

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

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Abstract

We analyse competition between two firms (ISPs) in the retail market for broadband access. One of the firms is vertically integrated and controls the input market for local access. The vertically integrated firm undertakes an investment that increases the quality of the input (upgrading to broadband). The retailers' ability to offer value-added services when the input quality is improved differs. We analyse the effect of an access price regulation that is set after the investment. The access price regulation may have negative effects on investment incentives, and we show that the total effect on consumer surplus and welfare depends on which firm has the highest ability to offer value-added services.

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1 Introduction

The purpose of this paper is to examine the interplay between a facility-based vertically integrated firm and an independent competitor in the retail 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. We assume that the regulator has only one instrument available, an access price regulation for the input sold to the independent rival.¹ The retail market is assumed to be unregulated.² Furthermore, we assume that the access price is set after the investment but prior to retail market competition since the regulator has limited commitment ability. Both the timing structure and the one-sided regulation of the input segment correspond to the dominant regulatory paradigm in the EU and the USA (Laffont and Tirole, 2000, Hausman, 1997, and Cave and Prosperetti, 2001). Installation of fiber in the local access network will be a substantial, lumpy, and irreversible investment, and the economic life of the investment will be longer than the regulation contract used for access prices (Hausman, 1997).³

The access price regulation may reduce investment incentives, and the main message of this paper is that the total welfare effect of access price regulation critically depends on which firm has the highest ability to transform input to output. The quality of the input component sold from the integrated firm is the same for both retailers, but the retailers may differ in their ability to offer value-added services (broadband services such as interactive video).⁴ Except for the case where the independent firm has the highest ability to use the improved input quality, the integrated firm will foreclose the rival from the market through the access price in an unregulated environment. However, this is not a sufficient condition to ensure that an access price regulation improves consumer surplus and total welfare. If the retailers do not differ too much with respect to their ability to offer value-added services when the input

¹ See Laffont and Tirole (2000) and Armstrong (2001) for comprehensive overviews of access price theory and practice. Cave and Mason (2001) give an extensive overview of the market structure and regulation in the Internet.

² See Laffont and Tirole (2000) for a discussion.

³ Price cap regulations in telecommunication do not exceed five years, and other types of access price regulation are usually set for a shorter period. In contrast to the present paper, the literature on price caps typically focuses on incentives for cost-reducing activities within the regulatory contract.

⁴ 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. The integrated firm's retailer may have an advantage in using the improved input quality due to economies of scope from integration. In contrast, if the independent retailer is a firm like AOL Time Warner, it may have an advantage compared to the integrated firm due to its experience from other markets.

quality is improved, we show that access price regulation reduces the vertically integrated firm's investment incentives. An access price regulation lowers consumer surplus and total welfare as long as the cost of investment is not too convex. If the vertically integrated firm's ability to offer value-added services is much higher than the independent rival, an increase in the investment will reduce the quantity offered by the independent retailer. An access price regulation still eliminates the vertically integrated firm's ability to use the access price as a foreclosure tool, but now the integrated firm may use overinvestment as an alternative tool to drive the rival out of the market.

Today the majority of residential consumers use their telephone lines for the last mile of narrowband Internet connectivity, and by upgrading their local networks the telecommunication providers are able to increase the speed of communication.⁵ 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 (Mackie-Mason, 1999).⁶ In the current regulation only the telephone access provider is mandated to supply local access as an input to non-facility based rivals in the retail market. Therefore, the telephony incumbent has been the only provider of local access as an input to independent ISPs⁷. Hence, given the existing asymmetry in regulation of the telecommunication and the cable-tv technologies (see Hausman et al., 2001), the present model only fits for services offered by the telecommunication incumbents.⁸

⁵ Measured by bits per second (bps). A conventional voice telephone call needs approximately 10 kilo-bps. The bandwidth requirement for broadband services will vary a lot, and it also varies between incoming and outgoing capacity. Compression technologies may reduce the bandwidth requirements considerably, but in order to support e.g. two interactive high-quality tv channels several mega-bps are needed. Current standard modem technology gives access speed of 56 kbps. 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.

⁶ 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. Mackie-Mason, 1999, and Faulhaber and Hogendorn, 2000). The situation seems to be different in Europe (Roche et al., 2001). There may be several reasons for this difference. First, there is high penetration of cable-tv in the US compared to many European countries. Second, and probably more important, the historical separation between local providers and long distance providers of telephony in the US between 1984 and 1996 (the AT&T break-up in 1984).

⁷ Internet Service Providers.

⁸ However, since the cable-tv providers face an analogous cost structure, the analysis will be relevant for broadband access using cable-tv technology if the cable-tv providers are required to offer broadband access as a wholesale product.

We assume that the investment in higher speed of communication may be seen as an unambiguous improvement of quality.⁹ The closer to homes the fiber is installed, the higher is the quality.¹⁰ The trade-off between the distance the existing lines are used and the network quality (speed) implies that the upgrading costs are convex in speed of communication.

In figure 1 we illustrate the Internet as a layered network with the physical network as the bottom layer. Local access is obviously an essential input component for the ISPs. The functions of the retail ISPs are to combine the components' local access, regional backbone capacity and global backbone capacity, and they act as a kind of portal to the applications and content in the Internet.

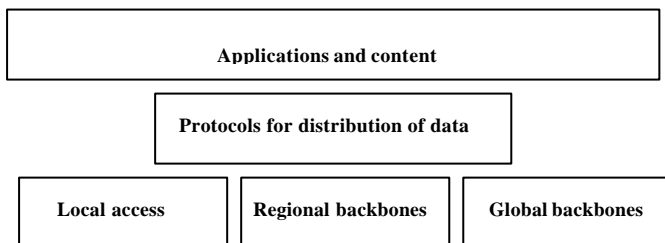


Figure 1: The layered structure of the Internet.

As described by Cave and Mason (2001) and Faulhaber and Hogendorn (2000), the retail ISPs must choose their regional and global backbone capacity before they serve the end users. This implies capacity constraints that limit the number of consumers that can be served.¹¹ With respect to timing in our model it is reasonable to assume that the investment choice of speed of communication in the access network is taken prior to the ISPs' choice of local and global

⁹ First, an increase in speed of communication gives access to new broadband services (e.g. interactive audio and video). Second, consumers' value from conventional Internet services like web-browsing and e-mail increases 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").

¹⁰ There may be horizontal differentiation in this market (see Foros and Hansen, 2001). However, we make this assumption in order to strengthen the foreclosure incentives of the vertically integrated firm in absence of access price regulation.

¹¹ Although the total number of retail ISPs is large, the market is quite concentrated since the largest providers are controlling a large part of the market. Cave and Mason (2001) argue that the current narrowband dial-up access limits the economies of scale in the ISP-segment. In the ISPs' local backbones the subscribers' traffic is combined and carried over shared lines, and the ISPs use statistical aggregation in order to reduce the investment in capacity. However, the capacity limits in the narrowband access are constraining the economies of scale from traffic aggregation. The situation will be different with broadband access technologies, and this will probably also increase the concentration in the ISP-segment (Cave and Mason, 2001). The regional ISPs usually have long-term contracts with the providers of transatlantic-lines and access to the core global backbones (Crémer, Rey and Tirole, 2000). To some extent, this will also give capacity constraints in the end-user market.

backbone capacity. The interplay between local retail ISPs and the upstream providers of global access will not be addressed in the present paper.

Our paper is related to the literature on strategic R&D investments with spillovers.¹² In contrast to our model, there is no opportunity for access pricing by the investing firms in this literature. The literature on R&D investments assumes that the investment leads to a reduction in costs, and that there is a spillover that also reduces rivals costs.¹³

Rey and Tirole (1997) analyse 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. Several recent papers analyse non-price foreclosure in telecommunications and the Internet. Similar to Economides (1998) we assume an exogeneously given market structure where an integrated firm controls the input-segment, and there is an unregulated Cournot duopol in the retail segment. Economides (1998) shows that the integrated firm will always use non-price foreclosure towards the retail rival. This result contrasts with Weisman (1995, 1998), Sibley and Weisman (1998), Weisman and Kang (2001) and Foros, Kind and Sørsgard (2002), who find that that the vertically integrated firm will be less inclined to degrade the quality of the input if the profit margin is high in the input segment. In all these papers the foreclosure activity is assumed to degrade the quality of the input sold to the rivals. In contrast, in our model there is no opportunity to unilaterally reduce the quality of the input sold to the rival. The quality level of the input is the same for both retailers. However, if the vertically integrated firm has significantly higher ability to offer value-added services than the rival, the integrated firm may commit itself to be more aggressive in the retail market by overinvesting in network quality improvement.

Faulhaber and Hogendorn (2000) and Foros and Kind (2002) analyse the broadband access market with focus on the choice of target market (where to upgrade to broadband), while the coverage decision is not analysed in the present paper. Another distinction from the present

¹² Spence (1984) models spillovers from the investment, but he assumes that the firms are symmetric in their ability to invest. The seminal paper on strategic R&D-investments and spillovers is D'Aspremont and Jacquemin (1988).

¹³ Investments that create positive demand side effects are not considered in this literature. Our formulation of the demand side spillover is analogous to Wey (1999), who examines symmetric firms' incentives to invest in compatibility under different degrees of co-operation. Note that the investment in network quality in the present paper may be equivalent to Katz and Shapiro (1985) who see the network quality as the number of expected consumers (see discussion below).

paper is that these two papers develop models of competition among several facility-based broadband access providers, while we analyse the interplay between a facility-based provider and a non-facility-based rival. Hausman, Sidak, and Singer (2001) analyse the asymmetric regulation of telecommunication providers and cable-tv providers regarding broadband access. Rubinfeld and Singer (2001) analyse the merged AOL Time Warner's incentive to engage into two types of non-price foreclosure in the broadband access market.¹⁴

The article is organised as follows. In section 2 we present the model. In section 3 we give some concluding remarks.

2 The model

In figure 2 we illustrate the stylised market structure analysed in the present paper. In the retail market for Internet connectivity there is competition between a vertically integrated firm's subsidiary and an independent ISP, ISP A and ISP B, respectively. The vertically integrated firm controls the local access component. The broadband Internet connectivity is sold by the two ISPs to end-users at a fixed subscription fee independent of actual usage (the number of packets actually sent and received) and time connected. This also corresponds with what we see in the market place for broadband Internet connectivity.¹⁵ Hence, the ISPs face a downward sloping demand curve. When the subscription fee is reduced (for given quality), more consumers will subscribe. The usage by the infra-marginal consumers is, however, not affected.¹⁶ The access input price charged by the facility-based firm will be a fee for each broadband subscriber served by the rival ISP (ISP B) over the vertical integrated firm's local network facilities.

¹⁴ Rubinfeld and Singer (2001) show that AOL Time Warner has both the ability and incentive to engage into non-price foreclosure. In contrast to our model, they do not consider investment incentives and access pricing, and they assume that the foreclosure activity will reduce the quality of the component offered to the rival.

¹⁵ This is in contrast to the current narrowband Internet connectivity through modem where the user pays a time-dependent price while he is connected. However, the current billing systems do not charge the users for their actual usage of bandwidth.

¹⁶ Thus, we implicitly assume that the direct network effects are insignificant. In other words, for a given speed of communication in the local loop, the willingness to pay is not affected by the number of consumers subscribing to broadband in the same area. This assumption seems realistic if the user is mostly downloading information from the US. However, if the user's main use of broadband Internet connectivity is to have video-conferences with neighbours this assumption is rarely fulfilled.

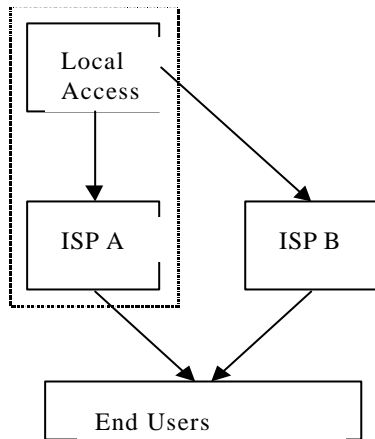


Figure 2: The market structure

When the network quality is improved, the demand curves for both retailers shift outwards, such that the willingness to pay for subscription increases for all potential consumers. If the firms differ in their ability to use the quality improvement of the input, the market shares of the firms will be affected.

We model a three-stage game with the following timing structure:

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

As mentioned above, we focus on how “fat” pipes to homes the vertically integrated firm chooses, and we do not consider the choice of target market (where to upgrade to broadband). Faulhaber and Hogendorn (2000) and Foros and Kind (2002) analyse the choice of target market for a given quality level. The choice of coverage may in fact be set street-by-street, and therefore be taken after the investment choice considered here. However, as long as the integrated firm is obligated to offer broadband access as a wholesale product to the

independent ISP in the entire target market, this will not alter the aspects analysed in the present paper.¹⁷

We assume Cournot competition in the retail market, and the quantity firms dump in the retail market is interpreted as the number of subscriptions they sell. An assumption of Cournot competition seems reasonable, since the retailers face capacity constraints in the regional and the global backbones (see above and the discussion by Faulhaber and Hogendorn (2000) and Crémer et al. (2000)).¹⁸

Demand side

The investment at stage 0 is given by x . We see this investment as a quality improvement of the local access input that increases the consumers' willingness to pay for broadband Internet connectivity. How much the input quality improvement increases consumers' willingness to pay for Internet connectivity depends on the retail firms' ability to transform input to output. Hence, we have a demand side spillover from the local access provider to the retailers:

$$a_1 = a + \mathbf{b}_1 x \quad \text{and} \quad a_2 = a + \mathbf{b}_2 x$$

Subscript 1 and 2 indicate the facility-based and the non-facility-based firm, respectively. The parameters \mathbf{b}_1 and \mathbf{b}_2 are the demand side spillover from the facility-based firm to its own subsidiary and the independent ISP, respectively.¹⁹ If $\mathbf{b}_1 > \mathbf{b}_2$, the vertically integrated firm has higher ability to offer a value-added service from the investment than the non-facility

¹⁷ However, an obligation to offer the input in the entire target market combined with an access price regulation will probably reduce the coverage where the integrated firm chooses to upgrade to broadband. The reason for this is that it reduces the revenue, but not the costs from serving a given region.

¹⁸ Faulhaber and Hogendorn (2000) assume that there is a capacity-constrained price game in the retail market for broadband access, and that the conditions for the Kreps-Scheinkman result are fulfilled in their model. They model a three-stage game where the coverage decision is taken in stage 1, stage 2 is the backbone capacity choice, and in stage 3 firms choose prices. Hence, the investment choice analysed in the present paper may be seen as a stage prior to the model analysed by Faulhaber and Hogendorn. The two last stages of their game are shown to be equivalent to a one-stage Cournot game. The result of Kreps and Scheinkman (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. However, since there are rigid capacity constraints we assume that the Cournot competition assumption seems more realistic than a Bertrand game in the retail market (see the discussion in Tirole, 1988, chapter 5). A necessary condition to ensure the Kreps-Scheinkman conditions in our context is that the ISPs simultaneously set the backbone capacity in a stage 2a, and that they thereafter compete in prices in a stage 2b.

¹⁹ The spillover is analogous to the spillover effect from R&D investment in D'Aspremont and Jacquemin (1988), among others. They assume process innovation, while we assume product innovation.

based firm. In contrast, if $b_2 > b_1$, the non-facility based firm has the highest ability to increase consumers' willingness to pay. We assume that $b_1, b_2 \in [0,1]$.

The consumers have unit demands. We assume that the consumers are heterogenous in their basic willingness to pay for Internet connectivity, but that they are homogenous in their valuation of the improved network quality. Hence, consumers valuation of ISP i 's service is $s + b_i x$, and s is distributed uniformly among the consumers. The consumer with the highest willingness to pay has s equal to a . The demand structure is analogous to Katz and Shapiro (1985) where the network quality depends on the number of expected consumers connected to firm i .²⁰

When p_i is the price charged by ISP i , a consumer of type s buys from ISP i if $s + b_i x - p_i > s + b_j x - p_j$ (where $i \neq j$). If $s + b_i x - p_i < 0$ for both retailers, the consumer of type s will not buy from any of them.

Thus, the inverse demand functions faced by the firms are:

$$\begin{aligned} p_1 &= a_1 - q_1 - q_2 \\ p_2 &= a_2 - q_1 - q_2 \end{aligned}$$

Note that the parameters $b_1 x$ and $b_2 x$ do not affect the slope of the inverse demand functions, so that an increase in x implies parallel shifts in the demand functions. If $b_2 \neq b_1$, there will be different magnitudes in the demand shifts.

Total production is $Q = q_1 + q_2$ and net consumer surplus is:

$$CS = \frac{a_1 - p_1}{2} q_1 + \frac{a_2 - p_2}{2} q_2$$

In absence of the investment we assume that the services offered by the firms are identical. For the existing network quality (absence of the investment), the ISPs offer access to conventional PC-centric services like www and e-mail. For these services there exist known

²⁰ In the Katz and Shapiro-model consumers value service i at $s + v(q_i^e)$, where q_i^e is the consumers' expectations of the size of firm i 's network.

and accepted standards, but the situation may change when new technology is implemented.²¹ When the access network quality is upgraded, the ISPs may offer new TV-centric interactive broadband services that are very different from conventional PC-centric services. Then, there may be differences in their ability to offer such services due to economies of scope from integration and/or different experience. As long as $\mathbf{b}_1 = \mathbf{b}_2$ the end user services from the two ISPs will be identical also when the investment is positive ($\alpha > 0$). Then the investment increases the quality level of the retailers' end-user services by the same level. In contrast, if $\mathbf{b}_i > \mathbf{b}_j$, then there will be a quality differential between the two retailers' services, and ISP i will offer a higher quality than ISP j (where $i, j=1,2$).

Supply side

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 irrespective of whether its own downstream subsidiary or the rival is 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 with respect to investment in higher speed (bandwidth) in the local loop, given by $C_1(x) = \mathbf{j}x^2 / 2$. The investment cost x is not related to each user; the investment is for every potential user. For simplicity, the marginal costs of buying all other inputs than local access (regional and global backbone capacity) are assumed to be the same for the two retailers, and normalised to zero.

The profit functions for the firms are given by:

$$\mathbf{p}_1 = (p_1 - c)q_1 + (w - c)q_2 - \mathbf{j}x^2 / 2$$

$$\mathbf{p}_2 = (p_2 - w)q_2$$

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

Throughout we make the following assumption

²¹ See e.g. discussion by Shapiro and Varian (1998).

Assumption 1: $p_2 \geq 0, p_1 \geq 0, w \geq c, x \geq 0$

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 firm in the retail segment. The last term states that the investment must be non-negative.

Welfare

The welfare function:

$$W = CS + p_1 + p_2$$

A benchmark

Let us consider a market context in absence of 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 firms compete à la Cournot. In this context the results can be summarised in the following lemma:

Lemma 1: *If the vertically integrated firm does not invest in quality improvement ($x=0$), the regulator sets the access price equal 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 are higher under the access regulation regime compared to the unregulated regime.*

2.1 Retail market competition

We solve the model by backward induction and assume Cournot competition between the two firms (the ISPs) in the retail market for broadband Internet connectivity.

Equilibrium quantities in the competitive segment are:

$$q_1^* = [(a - c) + (w - c) + x(2b_1 - b_2)] / 3$$

$$q_2^* = [(a - c) - 2(w - c) + x(2b_2 - b_1)] / 3$$

Until otherwise stated, we make the following assumption:

Assumption 2: $2\mathbf{b}_i - \mathbf{b}_j \geq 0$ where $i, j = 1, 2, i \neq j$

Assumption 2 ensures that the difference in ability to offer value-added services between the retail firms is not too high. When $2\mathbf{b}_1 - \mathbf{b}_2 \geq 0$, 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 $2\mathbf{b}_2 - \mathbf{b}_1 < 0$. Then the vertically integrated firm may use overinvestment 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:

$$\mathbf{p}_1 = q_1^2 + (w - c)q_2 - \mathbf{j}x^2 / 2$$

The first order condition with respect to w gives the equilibrium access price at stage 1:

$$w^* = (a + c) / 2 + x(4\mathbf{b}_2 + \mathbf{b}_1) / 10$$

If we insert for w^* into the equilibrium quantities, we have the following:

$$q_1^* = [5(a - c) + x(7\mathbf{b}_1 - 2\mathbf{b}_2)] / 10$$

$$q_2^* = 2x(\mathbf{b}_2 - \mathbf{b}_1) / 5$$

$$Q^* = [5(a - c) + x(3\mathbf{b}_1 + 2\mathbf{b}_2)] / 10$$

Proposition 1: *Let us assume no regulation of the access price. The condition $\mathbf{b}_2 > \mathbf{b}_1$ is necessary and sufficient to ensure that the downstream rival is active in the market.*

From *Lemma 1* we know that in absence of the investment ($x=0$) the independent firm is foreclosed from the market. In contrast, we see that under investment in quality improvement

($x > 0$) the independent retail firm will be active in the market if it has higher ability to use the improved input quality such that $\mathbf{b}_2 > \mathbf{b}_1$.

2.2.2 Stage 0:

Foreclosure:

From *Proposition 1* it follows that as long as $\mathbf{b}_1 \geq \mathbf{b}_2$, the vertically integrated firm 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 $q_m^* = 0.5[a - c + \mathbf{b}_1 x]$, and the objective function for the facility-based firm when it sets x as a downstream monopolist is $\mathbf{p}_1^m = (q_m)^2 - 0.5\mathbf{j}x^2$. Superscript m indicates downstream monopoly.

The first order condition with respect to x gives the following investment level:

$$\frac{\partial \mathbf{p}_1}{\partial x} = 0 \Rightarrow x_m^* = (a - c)\mathbf{b}_1 / A_m^* \quad \text{where } A_m^* = 2\mathbf{j} - \mathbf{b}_1^2$$

The second order condition is fulfilled as long as $A_m^* > 0$.²² Inserting for x_m^* gives the following equilibrium quantity:

$$q_m^* = \frac{(a - c)\mathbf{j}}{2\mathbf{j} - \mathbf{b}_1^2}$$

Market sharing:

From *Proposition 1* we know that both retail firms are active as long as $\mathbf{b}_2 > \mathbf{b}_1$. The objective function for the facility-based firm when it sets x is:

$$\max_x \mathbf{p}_1 = (q_1)^2 + (w - c)q_2 - 0.5\mathbf{j}x^2$$

We insert for w^* , q_1^* and q_2^* . Then the first order condition with respect to x gives the following investment level:

²² At the investment stage (stage 0) the second order condition ensures that the cost parameter \mathbf{j} is sufficiently high, such that the investing firm will not make an infinite investment in quality improvement.

$$\frac{\partial p_1}{\partial x} = 0 \Rightarrow x^* = 5b_1(a-c) / A^* \quad \text{where } A^* = [10j - 9b_1^2 + 8b_1b_2 - 4b_2^2]$$

The second order condition is fulfilled as long as $A^* > 0$. Comparing the investment level under foreclosure (i.e. $b_1 \geq b_2$) with the market sharing equilibrium ($b_2 > b_1$), we find the following (see appendix):

Lemma 2: *Let us assume no regulation of the access price. For a given level of b_1 the investment will be higher under market sharing (i.e. $b_2 > b_1$) than under foreclosure, (i.e. $b_1 \geq b_2$) as long as the second order conditions are fulfilled. Moreover, the investment and the rival's quantity increase with the rival's ability to use the quality improvement when $b_2 > b_1$, i.e. that $dx^* / db_2 > 0$ and $dq_2^* / db_2 > 0$.*

Without access price regulation, the vertically integrated firm may imitate the strategy in the foreclosure case in the market sharing case as well. 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 efficient in using the improved quality of local access, $b_2 > b_1$, the consumers have higher willingness to pay for the service from ISP 2 than that from 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 dampen the competition. Inserting for x^* gives the following total quantity:

$$Q^* = \frac{a-c}{A^*} [5j - 3b_1^2 + 5b_1b_2 - 2b_2^2]$$

The reason why the vertically integrated firm does not outsource the retail market to the more efficient rival is the assumption of a linear 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 efficient rival (ISP 2) through the fixed fee. In other words, if the network owner offers the two-part tariff $T(q_2) = p_2^m + cq_2$, the retail rival (ISP 2) makes no profit, and the upstream monopolist will achieve the same outcome as if ISP 2 were its own subsidiary (see e.g. Rey and Tirole, 1997). In the present paper we use the linear price assumption since this seems to be the business model the majority of the telecommunications incumbents use in their wholesale service for broadband

(see discussion by Petkovic and De Coster, 2000). So why is that the network owners do not outsource their retail activity through non-linear pricing? First, it may be due to economies of scope such that $b_1 > b_2$. Second, outsourcing the retail market activity may imply that the network owner does not retain the bargaining power needed to offer such a take-it-or-leave-it offer to the retail monopolist (ISP2). Third, if the wholesale segment is regulated, while the retail segment is not (see also footnote 24 below), the network owner may not want to outsource the unregulated activity.

2.3 Access price regulation

The government may regulate w to maximise 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 vertically integrated firm.

2.3.1 Stage 1:

The welfare function may be written as

$$W = \frac{(q_1 + q_2)^2}{2} + q_2^2 + q_1^2 + (w - c)q_2 - \frac{jx^2}{2}$$

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

The regulator sets the access price w after the investment in x has taken place. The first order condition with respect to w gives the regulated access price margin:²³

$$w - c = -(a - c) + x(4b_1 - 5b_2)$$

When $(w - c) < 0$, it is a violation of the constraint that $w \geq c$. Then we have the following result (given the assumption that $w \geq c$):

²³ The second order condition is fulfilled.

Proposition 2: Let us assume regulation of the access price. A necessary and sufficient condition to ensure that it is optimal for the regulator to set access price equal to marginal cost, ($w^r = c$), is $-(a - c) + x(4\mathbf{b}_1 - 5\mathbf{b}_2) < 0$.

In this section we assume that the necessary and sufficient condition in *Proposition 2* is fulfilled, such that optimal regulated access price will be set to marginal cost ($w^r = c$) at stage 1. Superscript r indicates regulated access price.²⁴

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

$$q_1^r = [(a - c) + x(2\mathbf{b}_1 - \mathbf{b}_2)] / 3$$

$$q_2^r = [(a - c) + x(2\mathbf{b}_2 - \mathbf{b}_1)] / 3$$

$$Q^r = [2(a - c) + x(\mathbf{b}_1 + \mathbf{b}_2)] / 3$$

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:

$$\max_x p_1 = [(a - c) + x(2\mathbf{b}_1 - \mathbf{b}_2)] / 3]^2 - 0.5j x^2$$

The first order condition with respect to x gives the following investment level:

$$\frac{\partial p_1}{\partial x} = 0 \Rightarrow x^r = 2(a - c)(2\mathbf{b}_1 - \mathbf{b}_2) / A^r \text{ where } A^r = 9j - 2(2\mathbf{b}_1 - \mathbf{b}_2)^2$$

Inserting for x^r into Q^r gives:

$$Q^r = \frac{(a - c)}{A^r} (6j + 2(2\mathbf{b}_1 - \mathbf{b}_2)(\mathbf{b}_2 - \mathbf{b}_1))$$

²⁴ Note that if the regulator were allowed to set the access price below the marginal cost ($w < c$), it would have done that in order to correct for the imperfect competition in the retail market. If the regulator may use a two-part tariff, it could set $w < c$, and still ensure through the fixed fee that the upstream unit of the integrated firm has non-negative profit. In this case, the regulator could use a unit-price w below marginal cost c in order to correct for the imperfect competition in the retail market.

From *Lemma 2* we know that under market sharing in the unregulated case the investment level increases when \mathbf{b}_2 increases. In contrast to the unregulated case, we now see that the investment level decreases in the rival's ability to offer value-added services as the input quality is improved, since $dx^r / d\mathbf{b}_2 < 0$ (see proof of *Proposition 3* in appendix). Since the facility-based firm has no revenue from its upstream sale, it sees the advantage of 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 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 \mathbf{b}_2 under market sharing. Under access price regulation we find that:

$$dq_2 / d\mathbf{b}_2 = (2x^r + (dx^r / d\mathbf{b}_2)(2\mathbf{b}_2 - \mathbf{b}_1)) / 3$$

The first term is positive and indicates that for a given investment level, the rival's quantity increases when \mathbf{b}_2 increases. The second term indicates that an increase in \mathbf{b}_2 will have an effect on the investment level and that this in turn will affect the quantity offered by the rival. We know that $dx^r / d\mathbf{b}_2 < 0$ and in this section we assume that $(2\mathbf{b}_2 - \mathbf{b}_1) > 0$. Hence, the second term is negative. This is due to the fact that for the vertically integrated firm the parameter \mathbf{b}_2 is now seen as a pure spillover, which reduces the investment incentives. And therefore, when the spillover increases, the incentives to invest will be reduced. The total effect on the rival's quantity is then ambiguous.

Related to the quantity offered by the vertically integrated firm's retailer, we have that the higher the spillover, the lower the retail quantity sold from the facility-based firm (such that $dq_1^r / d\mathbf{b}_2 < 0$). There are two effects leading to this result. First, the higher the spillover is, the lower is the investment. When the investment is reduced, the facility-based firm lowers its retail quantity. Second, since the quantities offered by the two rivals are strategic substitutes, the facility-based firm reacts to an increase in the quantity from the rival by reducing its own quantity (Bulow, Geanakoplos, and Klemperer, 1985). The second effect may be positive or negative (see above), but the total effect on the vertically integrated firm's quantity from an increase in \mathbf{b}_2 is negative.

2.4 Comparison of results with and without access price regulation

The motivation behind an access price regulation is to prevent foreclosure and increase competition such that welfare increases. Industry profit will be higher without regulation than with regulation. 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. In order to compare the levels of consumer surplus 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:

$$\mathbf{b}_2 \leq \mathbf{b}_1 \equiv 1$$

In the access price regulation equilibrium, the vertically integrated firm has no profit from the input segment. From assumption 2 we have that $\mathbf{b}_2 \geq 0.5$. Moreover, we assume that the cost parameter \mathbf{j} is so high that the second order conditions are fulfilled, i.e. $\mathbf{j} > \underline{\mathbf{j}}^{crit} = 0.5$ in this case.

We have the following results for investment and consumer surplus with and without regulation (see appendix):

Proposition 3: *In the case where $\mathbf{b}_2 \leq \mathbf{b}_1 \equiv 1$ 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 is lower with than without regulation as long as the investment cost is not too convex (such that $q_1^r + q_2^r < q_m^*$).*

Hence, the parameter \mathbf{j} must be above a critical value to ensure that regulation improves consumer surplus. Similarly, since industry profit is lower with than without regulation, we find that the total welfare is lower with than without regulation when the investment cost is not too convex. The critical value of \mathbf{j} that ensures that access price regulation improves

welfare is higher than the critical value of j that ensures that regulation increases consumer surplus.

In this case the vertically integrated firm has higher ability to transform input into 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. In order to ensure entry the regulator may then impose an access price regulation that prevents the vertically integrated firm from practising foreclosure. The regulator faces a classic trade-off between triggering competition and dampening investment incentives. Moreover, this trade-off implies that it may be better if the rival has significantly lower ability to offer value-added services than the vertically integrated firm since this will reduce the spillover from the investment. Put differently, the closer b_2 is to b_1 , the higher j has to be to ensure that the consumer surplus is higher with than without regulation. Thus we have:

Corollary 1: *In the case where $0.5 < b_2 \leq b_1 \equiv 1$, a lower b_2 makes it more likely that consumer surplus is higher with than without access price regulation.*

This gives rise to a paradox. It is more likely that it is optimal for the regulator to ensure entry by access price regulation if firm 2 has low ability to offer value-added services compared to the vertically integrated firm. Usually, we see that the potential entrants are arguing in the opposite direction. They argue that the regulator should encourage entry since they have at least the same ability to offer value-added services as the incumbent. Put differently, in the present model it may be better for the regulator to allow for an inefficient entrant than having an efficient retail monopoly.

Market sharing without regulation:

Both firms are active in the market also in the market equilibrium, and we make the following assumption:

$$b_1 < b_2 \equiv 1$$

We compare the results with and without regulation when the rival has the highest ability to transform the input to output, and we still assume that $j > \underline{j}^{crit} = 0.5$. Then we have the following results (see appendix):

Proposition 4: *In the case where $\mathbf{b}_1 < \mathbf{b}_2 \equiv 1$ 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 $x^r - x^* < 0$.*
- ii. *the consumer surplus is lower with than without regulation as long as the investment cost is not too convex (such that $q_1^r + q_2^r < q_1^* + q_2^*$).*

As in the previous case total welfare is also lower with than without regulation when the investment cost is not too convex.

For \mathbf{b}_1 close to 0.5 the welfare loss from dampened competition in the case without access price regulation will be high. The loss from dampened 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 \mathbf{b}_1 is compared to \mathbf{b}_2 (which is equal to one). Second, there will be a loss due to the fact that the less effective firm 1 will serve most of the market. For a given investment level, these two competition effects will imply that the consumer surplus and total welfare may be enhanced by access price regulation. However, access price regulation will reduce the investment incentives of the vertically integrated firm. For $\mathbf{b}_1=0.5$ the investment is zero. However, for \mathbf{b}_1 close to 0.5 the pro-competitive effects of regulation dominate the negative investment incentives effect even if the cost parameter \mathbf{j} is low. As in the previous case (Corollary 1) it is more likely that the consumer surplus is higher under access price regulation compared to the case without regulation if the difference between the firms' ability to offer value-added services is large.

2.5 Access price regulation and non-price foreclosure

In this section we analyse whether the vertically integrated firm may have incentives to overinvest as an alternative foreclosure tool when assumption 2 is altered. Until now we have assumed that the rival firm's quantity increases when the investment increases for a given access price (assumption 2). In contrast, we now assume that $2\mathbf{b}_2 - \mathbf{b}_1 < 0$, such that the rival will reduce its quantity when the investment increases for a given access price (since $dq_2^*/dx < 0$ in stage 2). For simplicity, we make the following assumption:

Assumption 3: $\mathbf{b}_1 \equiv 1 > 2\mathbf{b}_2 > 0$

At stage 0 the vertically integrated firm sets x , and at stage 1 the vertically integrated firm or the regulator sets the access price. We know that for low values of \mathbf{b}_2 , it may be optimal for the regulator to set the access price above marginal cost (see above). For the sake of simplicity, we assume that the optimal regulated access price at stage 1 is $\bar{w} \geq c$. 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 analysed by Dixit (1980).

The stage 2 quantities given that $\bar{w} \geq c$ are $q_1^* = (a - 2c + \bar{w} + x(2 - \mathbf{b}_2))/3$ and $q_2^* = (a + c - 2\bar{w} + x(2\mathbf{b}_2 - 1))/3$. We analyse whether the vertically integrated firm (the first-mover) chooses to invest to foreclose the rival (deterrence of entry) or to share the market with the rival (accommodation of entry).

Blockaded entry

The monopoly investment given assumption 3 is $x_m^* = (a - c)/(2\mathbf{j} - 1)$. If we insert x_m^* into q_2^* we find that entry is blockaded with the monopoly investment when $\underline{\mathbf{b}}^c \equiv \mathbf{b}_2 \leq (a - c)(1 - \mathbf{j}) + (\bar{w} - c)(2\mathbf{j} - 1)/(a - c)$. The question is whether the vertically integrated firm will overinvest in x when $\underline{\mathbf{b}}^c < \mathbf{b}_2 \leq 0.5$.

Entry deterrence through non-price foreclosure:

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

$$\frac{dp_2}{dx} = \mathbf{b}_2 q_2 + (-q_2)((2 - \mathbf{b}_2)/3) = 2q_2(2\mathbf{b}_2 - 1)/3$$

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, which will be negative. An increase in x increases the second stage choice of q_1 . Since the quantities offered by the two firms are strategic substitutes, an increase in q_1 will lower the profit margin for ISP 2.

When assumption 3 is met ($2\mathbf{b}_2 - 1 < 0$), the strategic effect dominates the direct effect. To foreclose the rival the vertically integrated firm should overinvest such that $q_2^f = 0$ (superscript f indicates foreclosure by overinvestment):

$$q_2^f = 0 \Rightarrow x^f = \frac{-a + 2\bar{w} - c}{2\mathbf{b}_2 - 1}$$

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 $\mathbf{b}_2 < 0.5$:

$$\frac{dx^f}{d\bar{w}} = \frac{2}{2\mathbf{b}_2 - 1} < 0$$

and

$$\frac{dx^f}{d\mathbf{b}_2} = \frac{-2(-a + 2\bar{w} - c)}{(2\mathbf{b}_2 - 1)^2} > 0$$

For a lower local access price, the vertically integrated firm's response is to increase the investment if it wants to deter entry. The higher \mathbf{b}_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. Inserting for x^f we find that $q_1^f = [(a - c)(\mathbf{b}_2 - 1) + (\bar{w} - c)] / (2\mathbf{b}_2 - 1)$. For $\mathbf{b}_2 < 0.5$ we see that:

$$\frac{dq_1^f}{d\bar{w}} = \frac{1}{2\mathbf{b}_2 - 1} < 0$$

Hence, a restrictive access price regulation may be effective even if no inputs are sold to the rival. When the access price increases, the vertically integrated firm must 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:

$$\mathbf{p}_1^f = (q_1^f)^2 - 0.5\mathbf{j} (x^f)^2$$

$$W^f = \mathbf{p}_1^f + 0.5(q_1^f)^2$$

Now it can be shown that:

$$\frac{dW^f}{d\bar{w}} = \frac{(a-c)(3\mathbf{b}_2 - 3 + 2\mathbf{j}) + (\bar{w} - c)(3 - 4\mathbf{j})}{(2\mathbf{b}_2 - 1)^2}$$

When this is negative, we see that an access price regulation may be effective even if the rival is still foreclosed from the market. The reason is that an access price regulation 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's point of view (Spence, 1975).

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

Even if $q_2^f = q_2^* = 0$, the welfare will increase if the regulator through a binding access price regulation gives the vertically integrated firm an incentive to increase the investment compared to x_m^* .

Proposition 5: *Let us assume that $\mathbf{b}_1 \equiv 1 > 2\mathbf{b}_2 > 0$ and that there is a binding access price regulation. Then we have the following results:*

- i. *The vertically integrated firm overinvests compared to the monopoly equilibrium without access price regulation, i.e. $x^f - x_m^* > 0$.*
- ii. *When the unconstrained monopoly underinvests seen from the regulator's point of view, access price regulation increases welfare since it forces the vertically integrated firm to invest more.*
- iii. *If the rival has a 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. $q_2^f = q_2^* = 0$.*

If the vertically integrated firm chooses not to foreclose the rival (accommodation of entry) it will set x to maximise its own profit. We interpret $\bar{\mathbf{b}}^c$ as the critical value for whether foreclosure is optimal or not. Hence we have three intervals analogous to Dixit (1980):

- i. Blockaded entry when $\underline{b}_2 \leq \underline{b}^c$: The rival is blocked from entry by the monopoly investment level x_m^* .
- ii. Deterrence of entry when $\underline{b}^c < \underline{b}_2 < \bar{b}^c < 0.5$: The vertically integrated firm overinvests to foreclose the rival.
- iii. Accommodation of entry when $0.5 > \underline{b}_2 \geq \bar{b}^c$: Then it is more profitable for the vertically integrated firm to set x that maximises its own profit, even if the rival is 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. Note that the main difference from the previous case is that $\underline{b}_1 > 2\underline{b}_2$. The literature on non-price foreclosure typically focuses on the detrimental impact on welfare when an access price regulation gives incentives to extend the untapped market power by non-price methods. In contrast, in our context, it may increase welfare.

3 Some concluding remarks

In this paper we have analysed a market structure where a vertically integrated firm controls an essential input for retail providers of Internet connectivity. The vertically integrated firm may undertake an investment that increases the quality of the input (upgrading to broadband). In an unregulated retail market the vertically integrated firm competes with an independent firm that buys access as an input. We analyse the effect of an access price regulation that is imposed on the vertically integrated firm. Since an upgrade of the local access network to broadband is an irreversible investment, we assume that the regulator has limited commitment ability with respect to the access price. Hence, the access price is set after the investment, but before retail competition.

We compare the access price regulation regime with the outcome without regulation. The total effect on consumer surplus and welfare critically depends on whether the vertically integrated firm has higher ability to offer value-added services (broadband services) than the rival firm. If the retailers do not differ too much with respect to their ability to offer value-added services, when the input is improved, we show that access price regulation reduces the vertically integrated firm's investment incentives. Furthermore, an access price regulation

lowers consumer surplus and total welfare as long as the cost of investment is not too convex. In contrast, if the vertically integrated firm's ability to offer value-added services is much higher than that of the independent rival, an increase in the investment level will reduce the quantity offered by the independent retailer. The vertically integrated firm may then use overinvestment as an alternative tool to drive the rival out of the market.

In our model the regulated access price will be set equal to or close to the marginal cost. Hence, compared to the case without access price regulation the regulator removes most of the vertically integrated firm's cost advantage in the retail market. If the retailers' ability to offer value-added services is quite similar, then the independent firm will have higher profit than the facility-based firm since the latter has to cover the investment costs. Put differently, the access price regulation may imply a second-mover advantage. In the present paper we have not focused on entry, but this feature of the regulation will probably discourage facility-based entry. In particular this will be true if we incorporate uncertainty in the analysis. The non-facility-based firm may enter the market later, and, furthermore, does not need to make the irreversible investment.

The timing structure seems to correspond to the current regulatory paradigm both in the EU and the USA. This paradigm mandates that the access price should be set to the long-run incremental costs (LRIC). At first glance, this may include the investments in e.g. broadband upgrades, while we show that the regulator will set the access price equal to the marginal cost as long as the retailers do not differ too much in their ability to offer value-added services. The main feature is, however, that the determination of the long-run incremental costs is highly discretionary and that the decision is taken after the investment is made. Hence, its impact on incentives to invest before the discretionary decision on the access price will be analogous to the case analysed in the present paper. Hausman (1997) argues that FCC's measure of LRIC ignores the existence of technological progress that is reducing the prices and increasing the quality of the components in a broadband access network. Hence, LRIC implies an access price corresponding to the most efficient components available at the time the access price is set, and this will not cover the investment costs under a rapidly changing technology. Uncertainty is not formerly analysed in the present model, but there is obviously a significant probability of failure when a firm invests in a broadband access network, and this will make the problem of investment incentives even more important. The current LRIC

approach does not cover the costs of unsuccessful services.²⁵ Cave and Prosperetti (2001) focus on the situation in the EU, and they argue that the incumbents do not have sufficient incentives to upgrade to broadband access, since they anticipate that they will be forced to offer access at cost-based prices.

If there was no ability to improve the network quality through the investment, a regulated access price close to or equal to marginal costs will improve welfare compared to the case without an access price regulation. This indicates that the current regulation regime in EU and the USA may be better than no regulation if static efficiency was the only goal for the regulator. In contrast, when there is an investment decision before the access price regulation is decided, the benchmark without access price regulation may imply higher welfare, but the conclusion is ambiguous. Obviously, the regulator may alter the outcome by non-linear wholesale prices, price regulation in the retail market, and line-of business restrictions, but the basic challenge seems to be the choice of rules versus discretion in the governments' policy. When the policymaker has the opportunity to set the access price discretionary after the investment, it will set the access price close to marginal cost (or LRIC). When the decision is taken after the investment, this is the best thing to do for the regulator, given the current situation. It is not a result of non-optimal behaviour from the regulator. If the regulator wishes to realise the outcome in the case without access price regulation, it has to credibly commit to a policy rule before the investment that prevents the regulator from using the discretionary access price regulation.²⁶

²⁵ See Hausman (1997) for further discussion on these issues.

²⁶ The classic paper on time inconsistency and rules versus discretion is Kydland and Prescott (1977).

References

- Armstrong, M. 2001. "The Theory of Access Pricing and Interconnection", in Cave, M., S Majumdar, and I. Vogelsang (eds.): *The Handbook of Telecommunications Economics*, North Holland, forthcoming.
- Bulow, J., J. Geanakoplos, P. Klemperer. 1985. Multimarket Oligopoly: Strategic Substitutes and Complements, *Journal of Political Economy*, 93, 488-511.
- Cave, M. and R. Mason. 2001. The Economics of the Internet: Infrastructure and Regulation, *Oxford Review of Economic Policy*, 17(2), 188-210.
- Cave, M. and L. Prosperetti. 2001. European Telecommunications Infrastructures, *Oxford Review of Economic Policy*, 17(3), 416-431.
- Crémer, J, P. Rey and J. Tirole, 2000, Connectivity in the Commercial Internet, *Journal of Industrial Economics*, XLVIII, 433-472.
- D'Aspremont, C. and A. Jacquemin. 1988. Cooperative and Noncooperative R&D in Duopoly with Spillovers, *American Economic Review*, 78 , 1133-1137.
- Dixit, A. 1980. The Role of Investment in Entry Deterrence, *The Economic Journal*, 90, 95-106.
- Economides, N. 1998. 'The incentive for non-price discrimination by an input monopolist', *International Journal of Industrial Organization*, 16, 271-284
- Faulhaber, G.R. and C. Hogendorn. 2000. The Market Structure of Broadband Telecommunications, *The Journal of Industrial Economics*, XLVIII, 305-329.
- Foros, Ø., H.J. Kind and L. Sjørgard. 2002. Access Pricing, Quality Degradation and Foreclosure in the Internet, *Journal of Regulatory Economics*, 22(1)
- Foros, Ø. and B. Hansen. 2001a. Competition and Compatibility among Internet Service Providers, *Information Economics and Policy*, 13(4), 411-425.
- Foros, Ø. and H.J. Kind. 2002. The Broadband Access Market: Competition, Uniform Pricing and Geographical Coverage, *Journal of Regulatory Economics*, forthcoming.

- Hausman, J. A., J. G. Sidak, and H. J. Singer. 2001. Cable Modems and DSL: Broadband Internet Access for Residential Customers, *The American Economic Review, Papers and Proceedings*, 91, 302-307.
- Hausman, J. A. 1997. Valuing the Effects of Regulation on New Services in Telecommunications, *Brookings Papers on Economic Activity, Microeconomics*, 1-38.
- Katz, M. and C. Shapiro. 1985. Network Externalities, Competition, and Compatibility, *American Economic Review*, 75, 424-440.
- Kreps, D.M. and J.A. Scheinkman. 1983. Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes, *Bell Journal of Economics*, 14, 326-337.
- Kydland, F.E. and E.C. Prescott. 1977. Rules Rather than Discretion: The Inconsistency of Optimal Plans, *Journal of Political Economy*, 85, 473-491.
- Laffont, J.J. and J. Tirole, 2000, *Competition in Telecommunication*, The MIT Press, Cambridge, Massachusetts.
- Mackie-Mason, J. 1999. Investment in Cable Broadband Infrastructure: Open Access is Not an Obstacle, available from www-personal.umich.edu/~jmm/
- Petkovic, Y. and R. De Coster. 2000. Broadband Access: New Business Models, Ovum September 2000
- Rey, P. and J. Tirole. 1997. A Primer on Foreclosure. Mimeo, IDEI, Toulouse. Forthcoming, *Handbook of Industrial Organization*, eds. M. Armstrong and R.H. Porter
- Roche, P.J., J.C. Garcia, J. Wilkins, S.C. Beardsley, P. Edin, P. Loulou, and W.A. Mohn. 2001. Pipe War: Which Broadband Technology will win the Race for Homes and Offices?, *The McKinsey Quarterly*, no. 1, 178-193.
- Rubinfeld, D.L. and H.J. Singer. 2001. Vertical Foreclosure in Broadband Access. *The Journal of Industrial Economics*, XLIX, 299-318.
- Sibley, D.S. and D.L. Weisman. 1998. Raising Rivals' Costs: The Entry of an Upstream Monopolist into Downstream Markets', *Information Economics and Policy*, 10, 451-470.
- Shapiro, C. and H. Varian. 1998. *Information Rules: A Strategic Guide to the Network*

Economy, Harvard Business School Press, Boston, Massachusetts.

Spence, M.A. 1975. Monopoly, Quality, and Regulation, *Bell Journal of Economics*, 6, 417-429.

Spence, M.A. 1984. Cost Reduction, Competition and Industry Performance”, *Econometrica*, 52(1), 101-121.

Tirole, J. 1988. *The Theory of Industrial Organization*, The MIT Press

Weisman, D. L. 1995. Regulation and the Vertically Integrated Firm: The Case of RBOC Entry into Interlata Long Distance, *Journal of Regulatory Economics*, 8, 249-266.

Weisman, D. L. 1998. The Incentive to Discriminate by a Vertically-Integrated Regulated Firm: A Reply, *Journal of Regulatory Economics*, 14, 87-91.

Weisman, D.L. and J. Kang. 2001. Incentives for Discrimination when Upstream Monopolists Participate in Downstream Markets, *Journal of Regulatory Economics*, 20, 125-139.

Wey, C. 1999. Compatibility Investments in Duopoly with Demand Side Spillovers under Different Degrees of Cooperation, *Zeitschrift für Wirtschafts- und Sozialwissenschaften*, 119, 399-427.

Appendix

Proof of Lemma 2:

A necessary and sufficient condition for market sharing is now that $\mathbf{b}_2 > \mathbf{b}_1$.

$$x^* - x_m^* = [4(a-c)\mathbf{b}_1(\mathbf{b}_2 - \mathbf{b}_1)^2] / (A^* A_m^*) > 0$$

$$dx^* / d\mathbf{b}_2 = 40(a-c)\mathbf{b}_1(\mathbf{b}_2 - \mathbf{b}_1) / (A^*)^2 > 0 \text{ if } \mathbf{b}_2 > \mathbf{b}_1$$

$$dq_2^* / d\mathbf{b}_2 > 0 \text{ if } \mathbf{b}_2 > \mathbf{b}_1. \text{ QED.}$$

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:

$$\frac{dx^r}{d\mathbf{b}_2} = -\frac{2(a-c)}{(A^r)^2} [A^r + 4(2\mathbf{b}_1 - \mathbf{b}_2)^2] < 0$$

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

$$dQ^r / d\mathbf{b}_2 = -2(a-c)[3\mathbf{j}(2\mathbf{b}_2 - 1) + 8(1 - \mathbf{b}_2) + 2\mathbf{b}_2^2] / (A^r)^2 < 0 \text{ for } \mathbf{b}_2 \in [0.5, 1]$$

- i. We have $dx^r / d\mathbf{b}_2 < 0$. Hence, it is sufficient to ensure $x^r - x_m^* < 0$ for $\mathbf{b}_2 = 0.5$. For $\mathbf{b}_2 = 0.5$ we have that $x^r - x_m^* = -(a-c) / 3A_m^* < 0$.
- ii. We have that $dQ^r / d\mathbf{b}_2 < 0$ for $\mathbf{b}_2 \in [0.5, 1]$. Hence, let us insert for $\mathbf{b}_2 = 0.5$. Then we have $Q^r - q_m^* = (a-c)[3\mathbf{j}^2 - 4.5\mathbf{j} + 1.5] / A^r A_m^*$ which is negative for $\mathbf{j}_{crit} < \mathbf{j} < 1$ and positive for $\mathbf{j} > 1$. QED

Proof of Proposition 4:

- i. $x^r - x^* = (a-c)[2(2\mathbf{b}_1 - 1)A^* - 5\mathbf{b}_1 A^r] / A^r A^*$. Hence to check $x^r - x^* \geq 0$ we see whether $[2(2\mathbf{b}_1 - 1)A^* - 5\mathbf{b}_1 A^r] \geq 0$. This requires that $\mathbf{j} \leq 2(2\mathbf{b}_1^2 - 3\mathbf{b}_1 + 1) / 5$ which will never be fulfilled for $\mathbf{b}_1 \in [0.5, 1]$ and $\mathbf{j} > \mathbf{j}_{crit} = 0.5$.
- ii. $Q^r - Q^* = (a-c)[A^*(6\mathbf{j} + 2(2\mathbf{b}_1 - 1)(1 - \mathbf{b}_1)) - A^r(5\mathbf{j} - 3\mathbf{b}_1^2 + 5\mathbf{b}_1 - 2)] / A^r A^*$. Let us check whether $[A^*(6\mathbf{j} + 2(2\mathbf{b}_1 - 1)(1 - \mathbf{b}_1)) - A^r(5\mathbf{j} - 3\mathbf{b}_1^2 + 5\mathbf{b}_1 - 2)] \geq 0$. When solving the inequality with respect to \mathbf{j} we find that: $\mathbf{j} \geq \frac{1}{3}(\mathbf{b}_1(3\mathbf{b}_1 - 1) + 2)$.

Moreover we see that the restriction on j to ensure $Q^r - Q^* \geq 0$ is stronger for higher b_1 since $\frac{\partial j}{\partial b_1} > 0$ for $b_1 \in [0.5, 1]$ QED.