i. *Obvious and, hence, omitted.*
- ii.  $\partial q_2^* / \partial \beta_1 = (a - c)[A^* - 10\beta_1(2\varphi - \beta_1)] / (A^*)^2$ . Hence  $\partial \pi_2^* / \partial \beta_1 > 0$  if  $[A^* - 10\beta_1(2\varphi - \beta_1)] \geq 0$ . This condition holds for  $\beta_1 \in (0.5, 1]$  and  $0.5 < \varphi \leq (\beta_1^2 + 8\beta_1 - 4) / 10(2\beta_1 - 1)$ . Note that the critical value of  $\partial \varphi / \partial \beta_1 = -2\beta_1(1 - \beta_1) / (2\beta_1 - 1)^2 < 0$ . Hence, for  $\beta_1$  close to one, there will probably be negative for firm 2 that firm 1 increases its ability to offer value-added services.
- iii.  $\partial Q^* / \partial \beta_1 = (a - c)[10\beta_1(5\varphi + 2\beta_1 - 2)] / (A^*)^2 > 0$ . QED.

*Proof of lemma 5:*

$$q_1^r = 3\varphi(a - c) / A^r, \quad q_2^r = (a - c)[3\varphi + 2(2\beta_1 - 1)(1 - \beta_1)] / A^r, \quad Q^r = q_1^r + q_2^r,$$

$$x^r = 2(a - c)(2\beta_1 - 1) / A^r, \quad \text{and } A^r = [9\varphi - 2(2\beta_1 - 1)^2].$$

Hence we have

- i.  $\pi_1^r = \varphi(a - c)^2 / A^r \Rightarrow \partial \pi_1^r / \partial \beta_1 = 8\varphi(a - c)^2(2\beta_1 - 1) / (A^r)^2 > 0$ .
- ii.  $\partial q_2^r / \partial \beta_1 = 2(a - c)[3\varphi(5 - 4\beta_1) + 2(2\beta_1 - 1)^2] / (A^r)^2 > 0$ .
- iii.  $dQ^r / d\beta_1 = 2(a - c)[3\varphi(4\beta_1 + 1) + 2(\beta_1 - 1)^2] / (A^r)^2 > 0$ . QED.

*Proof of Proposition 5:*

- i.  $x^r - x^* = (a - c)[2(2\beta_1 - 1)A^* - 5\beta_1 A^r] / A^r A^*$ . Hence to check  $x^r - x^* \geq 0$  we see whether  $[2(2\beta_1 - 1)A^* - 5\beta_1 A^r] \geq 0$ . This requires that  $\varphi \leq 2(2\beta_1^2 - 3\beta_1 + 1) / 5$  which will never be fulfilled for  $\beta_1 \in [0.5, 1]$  and  $\varphi > 0.5$ .

ii.  $Q^r - Q^* = (a - c) [A^* (6\phi + 2(2\beta_1 - 1)(1 - \beta_1)) - A^r (5\phi + 2\beta_1(1 - \beta_1) - 2(1 - \beta_1))] / A^r A^*$ .

Let us check whether

$[A^* (6\phi + 2(2\beta_1 - 1)(1 - \beta_1)) - A^r (5\phi + 2\beta_1(1 - \beta_1) - 2(1 - \beta_1))] \geq 0$ . When solving the inequality with respect to  $\phi$  we find that:

$\phi \geq \frac{6}{5}\beta_1^2 + \frac{16}{15}\beta_1 + \frac{8}{15} + \frac{1}{15}\sqrt{24\beta_1^4 - 6\beta_1^3 + 94\beta_1^2 - 16\beta_1 + 4}$ . Moreover we see that the restriction on  $\phi$  to ensure  $Q^r - Q^* \geq 0$  is stronger for higher  $\beta_1$  since:

$$\frac{\partial \phi}{\partial \beta_1} = \frac{4}{15}(9\beta_1 - 4) + \frac{48\beta_1^3 - 9\beta_1^2 + 94\beta_1 - 8}{15\sqrt{24\beta_1^4 - 6\beta_1^3 + 94\beta_1^2 - 16\beta_1 + 4}} > 0 \text{ for } \beta_1 \in [0.5, 1] \text{ QED.}$$

*Access price regulation and non-price regulation by overinvestment when assumption 3 holds:*

Prior to competition the vertically integrated firm chooses the investment  $x$  at stage 1. The objective function, and optimal investment level is:

$$\max_x \pi_1 = \left[ \frac{a - 2c + \bar{w} + x(2 - \beta_2)}{3} \right]^2 + (\bar{w} - c) \left[ \frac{a - 2\bar{w} + c + x(2\beta_2 - 1)}{3} - 0.5\phi x^2 \right]$$

$$\frac{\partial \pi_1}{\partial x} = 0 \Rightarrow x_{w=\bar{w}} = (2 - \beta_2) [2(a - c) + 5(\bar{w} - c)] / A^r$$

$$A \equiv 9\phi - 2(2 - \beta_2)^2$$

Insert  $x_{w=\bar{w}}$  into the quantity for the non-facility-based firms gives:

$$q_2 = \frac{[(a - c)(3\phi + 2(2 - \beta_2)(\beta_2 - 1)) - (\bar{w} - c)(6\phi - 3(2 - \beta_2)(1 + 2\beta_2))]}{A^r}$$

The last term at the right hand side is always negative. The first term

$(3\phi + 2(2 - \beta_2)(\beta_2 - 1))$  is negative when the cost parameter is low. For  $\phi = 1$  the first term

above is negative when  $\beta_2 < 0.18$ . Hence, even if the vertically integrated firm maximizes

profit, it may set  $x$  such that the rival is foreclosed. We denominate the critical value  $\bar{\beta}^c$ . For

$\bar{\beta}^c < \beta_2$  the vertically integrated firm chooses not to foreclose the rival for given  $\bar{w}$ .