Access Rules and Investment Incentives[*]

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Abstract

This paper studies firm's investment behavior for essential facilities under mandatory access provision. I show that firms underinvest when confronted with fixed access charges in a wide range of settings. I investigate two approaches to solve this problem. First, departing from the standard assumption of fixed per consumer payments, access charges are made contingent on firms' investment levels. I show that by choosing an appropriate rule, it is possible to reach socially efficient investment levels without distorting downstream competition. Second, I study the effects of lump sum access payments: firms have to pay a fixed fee proportional to investment costs to access its competitor's network. Using such rules results in higher investment than under fixed per consumer access payments. This result is independent of whether such payments are regulated or privately negotiated by firms. Furthermore, lower retail prices prevail. Despite these positive effects, investment is still too low compared to the social optimum in this case.

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1 Introduction

"Millions of our citizens want - but can't get - effective access to media services that their friends or family use in other parts of the world. It is therefore essential to establish clear regulatory guidelines to encourage investment in next generation access networks, while ensuring that such networks remain open and competitive in the interest of consumers."[1]

This recent statement by Neelie Kroos, the European Commissioner for Digital Agenda, highlights the challenges that arise from the development of the next generation fiber networks. Widespread high-speed internet is one of main goals of the Europe 2020 strategy to foster economic growth. Current regulation has failed to implement this, not sufficiently promoting the development of these networks in the EU. This raises the question why the regulatory guidelines that are currently in place perform poorly and how they should optimally look like.

There is wide range of possible solutions. For investment, one could for instance let the incumbent or another firm explore the new network alone, i.e. grant a (temporary) monopoly. Letting a group of operators invest jointly is another option. Moreover, public financing either via direct investment or by establishing a private-public partnership (PPP) is also possible. The next question is whether and how access should be regulated. Without regulation, foreclosure of competitors from the network might occur. Under mandatory access provision, access conditions determine the intensity of competition.

The main problem underlying these questions is to reconcile the conflicting goals of static and dynamic efficiency. A company is only willing to build a network if it has the prospect of earning profits at least covering its investment costs (plus a reasonable return on investment). Once the network is built, however, the regulator seeks to maximize consumer surplus, favoring a market structure that drives down consumer prices, i.e. forcing the firm to share its facilities. This, however, makes investment less profitable and may make projects non-viable in the first place. The authority, apart from seeking to assure efficiency, tries to keep intervention as low as possible.

Looking at the situation in different countries shows a mixed picture. In the German debate for instance, granting the exclusive right to explore the new network to the former incumbent has been the preferred solution by the government. This was planned to be supplemented by access holidays, i.e. competitors do not have access to the new

[1] EC press release, MEMO/10/137, `http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/10/137`

network. In France, on the contrary, any network operator can choose to invest individually in the new technology under the premise that additional fiber is installed at other service providers' requests (which then have to share the installation costs). Also in other parts of the world, development of next generation networks has been given top priority. In Australia, for instance, high-speed internet has been identified as a key to economic growth by the government. It has thus decided to finance the majority the new \$31 billion network publicly by establishing a PPP in which the state is the majority shareholder. It thus becomes obvious that these different possibilities do not just exist theoretically but rather that there is no consensus about which one is the best in reality.[2]

This paper investigates the effects of various investment and access regimes on investment for an essential facility and on downstream competition. Although the main motivation for the paper is given by fiber deployment, the analysis carries over to other situations. The idea followed in this paper is to depart from the common practice and standard assumption in the literature of fixed per consumer access payments. Two approaches are presented. First, a firm's access charge is made contingent on the amount of its own investment which I will call endogenous access charges in the following. A firm is rewarded with a competitive advantage in access terms if it invests more and thus is given more incentives to invest in the first place. By specifying an access rule depending on investment, the regulator has another tool to mitigate the tension between static and dynamic efficiency. Second, I explore the effects of investment cost sharing. Instead of paying marginal charges for each consumer, firms have to pay lump sum fees to access their rival's network. To which extent these rules prove to be useful will be the core question of this paper.

The remainder of the paper is organized as follows. The following section gives an overview of the related literature. Section 3 presents the model to study the problem at hand. Section 4 sets out the benchmark model which represents the current situation of fixed access charges and studies the welfare effects of such regimes. Endogenous access charges and their effects on investment behavior and welfare will be explored in the subsequent section. Section 6 examines the effects of investment cost sharing. Section 7 contrasts these results with the ones obtained under the endogenous access rule. The final section offers some concluding remarks. An appendix studies the role of uniform pricing constraints.

[2] See also Bourreau et al. (2010) for an overview of the current situation in some European countries.

2 Related literature

This paper is related to several strands of the literature. The first one is the literature on access pricing which recently has mainly focused on telecommunications. Starting with the seminal papers by Laffont et al. (1998) and Armstrong (1998), it has studied the role access charges play on competition between interconnected networks. The main difference with this literature is that it studies two-way access problems, both firms have to have access to each other's network to provide services for their customers. This is different from the situation considered here which can be better described as one of bilateral one-way access. Furthermore, this literature focuses on the divergence of interests when setting access charges from the regulator's and the firm's point of view. The present paper rather stresses the tension between investment incentives and competition.

The idea of not fixing access charges but rather make them depend on firms' decisions was brought up in the context of telecommunications by Jeon and Hurkens (2008). They show that it is possible to achieve socially efficient pricing behavior by firms. This is done by making access charges that one firm has to pay to its competitors depend on the retail price it charges its own customers. The advantage of their proposed rule is that the informational requirements for the regulator are very low: the optimal rule is independent of demand conditions. They also consider the case where operators can invest in the quality of their network. By choosing an appropriate rule it is possible to achieve dynamic (optimal amount of investment) and static (socially efficient retail prices) efficiency.[3]

Another literature related to this paper is about the financing of essential facilities. Caillaud and Tirole (2004) study such a situation when an incumbent has private information about market profitability. The regulator faces the decision of whether to allow a new firm to enter the market in exchange for a financial contribution or grant a monopoly to the incumbent. They show that it is not possible to make the incumbent truthfully reveal the demand state. It is thus optimal for the regulator not to use the incumbent's information. It should rather just rely on its own prior beliefs on market profitability when determining the market structure, highlighting the tension between static and dynamic efficiency.

Jullien et al. (2010) study investments in next generation networks. They examine a setting with a regulator, an incumbent who can upgrade its existing network and a local

[3]In a one way access context, a similar idea is followed by Klumpp and Su (2010). They show that by using a revenue neutral access rule static efficiency does not have to be sacrificed for dynamic efficiency.

authority which can also invest to build its own network. If the incumbent is the only one to invest, it is paid an access charge set by the regulator. In the case of duplication of the network, however, the local authority sets a socially optimal zero access charge. This leads to losses for the incumbent if it has invested before. With perfect information, there is no problem since the incumbent can perfectly anticipate the local authorities decision. Socially wasteful duplication hence would never happen. Under uncertainty about the local authorities behavior, however, the incumbent has to be either compensated for this risk or duplication mustn't be allowed. This shows that severe problems can arise under imperfect information in these cases.

Moreover, there has been a literature on network investments that mostly focuses on broadband networks.[4] Foros and Kind (2003), for instance, show that allowing firms to price discriminate between different locations is welfare improving. Imposing them to charge uniform prices hence is detrimental to welfare. Furthermore, competition may be welfare decreasing when uniform pricing is required. However, they focus on purely facility-based competition and do not allow operators to access each others' networks. Moreover, firms completely duplicate their networks in their model. Valletti et al. (2002) also study the effects of uniform pricing and coverage constraints on competition, highlighting their complex interaction.

A model related to this paper, is de Bijl and Peitz (2004). They study competition between an integrated firm that owns a network infrastructure and provides services to consumers and an entrant that is only active in the downstream market. They show that under inelastic demand, the integrated firm benefits from higher access prices whereas the entrant's profit is not affected by the level of access charges. Moreover, they study incentives to invest. They show that an access price schedule that is increasing in investment raises investment incentives independent of the intensity of competition in the downstream market. However, they are not explicit how such access prices should look like and to which extent they can be used.

Bourreau et al. (2009) study a model of two-tier competition between vertically integrated firms and unintegrated downstream firms. They demonstrate, among other things, how high access charges can be used to soften downstream competition between the integrated and non-integrated firms. Firms anticipate that some consumers to whom they do not sell downstream if they increase their prices, will buy from their non-integrated rival. This yields access revenue upstream and hence makes them price

[4] See Cambini and Jiang (2009) for a recent literature overview.

less aggressively downstream.

In an independent research, Henriques (2011) also develops the idea of linking access prices and investment which forms the first part of the present paper. While the basic result that this improves welfare is similar, the present paper is able to characterize to which extent this can be used to achieve the optimum. Moreover, the specifications of the access rule used in his paper differs from the one used in this paper. In his model, the access price the incumbent (entrant) receives (pays) depends positively (negatively) on its investment (contribution) whilst in my model only the access price received is contingent on a firm's investment.

The idea of this paper is to take a competitive market structure as given and see how different investment and access regimes perform from a social point of view. Moreover, firms have access to each others' networks on a regulated basis. In particular, I will propose to endogenize access charges or let firms share investment costs to improve social welfare.

3 Model

I study a situation where two firms denoted by $i = 1,2$ build non-overlapping networks and then provide differentiated network services to consumers.

There is a total mass two of consumers, a mass one in each of the two territories that exist. Hence, there is a unit mass of consumers in each territory that I assume to be uniformly distributed over the support $[0,1]$. Moreover, at each point of the support consumers are uniformly distributed over a Hotelling line at whose endpoints firms are located. One way to think of this is to see a territory as a continuum of cities where the population of each city is identical.

Each consumer chooses from which firm to buy the network service. Demand is thus assumed to be inelastic and equal to one unit for each consumer covered by any network. This assumption grasps the fact that almost all broadband offers today are flat-rates, hence contracts only entail a fixed fee without any variable usage costs. Subscribing to any network yields a fixed benefit v. Networks are locally differentiated à la Hotelling: consumers face a disutility from not being connected to their ideal taste network. Being located at x, a consumer incurs a transportation cost $t|x-l|$ when buying from firm i located at l, where $l=0$ for firm 1 and $l=1$ for firm 2. I assume these parameters to be small enough for the investment decision of firms detailed later on to have an interior solution. A consumer's utility is given by:

$$U = v - p_i - t|x - l| \tag{1}$$

There are no network externalities between consumers, i.e. the utility of consumers is independent of the number of people who buy the service. The motivation for this simplifying assumption can be seen in the context of fiber networks as follows. The gains from a faster internet connection are more important for services obtained from content providers (High Definition TV, websites etc.) than for communication between consumers. Hence I abstract from positive network externalities. Moreover, fiber technology allows for such high connection speeds that congestion is not an issue. Thus I neglect any negative network externalities. Furthermore, I assume that the decision of consumers of which network to join is independent of the network ownership in their territory.

Firms choose their network coverage K_i for which they incur a cost $C_i(K_i)$. The cost function is assumed to be increasing and convex in the size of investment, i.e. $\frac{\partial C_i}{\partial K_i} > 0$ and $\frac{\partial^2 C_i}{\partial K_i^2} > 0$. For technical simplification, I assume these costs to be quadratic. The cost function is thus given by $C_i(K_i) = K_i^2$. Marginal costs for serving a customer are normalized to zero. In the context of fiber-networks they are very low anyway, most of the costs occur due to network investment.[5] I assume that networks are non-overlapping, firms invest in distinct territories and hence there is no duplication. Without loss of generality assume that firm 1 invests in territory 1 and firm 2 in territory 2. The potential market size is thus given by the total coverage $\sum_{i=1}^{2} K_i = K$.

This setting can be reinterpreted in the following way. Firms choose in which regions they want to build their infrastructure. As investment eventually occurs in less dense areas, the cost of connecting the same number of consumers is increasing in the network size. The assumptions of uniform consumer density and convex costs thus capture the more realistic setting of having varying consumer density and constant or decreasing marginal costs for connecting additional consumers through economies of scale.

The two firms have access to each other's network on a regulated basis. Suppose a consumer subscribes to one firm's service but the territory's infrastructure is owned by the other firm. The service provider i then has to compensate the network owner j either by paying an access charge a_{ij} (up to section 5) or a lump sum fee A_{ij} (section 6).

I suppose that the regulator can commit to imposing the access rule ex ante. If this

[5] See e.g. Amendola and Pupillo (2008) for an overview of the costs of investment.

was not the case, network operators should anticipate that the regulator may impose an access regime promoting competition after investment has taken place. This may make investment unprofitable and will hence not be made in the first place.

The timing of the game is as follows. First, the regulator specifies an access rule. Then firms invest simultaneously in their respective territories. After that, firms set their retail prices, which are uniform across territories, simultaneously.[6] Finally, consumers choose which network to join.

Figure 1: Timing

I assume that firms choose to access its competitor's network as long as they make non-negative profits by doing so. Moreover, I suppose that the regulator only imposes access regimes that guarantee non-negative profits if access is bought, i.e. I abstract from margin squeezes.

I will use the model presented in this section to study various access and investment regimes. I use backward induction to look for the subgame perfect Nash equilibrium of this sequential game. Hence I solve for profit maximizing retail prices for a given coverage in a first step and then for optimal coverage afterwards.

4 Fixed access charges

4.1 Benchmark

In this section, I present firms' decisions when they are confronted with fixed reciprocal access charges. This will serve as a benchmark to which I then compare other access regimes. The analytical derivations follow the standard procedure of profit maximization for a Hotelling duopoly (see e.g. Troncoso-Valverde and Robert (2004) for a more detailed derivation and discussion of a similar problem).

[6]Non-uniform pricing will be studied in the appendix.

Firms' profits are given by:

$$\max_{p_i,K_i} \pi_i = \left[\phi_i(p_i,p_j)p_iK + \phi_j(p_j,p_i)aK_i - \phi_i(p_i,p_j)aK_j\right]$$
$$- C_i(K_i) \qquad i,j = 1,2, \quad i \neq j \tag{2}$$

where the probability of a consumer to subscribe to network i is denoted by ϕ_i and given by

$$\phi_i(p_i,p_j) = \max\left[\min\left\{\frac{1}{2} + \frac{p_j - p_i}{2t}; \frac{v - p_i}{t}; 1\right\}; 0\right] \tag{3}$$

The first part of profits represents retail revenues, the subsequent terms access revenue and payments, and the last investment costs. The expression in (3) can be explained as follows. If transportation cost is relatively low and consumers' valuations are high, firms are effectively competing for consumers and each firm's demand depends on the prices of both firms. Demand is given by the first term in brackets in this case. For higher transportation costs, some consumers have such a high disutility from being connected to either network that they prefer to remain unsubscribed. Each firm is thus only facing the decision of how many of the consumers who are located close to it, it wants to subscribe: firms are local monopolists over consumers. The rest of this expression ensures that the probability of subscribing a consumer is indeed between 0 and 1.

The following two lemmas give the equilibrium retail prices and investments.

Lemma 1 *Retail prices are given by*

$$p_i = \begin{cases} t + a & \text{if} \quad t \leq 2/3(v - a) \\ v - t/2 & \text{if} \quad v - \frac{K_j}{K}a \geq t > 2/3(v - a) \\ v/2 + \frac{K_j}{2K}a & \text{if} \quad t > v - \frac{K_j}{K}a \end{cases} \tag{4}$$

and hence symmetric for equal coverages, firms thus share the market equally.

Proof. Firm i's best-response correspondence is given by:

$$B_i(p_j) = \arg\max_{p_i}\left[\phi_i\left(p_i - \frac{K_j}{K}a\right) + \phi_j\frac{K_i}{K}a\right] \tag{5}$$

Taking the symmetric counterpart for firm j and finding the fixed points yields the given equilibrium prices. ■

Lemma 2 *Firms' investments are given by*

$$K_i = \begin{cases} \frac{t/2+a}{2} & \textit{if} \quad t \leq 2/3(v-a) \\ \frac{v/2-t/4+a/2}{2} & \textit{if} \quad v-a/2 \geq t > 2/3(v-a) \\ \frac{\phi_i(p_i)(v/2+5/4a)}{2} & \textit{if} \quad t > v-a/2 \end{cases} \tag{6}$$

where the different ranges stem from the corresponding retail price regions.

Proof. Once again follows from profit-maximization and using the symmetry to determine the upper bound (lower bound) of the second (third) range. ■

The following graph illustrates the results of retail prices for symmetric equilibrium investments which is the unique equilibrium here.

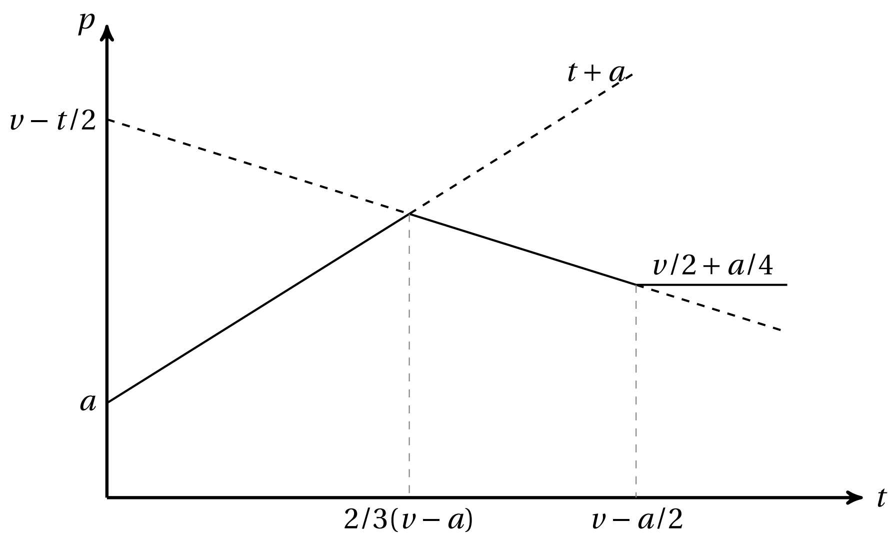

Figure 2: Equilibrium prices

The pricing behavior of firms, given by the solid black line, depends on the relative size of consumers' valuations, firm's differentiation and access charges. The standard Hotelling duopoly prices are prevailing if consumers' valuations are high and transportation costs and access charges are low. Retail prices are equal to a mark-up over access charges and all consumers subscribe to one of the two firms. The mark-up is determined by and increasing in consumers' transportation costs or differentiation of the two service providers. Note that any increase in the access price is passed on to consumers one-by-one. If transportation costs are in the range $v-a/2 \geq t > 2/3(v-a)$, firms find it profitable to decrease their prices as transportation costs increase. They prefer to get all consumers to subscribe to one of the firms over charging higher prices. Finally, if transportation costs are large, i.e. $t > v - a/2$, firms are monopolists over the consumers they are serving. They charge monopoly prices equal to $v/2 + a/4$ which leaves some consumers unsubscribed. The retail prices of both firms are the same and independent of the relative size of each network. The unique equilibrium is thus symmetric, $\phi_i = \phi_j$.

Let us now turn to firm's investment behavior. Intuitively, firms optimally invest until the marginal revenue of investment equals the marginal cost of investment. Marginal revenue is given by the retail revenue that one firm gets from its own customers plus the access charges it gets from its rival's customers. This yields investment as described in Lemma 2.

In the following sections I want to focus on equilibria where the market is fully covered and thus assume that $v - a/2 \geq t$, i.e. I will ignore the last of the three cases considered in this section.

4.2 Constrained second best

To see how fixed access charges perform from a social point of view, let us consider the first best solution a benevolent planer would achieve. The social optimum is obtained by maximizing total welfare given by the unweighted sum of consumer surplus and profits. Formally:

$$\max_{\phi_i, K_i, K_j} W = CS + \pi_i + \pi_j = K\left[\int_0^{\phi_i} (v - tx)dx + \int_{\phi_i}^{1} v - t(1-x)dx\right] - \sum_{i=1}^{2} K_i^2 \tag{7}$$

From a social point of view, consumers' valuations are driving the optimal network size. As seen in the previous section, profitability determines the extent of the network under private investment.

Due to consumers' transportation costs, the welfare maximizing market shares are given by $\phi_i = \phi_j = 1/2$. Note that retail prices are welfare neutral when demand is inelastic since payments are just a redistributions between firms and consumers. The only requirement for prices is thus that $p_i = p_j$ ($< v - t/2$ to satisfy the assumption of inelastic demand). If both firms charge the same price, they share the market equally. This minimizes consumer's disutility from not being connected to her ideal taste network.

Furthermore, maximizing welfare with respect to coverage yields:

$$\frac{\partial W}{\partial K_i} = (v - t/4) - 2K_i = 0 \tag{8}$$

At the optimum, the marginal gain in consumer surplus of investment given by $v - t/4$ is equal to the marginal costs of investment. Solving this for the optimal coverage, we obtain:

$$K_i^* = \frac{v - t/4}{2} \tag{9}$$

Having calculated the socially optimal coverage, we can now compare this first best coverage to the one derived under private investment and fixed access charges in the previous section. The result is given in the following proposition.

Proposition 1 *Under fixed access charges, firms underinvest compared to the social optimum.*

Proof. First consider the case where $t \leq 2/3(v - a)$. For demand to be in this range, $p \leq v - t/2$. Thus $v \geq 3/2t + a$. If this holds, $v - t/4 > t/2 + a$ and hence $K_i^* > K_i$. Second, let us turn to the case where $v - a/2 \geq t > 2/3(v - a)$. Comparing K_i^* and K_i and simplifying, $K_i^* > K_i$ if and only if $v > a$. The condition $v > a$ has to hold since otherwise $p < a$ and hence firms would make losses accessing its rival's network which can not happen in equilibrium. ■

The intuition for this result is the following. Given competition and uniform pricing, firms are never able to extract the entire surplus created by investment. This result is general and not limited to the specific demand function chosen here. In this model, only perfectly price discriminating firms charging each consumer exactly her net surplus (her valuation minus her transportation cost times the distance to the nearest firm) would be able to do so absent fierce competition. Under uniform pricing and competition, the marginal revenue from investment is strictly lower than the marginal gain in consumer surplus. Optimality requires both of them to be equal to marginal cost. Hence firms invest less than would be socially desirable.

The problem we are facing is thus underinvestment by firms. In the following section I am thus looking for means to improve upon the outcome under fixed access charges. The challenge is to find ways to encourage investment.

Before turning to this question, let us briefly consider the role the level of access charges play here. As shown in this section, fixed access charges are a poor mean to achieve efficiency. Let us now investigate how private and social interests in setting fixed access charges compare.

Proposition 2 *Given fixed access prices, private and social interests in setting access charges are completely aligned, firms and the regulator prefer* $a = a^* = 2(v - t)$.

Proof. Although access payments cancel out in a symmetric equilibrium which is the unique equilibrium here, higher access charges inflate retail prices (except for $2(v-t) \geq a > v - 3/2t$) and increase the amount of access charges received. These two effects affect investment incentives. Plugging (4) and (6) into (2), the changes in firms' profits due to changes in access charges are given by

$$\frac{d\pi_i}{da} = \begin{cases} t/2 + a/2 > 0 & \text{if} \quad a \leq v - 3/2t \\ p_i/2 - a/2 > 0 & \text{if} \quad 2(v-t) \geq a > v - 3/2t \\ \frac{1}{2t}(v - 2p_i) < 0 & \text{if} \quad a > 2(v-t) \end{cases} \tag{10}$$

Hence firms would choose the upper bound of the middle range $a = 2(v-t)$ to maximize their profits if they can decide on the access price. Since this level of a maximizes coverage and there is full participation, a social planner would choose the same access price. ■

Note that this implies that firms would like to implement $a < 0$ if $t > v$ in order to increase participation.

The effects of access charges in the respective ranges are the following. For $a \leq v - 3/2t$, increasing a increases profits through increased retail price and increased coverage, any increase in the access charge is passed on entirely to consumers. This effect is similar to the basic result in the telecommunications literature that firms would collusively agree on high access charges above costs (see Laffont et al. (1998) and Armstrong (1998)).

In the second range where $2(v-t) \geq a > v - 3/2t$, an increase in the access price does no longer effect retail prices. However, higher a's increase the marginal revenue of investment through increased received access payments, resulting in higher equilibrium coverages and profits by firms. Any increase of a beyond $2(v-t)$ lowers profits since it results in some consumers remaining unsubscribed which implies a waste of investment.

Since the best a social planner can do is to maximize profits given full participation, the objectives of firms and the planner are aligned. The reaction of retail prices to changes in access charges given in the following figure provides some intuition for this result.

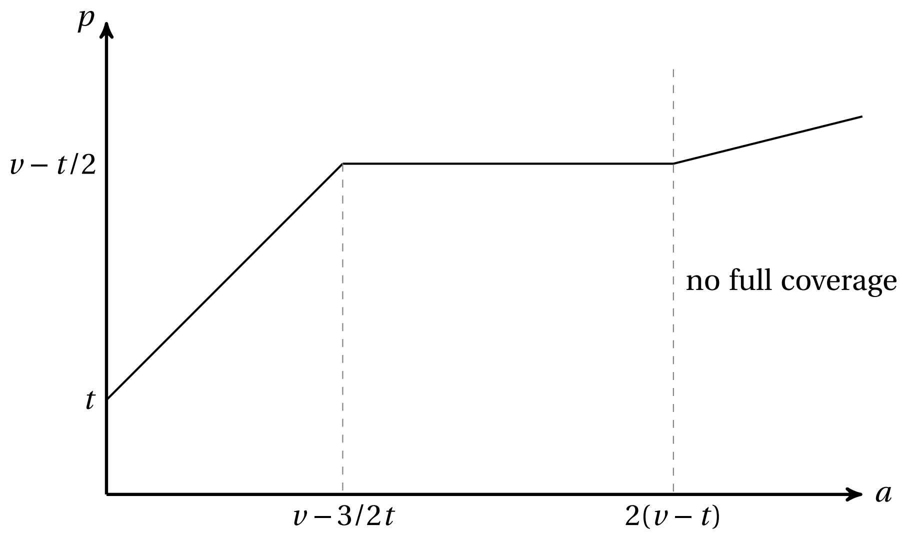

Figure 3: Effect of access charges on equilibrium prices

For $a \leq v - 3/2t$, any increase in the access charge is passed on entirely to consumers. For $2(v-t) \geq a > v - 3/2t$, retail prices do not react to access price changes. For $a > 2(v-t)$, only 1/4 of the access price is passed on to consumers.

5 Endogenous access charges

The approach I want to take in this section to increase investment incentives is to endogenize access charges. Contrary to the benchmark case, consider the situation where access charges are no longer fixed but determined by the investment levels of firms. Apart from the additional retail or access revenue that stem from owning a larger infrastructure, investment now affects profits through the changes in access terms.

Concerning access charges, I make the following assumption. The access rule must be non-discriminatory in the sense that it has to be independent of the identity of the firm:

$$\frac{\partial a_{ij}(K_i, K_j)}{\partial K_j} = \frac{\partial a_{ji}(K_i, K_j)}{\partial K_i}$$

The marginal impact on the access charges is the same for investment by any of the two firms. This assumption is driven by equity concerns, a regulator should not favor any firm over the other if they are identical otherwise.[7]

[7] Such non-discrimination is standard in any law as stated e.g. Article 10 of the Access Directive of the

Let us start with the simplest case where the access charges a firm receives are a linear function of its own investment. Formally:

$$a_{ji} = \lambda K_i \tag{11}$$

where $\lambda > 0$. When faced with such access charges, firms' decisions are as follows.[8] Contrary to the benchmark case, the access charges that firms have to pay to each other may be different. The FOC thus becomes:

$$\frac{\partial \pi_i}{\partial p_i} = \frac{1}{2} + \frac{p_j - p_i}{2t} - \frac{1}{2t}\left(p_i - \frac{K_i}{K}a_{ji} - \frac{K_j}{K}a_{ij}\right) = 0 \tag{12}$$

yielding the following reaction function:

$$p_i = \frac{t}{2} + \frac{p_j}{2} + \frac{1}{2}\frac{K_i}{K}a_{ji} + \frac{1}{2}\frac{K_j}{K}a_{ij} \tag{13}$$

Using the equivalent reaction function of firm j, this can be solved for:

$$p_i = t + \frac{K_i}{K}a_{ji} + \frac{K_j}{K}a_{ij} = p_j \tag{14}$$

Retail prices once again are equal to a mark-up over access terms as in the benchmark case. The access terms, however, are given by the sum of the respective access charges weighted by each firm's relative network size. The unique retail price equilibrium is symmetric and firms hence share the market equally.

Optimal investment now requires

$$\frac{\partial \pi_i}{\partial K_i} = \left[\frac{\partial p_i}{\partial K_i}\phi_i K + \phi_i p_i + \phi_j a_{ji} + \frac{\partial a_{ji}}{\partial K_i}\phi_j K_i\right] - \frac{\partial C_i}{\partial K_i} = 0 \tag{15}$$

The marginal impact of investment on access charges given by the last term in brackets is new compared to the benchmark case. Moreover, retail prices now depend on firms' coverage decisions and hence the first term in brackets is non-zero. Equating this FOC with the equivalent FOC of firm j, it is straightforward to verify that the unique equilib-

European Union.

[8]For technical simplicity, I will focus on the case where $v \geq 9/4t$ such that equilibrium retail prices are in the region where increases in access charges increase retail prices. Without this assumption, the following derivatives are not continuously differentiable everywhere.

rium is symmetric, i.e. $K_i = K_j$ and given by

$$K_i = \frac{t/2}{2-2\lambda} = K_j \tag{16}$$

This enables us to compare this access rule to fixed access charges.

Proposition 3 *A simple endogenous linear access rule can boost investment without altering retail prices. Moreover, it allows to implement first best investment levels if firms are not too much differentiated.*

Proof. For retail prices to be equal under this access pricing rule and fixed access charges, the two equilibrium access charges have to be equal, i.e. $\lambda K_i = a$. The resulting coverage decisions are given by $K_i^\lambda = \frac{t/2}{2-2\lambda}$ and $K_i^a = \frac{t/2+\frac{\lambda t/2}{2-2\lambda}}{2}$ where I denote by K_i^λ (K_i^a) the investment outcome under this endogenous access rule (fixed access charges). Rearranging terms, this yields $K_i^\lambda \geq K_i^a$ since $t \geq t/2(2-\lambda)$. Hence for $\lambda > 0$, the endogenous access rule dominates fixed access charges.

In order to implement the first best coverage, i.e. have $K_i = K_i^*$,

$$\lambda^* = 1 - \frac{t}{2v - t/2} \tag{17}$$

The resulting access charge is then given by

$$a_{ji}^* = \lambda^* K_i^* = \left(1 - \frac{t/2}{v - t/4}\right)\frac{v - t/4}{2} = v/2 - 3/8t \tag{18}$$

and hence equilibrium prices by $p^* = v/2 + 5/8t$. For demand to be in the range where $dp/da > 0$, $v - t/2 \geq v/2 + 5/8t$ or $v \geq 9/4t$. If this holds, K^* can be implemented. ■

The second part of this proposition seems to be a bit counterintuitive at a first glance. It states that only in situations where private investment would be low otherwise, i.e. where intervention through the access rule changes investment decisions a lot, such access rules allow to achieve the efficient outcome. The reason for this is that higher differentiation not only increases profitability and thus investment incentives but also decreases consumer's utility. For endogenous access charges to have effects on investment behavior, $dp/da > 0$ which only holds if transportation costs are not too large.

The effects of endogenizing access charges are two-fold. First, as a direct consequence, equilibrium access charges received by a firm increase. Second, retail price competition is relaxed since the increased access charges are entirely passed on to consumers. Both effects are of the same magnitude due to the symmetry of the retail equilibrium.

This simple access rule thus allows to achieve efficient investment levels if firms are not too much differentiated. However, as access charges are strictly increasing in network coverage, equilibrium access charges and hence retail prices are high. The access rule gives incentives to invest at the expense of consumer surplus. Moreover, consumers in inframarginal regions lose from additional investment by firms since retail prices increase in network coverage due to increased access payments. I will thus look for alternative specifications that address these equity concerns.

The next step I want to take, is to consider the effects of mixing fixed access payments with the proposed endogenous access rule. Let us investigate the effects of making it non-linear by adding a fixed part f to the access payments. We thus have

$$a_{ji} = f + \lambda K_i \tag{19}$$

The effects of doing so are given in the following proposition.

Proposition 4 *Adding a fixed component to endogenous access charges cannot improve total welfare and hurts consumers.*

Proof. Investment under this access rule is given by $K_i = \frac{t/2+f}{2-2\lambda}$. In order to have optimal investment, i.e. $K_i = K_i^*$, $\lambda^* = 1 - \frac{t/2+f}{v-t/4}$. The total differential of the access charge is given by $da = df + K^* d\lambda^*$ and hence

$$\frac{da}{df} = 1 + K^* \frac{d\lambda^*}{df} = 1/2 \tag{20}$$

In order to achieve the same efficient amount of investment, fixed payments have to be increased while adjusting λ in a way such that the resulting equilibrium access charges strictly increase. Since access charges are entirely passed on to consumers, they are made worse off. ■

Another way to put this result is that consumers would actually benefit from a negative fixed payment that firms can then overcome by investing more, i.e. have $f < 0$. The reason for this is that endogenous access rules are much better for consumers to achieve efficiency. The equilibrium access charges and hence retail prices are lower for the same amount of investment. Imposing possibly negative access payments is, however, not feasible and I thus constrain f to be non-negative. From the proposition above, the best we can do is thus to set $f = 0$.

Although negative fixed payments are not feasible there are other ways to mitigate the problem of too high retail prices and increase consumer surplus. Consider the following rule

$$a_{ji} = \lambda \max\{0, K_i - \underline{K}\} \tag{21}$$

Access payments a firm receives are again affected by the level of its own investment but only if investment exceeds a certain threshold $\underline{K}$. For $K_i > \underline{K}$ it is linear in investment.

Under this access rule, firms invest by maximizing (2) with respect to coverage and thus as follows

$$K_i = \frac{t/2 - \lambda \underline{K}}{2 - 2\lambda} \tag{22}$$

Hence, in order to have efficient investment $K_i = K^*$

$$\lambda^* = \frac{2v - 3/2t}{2v - t/2 - 2\underline{K}} \tag{23}$$

Altering access rules in such a way yields the following result:

Proposition 5 *By introducing a threshold $\underline{K}$ for investment to have an affect on access charges, it is possible to achieve socially optimal investment and increase consumer surplus.*

Proof. Fix $K_i = K_i^*$. The change in the access charge when introducing $\underline{K}$ is given by

$$da = \lambda^* dK_i^* + K_i^* d\lambda^* - \lambda^* d\underline{K} - \underline{K} d\lambda^* \tag{24}$$

and hence

$$\left.\frac{da}{d\underline{K}}\right|_{\underline{K}=0} = \frac{4v - 3t}{(2v - t/2)^2} \frac{v - t/4}{2} - \frac{2v - 3/2t}{2v - t/2} = -\frac{2v - 3/2t}{4v - t} < 0 \tag{25}$$

which is strictly negative due to the assumption made before (recall that I supposed that $v > 9/4t$). ■

Modifying access rules like this affects the incentives on the margin to keep investment at the desired level in a way that lowers equilibrium access payments. The gained flexibility of this access rule thus allows to address equity concerns and achieve efficiency simultaneously. One way of thinking of such thresholds to have an effect on access charges is the following. The investing firm does not get better access terms as long as investment takes place in very dense areas (those below $\underline{K}$). When invest in rural areas where it would not invest otherwise (areas above $\underline{K}$), it is granted a competitive advantage through increased access payments received.

$\underline{K}$, however, cannot be set arbitrarily. Consider the second order condition of profit maximization given by $\frac{\partial^2 \pi_i}{\partial K_i^2} = 2\lambda - 2$. Profits are strictly concave if $\lambda^* < 1$. For this to hold (see equation (23)), $\underline{K} < t/2$. We thus have the following result:

Proposition 6 *Any access rule with $\lambda^* = \frac{2v - 3/2t}{2v - t/2 - 2\underline{K}}$ where $\underline{K} \in [0, t/2)$, can be used to achieve optimal investment. The choice of $\underline{K}$ distributes social surplus where higher $\underline{K}$ favor consumers over firms.*

Proof. The value of λ^* and the set of $\underline{K}$ follow from the derivations above. Equilibrium prices are given by

$$p_i = t + \frac{2v - 3/2t}{2v - t/2 - 2\underline{K}} \left(\frac{v - t/4}{2} - \underline{K} \right) \tag{26}$$

and hence

$$\frac{dp_i}{d\underline{K}} = \frac{2v - 3/2t}{2v - t/2 - 2\underline{K}} \left[\left(\frac{v - t/4}{2} - \underline{K} \right) \frac{2}{2v - t/2 - 2\underline{K}} - 1 \right] < 0 \tag{27}$$

Consumers benefit from higher $\underline{K}$ since it restricts access payments and hence lowers retail prices. Decreasing retail prices while holding network coverage constant implies decreasing profits. Equilibrium profits are given by

$$\pi_i(\underline{K}) = \frac{v - t/4}{2} \left[t + \frac{2v - 3/2t}{2v - t/2 - 2\underline{K}} \left(\frac{v - t/4}{2} - \underline{K} \right) - \frac{v - t/4}{2} \right] \tag{28}$$

and indeed

$$\frac{d\pi_i}{d\underline{K}} = \frac{v - t/4}{2} \frac{dp_i}{d\underline{K}} < 0 \tag{29}$$

Firms' profits are strictly decreasing in $\underline{K}$ and hence firms would like $\underline{K}$ to be as low as possible. The $\underline{K}$ chosen thus determines how social surplus is distributed. ■

The following graph illustrates and summarizes the results of this section. Investment levels K_i are given on the horizontal axis whereas the marginal changes (as investment increases) of revenue (the colored dashed lines representing the different access regimes), consumer surplus (green solid horizontal line) and costs (upward sloping red solid line) are drawn on the vertical axis.

The dashed black line represents the case of fixed access charges. With fixed access charges, marginal revenue is constant and strictly below the marginal gain of consumer surplus. Recall that the gain of consumer surplus is equal to the gain of total surplus

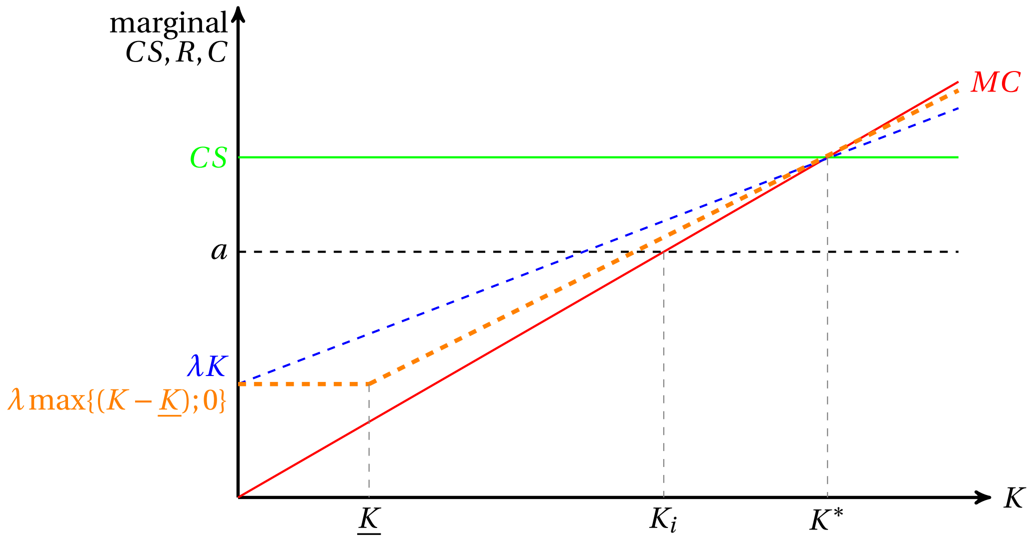

Figure 4: Comparison of different access regimes

since revenue is welfare neutral. Hence equilibrium investment given by the intersection of the marginal revenue curve with the marginal cost curve is strictly below K_i^*.

Making access charges dependent on investment leads to the marginal revenue of investment no longer being constant but increasing in the amount of investment. Looking at the simple linear rule given by the dashed blue line shows that this allows to achieve first best investment. The slope of the marginal revenue curve given by 2λ can be designed such that marginal revenues equal marginal costs of investment at the social optimum.

The case where access payments a firm receives are affected by the level of its own investment only if investment exceeds a certain threshold $\underline{K}$ is represented by the dashed orange line. For $K_i \leq \underline{K}$, marginal revenue of investment is constant and then for $K_i > \underline{K}$ it is linear in investment. The effects of this can be seen in the graph. Introducing $\underline{K}$ decreases the marginal revenue of investment and hence profits of firms (the blue line is above the green one everywhere for $K < K^*$) but increases consumer surplus since the resulting equilibrium price is lower.

6 Cost sharing

In the previous section, I investigated the possibility of giving investment incentives through the possibility of influencing access prices. Now I want to study the effects of cost sharing. Instead of paying per customer access charges, firms have to pay a lump sum fee $A_{ji} = \alpha C_i$ proportional to the investment cost to their competitor if they want to gain access to its network. Under such a regime, firms' profits are given by:

$$\max_{p_i, K_i} \pi_i = \phi_i(p_i, p_j) p_i K - (1-\alpha_i) C_i(K_i) - \alpha_j C_j(K_j) \qquad i, j = 1, 2, \quad i \neq j \tag{30}$$

The equilibrium retail prices and investments are given in the following lemma assuming that the cost sharing parameters are the same for both firms $\alpha_i = \alpha_j = \alpha$.

Lemma 3 *Retail prices are given by*

$$p_i = \begin{cases} t & \text{if} \quad t \leq 2/3v \\ v - t/2 & \text{if} \quad v \geq t > 2/3v \\ v/2 & \text{if} \quad t > v \end{cases} \tag{31}$$

and investment by:

$$K_i = \begin{cases} \frac{t/2}{2-2\alpha} & \text{if} \quad t \leq 2/3v \\ \frac{v/2 - t/4}{2-2\alpha} & \text{if} \quad v \geq t > 2/3v \\ \frac{\phi_i v/2}{2-2\alpha} & \text{if} \quad t > v \end{cases} \tag{32}$$

Proof. Follows the same strategy as in lemma 1. ■

Using these results, we can state the following:

Corollary 4 *The choice of the cost sharing parameter α does not affect downstream competition.*

Proof. The choice of α only effects investment but not retail pricing decisions since there are no marginal access payments (per consumer) of firms. ■

Therefore, we have:

Corollary 5 *Commitment of the authority is not an issue.*

Proof. The regulator cannot improve consumer welfare by changing α after investment has taken place, since α has no effect on downstream competition. ■

Moreover, comparing this rule to the endogenous access rule of the precedent section, we see that:

Corollary 6 *Cost sharing rules $A_{ji} = \alpha C_i$ and simple linear endogenous access rules $a_{ji} = \lambda K_i$ yield equivalent formulas for investment (for $v \geq 9/4t$).*

Proof. Comparing the results from lemma 1 and lemma 3 shows that, $K^\alpha = K^\lambda$ for $\alpha = \lambda$ and hence $\alpha^* = \lambda^*$. ■

Both regimes yield the same investment decisions for K_i if $\lambda = \alpha$ although they work through different mechanisms: endogenous access charges increase the marginal revenue of investment whereas cost sharing lowers the marginal costs of investment.

Let us now investigate the choice of the cost sharing parameter α. The results are given in the following propositions.

Proposition 7 *If symmetric firms can privately negotiate cost sharing agreements, they will always agree to share the costs equally.*

Proof. A single firm without cost sharing invests until its own marginal revenue (market share times retail price) equals its marginal cost of investment. Jointly, investment is undertaken until marginal costs equal the sum of marginal revenues of both firms which is twice as high due to symmetry. To achieve this, $\alpha = 1/2$. This internalizes the fact that additional investment yields retail prices for either of the firms. ■

Proposition 8 *If firms unilaterally decide on the contribution of the competitor to access its network, they set* $\alpha^m = 2/3$. *Moreover, if they can decide unilaterally on their contribution to the other network, they choose to contribute* $\alpha = 1/3$.

Proof. $\frac{d\pi_i}{d\alpha_i} = \phi_i p_i \frac{dK_i}{d\alpha_i} + K_i^2 - (1-\alpha_i)2K_i \frac{dK_i}{d\alpha_i} > 0$ for $\alpha_i < 1$. Hence, the chosen α will be the highest that guarantees non-negative profits for the accessing firm which is $\alpha^m = 2/3$. Similarly, $\frac{d\pi_i}{d\alpha_j} = \phi_i p_i \frac{dK_j}{d\alpha_i} - K_j^2 - \alpha_j 2K_j \frac{dK_j}{d\alpha_j}$ which is strictly decreasing in α_j and equal to zero for $\alpha_j = 1/3$, firms optimally want to bear 1/3 to their rival's investment cost. ■

When firms decide on their contribution to give, they would contribute until their marginal contribution is equal to their marginal gain from doing so. This yields $\alpha_j = 1/3$ for firm i. If firm i can decide on the contribution it receives, it benefits from any increase in α_i and thus is only constrained by the profits of its rival which must not be negative for access to be bought. This shows that the unilateral setting of α yields higher (lower) contributions if the decision is on the share of costs paid by the other firm (by itself).

Let us now contrast this with the regulatory outcome. Due to equity reasons, it seems to be plausible to assume the following:
Assumption *The regulator sets* $\alpha^r \leq 1/2$.

This assumption says that the investing firm should bear at least half of investment costs. The non-investing firm should not end up paying more for access than the investing firm effectively pays for building the network.

Under this assumption, the following holds.

Corollary 7 *Leaving the choice of how to share investment costs to firms yields the same outcome a social planner would choose.*

Proof. α^r is constrained to be less or equal than 1/2. Higher α^r yield higher coverage and no distortion of downstream competition, hence $\alpha^r = 1/2$. The privately negotiated outcome is $\alpha = 1/2$ from the proposition above. ■

Moreover, considering total welfare, I find the following:

Proposition 9 *Joint or regulated cost sharing agreements never allow to obtain the first best optimum and under-investment prevails. Unilateral setting of cost sharing conditions can result in either optimal, over- or underinvestment.*

Proof.

$$\alpha^* \in \begin{cases} [3/5;1) & \text{if} \quad t \leq 2/3v \quad \text{and} \quad d\alpha^*/dt < 0 \\ (3/5;2/3] & \text{if} \quad v \geq t > 2/3v \quad \text{and} \quad d\alpha^*/dt > 0 \end{cases} \tag{33}$$

Joint or regulated cost sharing agreements yield $\alpha^r = \alpha = 1/2$, and hence firms underinvest. $\alpha^m = 2/3$ and thus optimal, over- or underinvestment can happen under unilateral cost sharing contracts. ■

The point is that by joint cost sharing agreements, the investing firm completely internalizes the revenue from the other firm. This, however, is still too low from a social point of view since also firms together are never able to extract the entire consumer surplus (see proposition 1 for a more detailed discussion of this problem). In order to implement the optimal coverage K^*, α^* has to be strictly larger than 1/2 which can only be the case if cost sharing is decided unilaterally.

Although first best investment cannot be achieved, cost sharing is still beneficial for welfare. Comparing it to the benchmark of fixed access prices shows that:

Proposition 10 *Cost sharing strictly dominates fixed access charges from a welfare point of view.*

Proof. The marginal profitability of investment is equal to p and not just $p/2 + a/2$, lower retail prices prevail additionally ($p = t$ vs. $p = t + a$). Hence investment is always strictly higher/coverage larger plus retail prices are always strictly lower under cost sharing. ■

Finally, let us consider redistribution concerns. As seen before, retail prices increase in coverage under endogenous access charges. One might thus think that it is better for inframarginal consumers to let firms share investment costs. However, I find the following.

Proposition 11 *Any network coverage that can be implemented by using regulated or bilateral cost sharing agreements can be implemented by using endogenous access charges. Moreover flexible specifications of endogenous access charges allow to duplicate the outcome under cost sharing, i.e. consumers are not made worse off by doing so.*

Proof. Recall that under endogenous access charges, $K_i = \frac{t/2-\lambda \underline{K}}{2-2\lambda}$. For $K_i^\lambda = K_i^\alpha$, $\lambda = \frac{t/2}{t-\underline{K}}$. Take $\underline{K} = \underline{K}^{max} = t/2-\epsilon$. Thus $\lambda = 1-\epsilon$ and hence $p_i = t$ as ϵ can be arbitrarily small, the same retail price as under cost sharing can be achieved for equal investment levels. ■

The corollary of this is that there is no investment/retail price trade-off if $\alpha \leq 1/2$. Endogenous access rules perform at least as well as cost sharing rules. Only for unilateral decisions on α and a higher weight on consumer surplus than on profits, cost sharing strictly dominates. Let me relate the results of the two access regimes presented here in the following section.

7 Comparison of cost sharing and endogenous access charges

An interesting point to note is that commitment of the regulator is no issue under cost sharing. Contrary to most circumstances where firms absent commitment (or the lacking possibility of commitment) of the regulator would not invest, this poses no problem under cost sharing. Cost sharing does not influence downstream competition and hence neither retail prices nor consumer surplus. Under endogenous access charges, however, the regulator could try to impose lower access charges to increase consumer surplus once investment has taken place.

Moreover, private negotiation of cost sharing yields the same outcome the regulator would have chosen. Hence there is no need for intervention. It is sufficient to ensure the possibility to share investment costs. Endogenous access rules have to be set by regulator as firms would otherwise choose rules yielding too high access charges.

As shown before, the two access regimes perform well in different situations. Cost sharing only works well if firms are highly differentiated. If differentiation is low, α^* may be higher than 2/3. The accessing firm, however, has no possibility to recoup access costs due to intense competition and coverages that can be implemented are thus lower than the social optimum. Endogenous access charges on the other hand only work well if differentiation is low, the possibility to relax competition through access charges is needed to achieve efficiency.

One issue that my analysis has not touched upon are informational constraints as I assumed complete information. If the regulator cannot observe the costs of firms, the two access regimes perform differently. Cost sharing is not subject to adverse selection problems since optimal rules are independent of the underlying conditions, the regulator wants to implement $\alpha = 1/2$ in any case. Under endogenous access rules, firms have incentives to overstate costs. This would make the regulator implement a higher effect of investment on access charges λ, or equivalently lower the threshold $\underline{K}$ for investment to have an effect of access charges. On the other hand, moral hazard is only an issue under cost sharing. When they bear only part of the investment costs, firms have less incentives to invest efficiently.

8 Conclusion

This paper has studied investment in essential facilities when firms are mandated to grant access to their competitors. It has examined the effects of access regimes on firm's investment behavior in the facility and pricing in the downstream market.

Firms generally underinvest compared to the social optimum when they are confronted with fixed access charges. Given competition and uniform pricing, firms are never able to appropriate the entire surplus from additional investment and hence invest less than would be socially desirable. Starting from this result, I propose two approaches to solve this problem.

Departing from the standard assumption of fixed payments, access charges are made contingent on firms' investment levels. A firm is rewarded with a competitive advantage in access terms if it invests more. I show that by choosing an appropriate rule, it is possible to reach socially efficient investment levels without distorting downstream competition. A simple linear rule where the access charges a firm receives for sharing its facilities depend on its investment is able to induce efficient investment if competition is tough otherwise. The increased access charges soften competition. A non-linear specification where access payments are given by a fixed part in addition to the linear rule does not increase welfare and hurts consumers. On the contrary, requiring investment to be above a certain threshold to have an effect on access charges increases consumer surplus. These thresholds thus allow to shift surplus between consumers and firms.

Cost sharing rules under which firms have to pay lump sum fees for access have the benefit of not interfering with downstream competition. This, however, comes at the price of not being able to induce efficient investment in most circumstances. Only when firms unilaterally decide on the access price for their network and competition is soft, the first best can be obtained. In case of tough competition, firms are not able to recoup investment costs in the retail market and thus invest too less.

The two approaches, working through different mechanisms, are thus suitable for different situations. Endogenous access rules increase investment via softened competition whereas cost sharing rules do so by internalizing the retail revenue of the non-investing firm. Both, however, as the analysis showed, strictly dominate the current practice of fixed per-consumer access payments.

References

Amendola, G. B. and Pupillo, L. M. (2008). The economics of next generation access networks and regulatory governance: Towards geographic patterns of regulation. MPRA Paper 8823, University Library of Munich, Germany.

Armstrong, M. (1998). Network interconnection in telecommunications. *The Economic Journal*, 108(448):545–564.

Bourreau, M., Cambini, C., and Hoernig, S. (2010). National ftth plans in france, italy and portugal. RSCAS Working Papers 2010/51, European University Institute.

Bourreau, M., Hombert, J., Pouyet, J., and Schutz, N. (2009). Upstream competition between vertically integrated firms. Working papers, HAL.

Caillaud, B. and Tirole, J. (2004). Essential facility financing and market structure. *Journal of Public Economics*, 88(3-4):667–694.

Cambini, C. and Jiang, Y. (2009). Broadband investment and regulation: A literature review. *Telecommunications Policy*, 33(10-11):559 – 574.

de Bijl, P. and Peitz, M. (2004). Unbundling the local loop: One-way access and imperfect competition. Discussion Paper 2004-025, Tilburg University, Tilburg Law and Economic Center.

Foros, O. and Kind, H. J. (2003). The broadband access market: Competition, uniform pricing and geographical coverage. *Journal of Regulatory Economics*, 23(3):215–35.

Henriques, D. (2011). Can access price indexation promote efficient investment on next generation networks? available at http://docentes.fe.unl.pt/~dthenriques/.

Jeon, D.-S. and Hurkens, S. (2008). A retail benchmarking approach to efficient two-way access pricing: no termination-based price discrimination. *RAND Journal of Economics*, 39(3):822–849.

Jullien, B., Pouyet, J., and Sand-Zantman, W. (2010). Public and private investments in regulated network industries: Coordination and competition issues. *Review of Network Economics*, 9(4).

Klumpp, T. and Su, X. (2010). Open access and dynamic efficiency. *American Economic Journal: Microeconomics*, 2(2):64–96.

Laffont, J., Rey, P., and Tirole, J. (1998). Network competition: I. overview and nondiscriminatory pricing. *The RAND Journal of Economics*.

Troncoso-Valverde, C. and Robert, J. (2004). On Hotelling's Competition with General Purpose Products. *FACE Working Paper Series*, (3):1–17.

Valletti, T. M., Hoernig, S., and Barros, P. P. (2002). Universal service and entry: The role of uniform pricing and coverage constraints. *Journal of Regulatory Economics*, 21(2):169–90.

Appendix: Uniform vs. discriminatory pricing

In this appendix I want to discuss briefly the effects of allowing firms to charge different prices in different territories depending on the network ownership.

Consider a variant where firm i charges different prices in the territory where it invests itself (denoted p_{ii}) and the territory where it has to buy access (p_{ij}). Profits are then given by

$$\pi_i = K_i \left[p_{ii}\phi_{ii}(p_{ii}, p_{ji}) + \phi_{ji}(p_{ii}, p_{ji}) a \right] + K_j \left[p_{ij}\phi_{ij}(p_{ij}, p_{jj}) - \phi_{ij}(p_{ij}, p_{jj}) a \right] \quad (34)$$

$$- C_i(K_i) \qquad i, j = 1, 2, \quad i \neq j \quad (35)$$

This yields the following result:

Proposition 12 *Allowing firms to price discriminate between territories does not alter equilibrium prices if firms are not too much differentiated. Moreover, local symmetry of retail prices also holds for different access prices in this case.*

Proof. Computing the best response correspondences in this case, it is straightforward to verify that the resulting equilibrium prices are given by

$$p_{ii} = \begin{cases} t + a & \text{if} \quad t \leq 2/3(v - a) \\ v - t/2 & \text{if} \quad v \geq t > 2/3(v - a) \\ v/2 & \text{if} \quad t > v \end{cases} \quad (36)$$

and

$$p_{ij} = \begin{cases} t + a & \text{if} \quad t \leq 2/3(v - a) \\ v - t/2 & \text{if} \quad v - a \geq t > 2/3(v - a) \\ v/2 + a/2 & \text{if} \quad t > v - a \end{cases} \quad (37)$$

and hence symmetric and equal to the ones obtained under uniform pricing as long as $v \geq t + a$. ■

The reason for this is that firms do not find it profitable to undercut their rival even when their costs of serving consumers is lower. If they own the infrastructure in a territory, their opportunity cost of charging lower prices is given by the access charge. They also benefit from every customer subscribing to their rival. This keeps them from lowering prices. Only if firms are local monopolists and the marginal consumer earns zero rents, their pricing behavior is different and equal to the monopoly prices which differ by the amount of access charges. This result is similar to the one obtained by de Bijl and Peitz (2004) and Bourreau et al. (2009). Allowing firms to charge different prices in each territory thus does neither foster nor soften competition.