Unbundling the Local Loop: One-Way Access and Imperfect Competition

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Abstract

A major promise of the 1990s was the rollout of local access networks in telecommunications markets. Nevertheless, local network rollout has been somewhat disappointing, and even though the local loop has been unbundled competition in the 'local loop' is hardly mature. At present, local-loop unbundling (LLU) seems most promising as a means for entrants to offer broadband internet access. As voice telephony can be implemented by using the 'internet protocol' when consumers have broadband access, LLU may, in the end, spur competition in markets for voice telephony as well. Thus LLU is an important way to stimulate competition in the broadly defined market for fixed telecommunications. We explore situations of one-way access in which the entrant, the firm without the essential input, has market power. We first review the nature of LLU when there is full consumer participation. Next, we explore the case of partial participation, where the entrant can attract further participation. In the first case, unbundling requirements are neutral to competition. This result breaks down under partial consumer participation. Hence, regulation of unbundling requirements should be particularly concerned with market segments such as broadband access in which partial participation seems to be a key feature.

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1 Introduction

A major promise of the 1990s was the rollout of local access networks in telecommunications markets. Nevertheless, local network rollout has been somewhat disappointing, and at present, competition in the 'local loop' is hardly mature. Network rollout has been narrowly targeted; while some operators found it worthwhile to connect business districts and metropolitan areas, residential customers have hardly been exposed to entrants with their own networks. Therefore the traditional providers of fixed voice telephony (the former incumbents) still have strong positions in the market. Consumers did, however, to some extent benefit from entry made possible by 'carrier select' and 'local loop unbundling' (LLU). At present, LLU seems most promising as a means for entrants to offer broadband internet access, based on DSL technology. Nevertheless, as voice telephony can be implemented by using the 'internet protocol' when consumers have broadband access, LLU may, in the end, also spur competition in markets for voice telephony. Thus LLU is, potentially, still an important way to stimulate competition in the (broadly defined) market for telecommunications.

In telecoms, unbundling usually implies wholesale leasing of the local loop. In other markets, unbundling can be interpreted more broadly. More generally, unbundling can be seen as a method of implementing 'one-way' access to an incumbent's network. Unbundling typically implies that the incumbent's essential input (and perhaps others as well) is separated out of its overall facilities or operations, in order to allow for commercial wholesale supply of this input. Hence, although it is typically discussed within the framework of telecommunications, it has wider relevance. In postal markets, for instance, through unbundling regulators may enforce access to the incumbent's system for local mail delivery (access to 'the postman'). Consider, for instance, the notion known as worksharing, which is an unbundling of the postal value chain in the sense that it allows competitors to buy the incumbent's delivery function, and perhaps others as well, such as the sorting of mail items. In electricity, regulators may mandate access to electricity companies' local distribution networks. In financial securities trading, the book depository function (the legal records of ownership changes) may be unbundled from the broad set of clearing and settlement services.[1]

In this paper we explore situations of one-way access in which an entrant, that is the firm without the essential input, has market power. Accordingly, there is imperfect competition between an integrated firm, the incumbent, and a non-integrated firm. We strongly believe

[1] In the latter example, unbundling may serve to create a central register, rather than to introduce competition.

that such a situation often better represents the real world than situations in which there is a competitive fringe that needs to purchase the essential input. Indeed, the appearance of entrants on the market immediately tends to generate some discipline on incumbents, and it is crucial to understand the interactions that take place when entrants have some market power, no matter how little in the beginning.

We first explore the nature of LLU when there is full consumer participation. Full consumer participation here means that total demand is perfectly inelastic with respect to price changes. Next, we explore the more specific case of partial participation by consumers. Here, we explore the case that an entrant generates additional demand and that this additional demand depends on price. To analyze these situations we present simple models of competing telecommunications networks. In the baseline model with full participation unbundling requirements are neutral to competition: they do neither affect the entrant's profit nor its market share; this is a generalization of earlier results, see for instance De Bijl and Peitz (2002). In this context we discuss investment incentives of the integrated network. Furthermore, we extend the analysis to partial consumer participation. In particular, we show that the neutrality result breaks down under partial consumer participation. This implies that regulation of unbundling requirements should be particularly concerned with market segments such as broadband access in which partial participation seems to be a key feature of the consumer side. Based on the analysis, we draw policy-relevant conclusions that are timely given the rather slow progress of LLU-based entry so far. We give specific attention to the possibility of 'voice over internet protocol' (VoIP) as a new technology to stimulate competition. In particular, entrants that lease local loops in order to offer broadband Internet access, widen the possibilities for voice telephony over the Internet.

It should be noted that although our model is placed within the context of telecommunications, our results are more general and have applicability to other sectors as well. In fact they have relevance to all markets where unbundling and one-way access are potential means to facilitate competition.

Previous work on one-way access has focussed on the optimal second-best pricing (Ramsey pricing) in the context of one-way access for homogeneous services or differentiated services with a competitive fringe. The literature has also considered access price rules for given retail prices, in particular the efficient component pricing rule (ECPR) has received a lot of attention. Both these strands are thoroughly analyzed and discussed in Armstrong (2002); see also Laffont and Tirole (2000). We do not know of any work with price-setting imperfectly competitive networks except Laffont and Tirole (1994), who only analyze the Ramsey prices in such a situation.

Typically, this literature is a short-term analysis which ignores investment incentives (it should be acknowledged that the issue of inefficient entry has been discussed). Valletti (2003) provides a useful discussion of investment incentives. However, the theoretical literature is rather silent on the issue.[2]

The structure of this paper is as follows. Section 2 provides background information on unbundling in practice. Section 3 revisits LLU in the case of full participation by end-users. Section 4 explores a straightforward case of partial participation. Section 5 concludes the paper.

2 Policy on Local-Loop Unbundling in Telecoms

To provide some institutional background, this section provides an overview of regulation and policy towards unbundling of the local loop in telecommunications markets. We focus on the European situation.

Already before the introduction of the new regulatory framework, European regulation mandated the provision of unbundled access to the local loop.[3,4] The general philosophy is that mandatory access is an effective means to deal with persistent network monopolies, but as it reduces entrants' incentives to innovate and invest in networks themselves, it should be gradually withdrawn as competition becomes sufficiently mature. According to the EC,[5]

> "The high cost of duplicating the local access infrastructure is ruling out new market entrants. This is affecting the level of competition, which the Regulation is intended to increase by offering unbundled access to the local loop, i.e. by enabling new competitors to offer high bit-rate data transmission services for continuous

[2] One exception is Bourreau and Dogan (2003) who highlight the importance of access charges for LLU on the entrant's incentives to invest in its own facilities. They focus on the case where access charges are not regulated. See also the discussion in De Bijl and Peitz (2002).

[3] Regulation (EC) No 2887/2000 of the European Parliament and of the Council of 18 December 2000 on unbundled access to the local loop, *Official Journal of the European Communities* L 336, 30.12.2000, p. 4-8. See also Delgado et al. (2004, p. 170).

[4] The EC defines the local loop as the "physical twisted metallic pair connecting the network termination point at the subscriber's premises to the main distribution frame or equivalent facility in the fixed public telephone network".

[5] Summary of legislation on unbundled access to the local loop (Regulation (EC) No 2887/2000), http://europa.eu.int/scadplus/leg/en/lvb/l24108j.htm, consulted 22-9-2004.

> Internet access and for multimedia applications based on digital subscriber line technology as well as voice telephony services."

For example, in 2003 there were 307 agreements on fully unbundled lines throughout 15 countries in Europe, even though they were probably mostly aiming at broadband internet access instead of voice. However, since broadband internet access allows for voice telephony by using 'voice over internet protocol' (VoIP) and 'voice over digital subscriber line' (VoDSL), these unbundling agreements may become (or already are) also relevant for voice telephony. The EU average monthly rental was € 11.5 and the average connection charge was € 68.2 in 2003 (see European Commission, 2003, p.48, 60). Mandated unbundling applied only to operators that had been designated by their NRAs (national regulatory authorities) as having significant market power (SMP). Moreover, wholesale prices (the line rentals of the local loop) must be transparent, non-discriminatory, fair, and proportionate to costs.

Similarly under the new framework, unbundled access of the local loop has become a regulatory remedy to deal with dominance (see e.g. Buigues, 2004). If the NRA establishes SMP, it must apply appropriate remedies. This has to be done on the basis of a list of obligations formulated in the Access Directive,[6] related to transparency, non-discrimination, accounting separation, access (unbundled access and resale of facilities), price control and cost accounting. Note that the NRA is not obliged to impose obligations on operators with SMP. However, access regulation is typically appropriate (and hence obligatory), especially in the early stages of competition, when entrants have not yet rolled out alternative infrastructures (see e.g. the results obtained by De Bijl and Peitz, 2002).

Local loop unbundling implied a major promise for opening telecommunications markets throughout Europe, but its success has been meager so far, which is somewhat surprising (see e.g. Delgado et al., 2004). Given that facilities-based entry has been narrowly targeted (especially at business parks and metropolitan areas), unbundled access provides, in principle, an attractive way of capturing market share beyond the reach of an operator's connections to end-users. This is especially true as unbundled access gives entrants full control of the local loop, allowing them to configure their own services. Nevertheless, Carrier Select-based entry has been observed much more frequently, at least in markets for voice telephony.[7] We do

[6] Directive 2002/19/EC of the European Parliament and of the Council of 7 March 2002 on access to, and interconnection of, electronic communications networks and associated facilities (Access Directive), *Official Journal of the European Communities* L 108, 24.4.2002, 7-17.

[7] See e.g. European Commission (2003). This report, while providing statistics about facilities used by entrants to offer voice telephony (particularly to residential users), only presents information about Carrier

not know why LLU has hardly shown positive results for market structure and competition in voice telephony. A possible reason is that lease prices are too high to encourage entrants to offer voice through LLU.[8] Also, offering broadband internet access is probably much more attractive from a commercial viewpoint than selling voice. In any case it is important to understand the effects of wholesale prices on competition and the resulting market outcomes.

3 Regulatory Theory with Full Participation

We consider a market of two networks, one vertically integrated network (denoted as firm 1) which owns local-loop plus additional facilities (in particular a backbone and switches) and one non-integrated network (denoted as firm 2) which owns only a backbone and switches, and needs access to the other firm's local loop. More generally, two firms compete with each other, while one them owns an essential facility which provides a necessary input for the production process. The price at which the integrated network sells access to the essential facility is fixed by a regulator. We call it the lease price, or line rental, and denote it by l.

Network 1's per-user cost of the essential input is denoted by f_1. A local connection to an end-user comprises two components, namely a 'local line' and a 'line card', with associated costs per user f_1^{ll} and f_1^{lc}, respectively. We assume that $f_1 = f_1^{\text{ll}} + f_1^{\text{lc}}$. When firm 2 requests unbundled access to network 1, it installs its own linecard, with a cost per user $f_2^{\text{lc}} = f_1^{\text{lc}}$, and uses firm 1's local line. Accordingly, firm 2's perceived per-user cost equals $f_2 = l + f_1^{\text{lc}}$.

There is a continuum of consumers with mass 1. Each consumer subscribes to one network, or alternatively, purchases one unit from the operator he or she selects. Consumers have an inelastic demand for a single subscription, while their willingness to pay is assumed to be sufficiently high so that they will always make a purchase.

The local network owner (firm 1) derives revenues from subscriptions and from line rental. Since the lease price of the local loop is regulated, the only strategic variable of the local network owner is the price that consumers have to pay for the services if they subscribe. We denote that price by p_1. Also, the entrant charges a price p_2 to consumers that demand its services. An example for prices p_i are flat rates for internet access. Market shares $s_i(p_1, p_2)$ depend on the prices charged by both operators. It is then natural to assume that market

Select and Preselect, not unbundled local loops. When providing information about unbundled local loops, it applies to broadband internet access.

[8] Kallen and Woehrl (2003) cite officials of DG Competition of the European Commission who explain the negative result for voice telephony by invoking incumbents' pricing policies and NRAs' ineffective responses to price squeezes. It should be noted, though, that Kallen and Woerhl do not subscribe to this view.

share is decreasing in its own price and increasing in the price of the competitor. Furthermore, we assume that market shares only depend on the price difference $p_2 - p_1$. This assumption is satisfied for quasi-linear preferences when consumers have identical demand functions. With full participation, total market demand is fixed. For an example see below.

Profit functions are as follows. Firm 1's profits can be written as

$$\pi_1(p_1, p_2; l) = s_1(p_1, p_2)(p_1 - f_1) + (1 - s_1(p_1, p_2))(l - f_1^{\mathrm{ll}}),$$

and firm 2's profits as

$$\pi_2(p_1, p_2; l) = s_2(p_1, p_2)(p_2 - l - f_2^{\mathrm{lc}}).$$

The property that market share changes continuously with price implies that firms have market power. Consumers do not consider the services provided by the two firms as perfect substitute and therefore do not necessarily go for the lower priced service. A situation with imperfect substitutes seems to be common in telecommunications and other markets. For instance, brand recognition and switching costs lead to imperfect substitutes. Also, the services by firms are often bundles of different offers and features. If firms offer different bundles, they are considered as imperfect substitutes.

A special case of our general model is obtained by assuming that the networks are horizontally differentiated. Suppose, for instance, that consumers are uniformly distributed on the interval $[0, 1]$. Firm 1 is located at location $y_1 = 0$ on the interval, and firm 2 at $y_2 = 1$. A consumer located at z buying from firm i incurs a disutility $-\theta|y_i - z|$. Note that a higher value of parameter θ corresponds to more differentiation between the networks. A consumer at z buys from firm 1 if $v_1(p_1, p_2) - \theta z > v_2(p_1, p_2) - \theta(1 - z)$, where $v_i(p_1, p_2)$ denotes the conditional indirect utility of a network at the ideal location z. Market shares then satisfy $s_i(p_1, p_2) = \frac{1}{2} + (v_i(p_1, p_2) - v_j(p_1, p_2))/(2\theta)$, where $j \neq i$. This is the simple Hotelling specification which has also been used in models on two-way access (see e.g. Armstrong, 2002).

In a more elaborate model, one could incorporate that consumers have a demand to make calls, or to have access to the Internet, in addition to the demand for a subscription. Such extensions lead to additional interactions between the operators, for instance because there is call traffic between the networks.[9] Nevertheless, the present model captures the crucial strategic effects of one-way access.

Operators choose prices in order to maximize profits. Consumers make purchasing decisions, based on utility maximization, after observing the prices. We are interested in an

[9] See De Bijl and Peitz (2004) for an inclusion of call traffic.

equilibrium configuration (p_1^*, p_2^*) in which both firms do not have an incentive to change their retail prices. That is, given the competitor's retail price, each operator maximizes its profits. Accordingly, given the equilibrium price of the competitor, the profit maximization problem of operator 1 can be written as

$$\max_{p_1} \pi_1(p_1, p_2^*; l), \tag{1}$$

while operator 2 maximizes

$$\max_{p_2} \pi_2(p_1^*, p_2; l). \tag{2}$$

Suppose that there exists a unique pair (p_1^*, p_2^*) which solves both problems simultaneously (hence it constitutes an equilibrium). We are then interested in which way a change in regulatory policy affects market outcomes. Suppose that under the new regulatory regime the lease price is changed to $l' = l + \Delta l$. We can then show that this increase in the lease price is passed through to consumers. Equilibrium market shares are unaffected and the non-integrated network's profit are neutral to regulation. However, the integrated network benefits two-fold: it charges higher retail prices and it receives a higher lease price for those consumers who subscribe to the competitor's network. Consumers suffer from the lease price increase: they face higher prices by both networks.

Given the new lease price $l' = l + \Delta l$, we claim that equilibrium retail prices are $p_1^{**} = p_1^* + \Delta l$ and $p_2^{**} = p_2^* + \Delta l$. Our proof consists of establishing that p_i^{**} is the solution of the maximization problem of operator i, $i = 1, 2$.

Operator 1: Given the new lease price l', the vertically integrated network's profit can be written as

$$s_1(p_1, p_2^{**})(p_1 - f_1) + (1 - s_1(p_1, p_2^{**}))(l + \Delta l - f_1^{ll})$$

Profit can be rewritten as

$$s_1(p_1, p_2^{**})(p_1 - \Delta l - f_1) + (1 - s_1(p_1, p_2^{**}))(l - f_1^{ll}) + \Delta l$$

Provided that the competing operator sets $p_2^{**} = p_2^* + \Delta l$, market shares satisfy $s_1(p_1, p_2^{**}) = s_1(p_1 - \Delta l, p_2^*)$ because they only depend on price differences. Hence the vertically integrated network's profit can be rewritten as

$$s_1(p_1 - \Delta l, p_2^*)(p_1 - \Delta l - f_1) + (1 - s_1(p_1 - \Delta l, p_2^*))(l - f_1^{ll}) + \Delta l$$

With a change of variable $\widetilde{p}_1 \equiv p_1 - \Delta l$, the maximization problem becomes

$$\max_{\widetilde{p}_1} s_1(\widetilde{p}_1, p_2^*)(\widetilde{p}_1 - f_1) + (1 - s_1(\widetilde{p}_1, p_2^*))(l - f_1^{ll}) + \Delta l \tag{3}$$

Clearly, p_1^* is the solution to this problem because it is formally the same maximization problem as problem (1) except for the constant Δl. Since $\widetilde{p}_1 \equiv p_1 - \Delta l$ we have shown that $p_1^{**} = p_1^* + \Delta l$, provided that $p_2^{**} = p_2^* + \Delta l$.

Operator 2: Given the new lease price l', the non-integrated network's profit can be written as

$$s_2(p_1^{**}, p_2)(p_2 - l - \Delta l - f_2^{lc})$$

Provided that the competing operator sets $p_1^{**} = p_1^* + \Delta l$, market shares satisfy $s_2(p_1^{**}, p_2) = s_2(p_1^*, p_2 - \Delta l)$. Hence, using the change of variable $\widetilde{p}_2 = p_2 - \Delta l$ the maximization problem of the non-integrated network's profit can be written as

$$\max_{p_2} s_2(p_1^*, \widetilde{p}_2)(\widetilde{p}_2 - l - f_2^{lc}) \tag{4}$$

Clearly, p_2^* is the solution to this problem because it is formally the same maximization problem as problem (2). Since $\widetilde{p}_2 \equiv p_2 - \Delta l$ we have shown that $p_2^{**} = p_2^* + \Delta l$, provided that $p_1^{**} = p_1^* + \Delta l$.

Hence, we have established the following result:

Result 1. *With full participation, firm 2's (the non-integrated network) profits are neutral to the lease price of the local loop. An increase of the lease price by Δl is passed on to consumers one-to-one and firm 1 (the vertically integrated network) benefits from such a policy.*

We believe it to be useful to elaborate on the above result. A lease price increase by Δl works affects prices in the same way as a per-user cost increase (of the same magnitude Δl) that is experienced by both networks; think of an increase of the line card's per-user cost f_i^{lc} for both firms. This can be seen as follows. The profits of operator 2 are equal to $s_2(p_1, p_2)(p_2 - l - (f_2^{\mathrm{lc}} + \Delta l))$, that is, the profit function has the same form as with a lease price l and costs $f_2^{\mathrm{lc}} + \Delta l$. The profit function of operator 1 becomes

$$\pi_1(p_1, p_2; l + \Delta l) = s_1(p_1, p_2)(p_1 - f_1) + (1 - s_1(p_1, p_2))(l + \Delta l - f_1^{\mathrm{ll}}).$$

The profit-maximizing price p_1 when p_2 is given, is determined by the first-order condition of profit maximization:

$$\frac{\partial s_1(p_1, p_2)}{\partial p_1}(p_1 - f_1) - \frac{\partial s_1(p_1, p_2)}{\partial p_1}(l + \Delta l - f_1^{\mathrm{ll}}) + s_1(p_1, p_2) = 0,$$

which is equivalent to

$$\frac{\partial s_1(p_1,p_2)}{\partial p_1}(p_1-(f_1+\Delta l))-\frac{\partial s_1(p_1,p_2)}{\partial p_1}(l-f_1^{\mathrm{ll}})+s_1(p_1,p_2)=0.$$

This equation is also the first-order condition of profit maximization given lease price l and costs for the linecard $f_1^{\mathrm{lc}}+\Delta l$, which leads to a total per-user cost of $f_1+\Delta l$. Hence, a lease price increase is passed on to consumers in exactly the same way as a cost increase. The only difference is that the owner of the essential facility, that is, the integrated network, benefits from a lease price increase because the associated 'downstream' cost increase generates revenues 'upstream' at the essential facility.

In the present context an analysis of total surplus is straightforward. Provided that the market is symmetric the socially desirable market share is 1/2. This is indeed implemented by the equilibrium for any lease price (such that the participation constraint of consumers is not violated and participation is indeed (perfectly) inelastic). However, if the market is not fully symmetric strategic behavior between firms typically does not lead to an implementation of a socially optimal outcome. In particular, if one network is more attractive than the other on average then the equilibrium market share of the less attractive network is socially excessive. A detailed analysis of asymmetric situations is certainly of interest but here we do not explore this issue any further.

To analyze investment incentives by the integrated network in the local loop we introduce a quality parameter q. Alternatively, parameter q can be interpreted as a capacity level. The former interpretation applies to both voice and Internet access, and the latter mainly to internet access. For simplicity, we assume that an increase of this parameter shifts the profit function by a factor $d(q)$ outward for given lease price and gross of costs associated to this improvement. The cost of implementing a quality or capacity improvement $q>1$ is denoted by $C(q)$ with the convention $C(1)=0$. Also by convention, $d(1)=1$. We can then write the integrated network's profits as

$$d(q)\pi_1(p_1,p_2,l)-C(q)$$

Clearly, if the lease price does not respond to the provided quality, then quality (or capacity) is chosen such that it satisfies $d'(q)\pi_1(p_1^*,p_2^*;l)-C'(q)=0$. If d is concave and C strictly convex, there exists a unique solution to the profit maximization problem at the investment stage at which firm 1 chooses q. Observe that a larger lease price leads to an increase in π_1, and hence strengthens the incentives of the integrated network to invest in the quality or capacity of the local loop.

Regulatory policy should take into account that the quality of the local loop is affected by its lease price regulation. To further strengthen the investment incentives without granting large profit margins at the local loop regulators may make their lease price depend upon quality. Suppose that the regulator can commit to a schedule $l(q)$ with $l'(q) > 0$. Note that equilibrium market shares are not affected by the level of the lease price (see Result 1 above). The first-order condition of profit maximization at the investment stage can then be written as

$$d'(q)\pi_1(p_1, p_2; l) - C'(q) + d(q)[s_1(p_1^*, p_2^*)\frac{dp_1^*(l)}{dl} + (1 - s_1(p_1, p_2))]l'(q) = 0,$$

which reduces to

$$d'(q)\pi_1(p_1, p_2; l) - C'(q) + d(q)l'(q) = 0$$

since $dp_1^*(l)/dl = 1$. We observe that with full participation, investment incentives are affected by the shape of the lease price schedule but independent of the degree of competition in the market. Furthermore, a more sensitive lease price schedule tends to increase investments incentives. In other words, if the regulator wants to achieve a certain quality level without giving large margins in the local loop he can do so by designing a sufficiently sensitive lease price schedule. We summarize our discussion by the following result.

Result 2. *With full participation, the regulator can provide stronger incentives to invest in the quality or capacity of the local loop by increasing the sensitivity of the regulated lease price to the quality or capacity level.*

4 Regulatory Theory with Partial Participation

We extend our previous setup to include partial participation so that total demand depends on prices. The perhaps easiest way to do so, is to assume that the services offered by the non-integrated network leads to a market expansion. This can be motivated by seeing the non-integrated network operator as a firm which can offer unique services (bundled into its product) which are desired by a certain group of consumers. The integrated network owner does not provide these tailored services and therefore cannot cater to the tastes of these consumers.

Formally, we consider a market consisting of two segments. In the first segment, the integrated and the non-integrated network are competitors. Segment 1 corresponds to the market analyzed in the previous segment. In segment 2 only the non-integrated network is active. The non-integrated network is assumed not to be able to price discriminate between the two segments. Clearly, in such a setup we should expect the neutrality result that firm 2's profits do not depend on the lease price, to break down. Furthermore, the integrated network has now (at least locally) some incentive not to inflate the lease price, if it were able to set it itself. The reason is that the higher the lease price, the higher the retail price set by the non-integrated network, but this implies a reduction of demand for segment 2, which in turn reduces firm 1's access revenues.

Additional demand for the product offered by the non-integrated network is denoted by $a(p_2)$, which is a decreasing function of operator 2's retail price. This function reflects the heterogeneous willingness-to-pay of consumers in the captive segment.[10] Obviously, this demand does not depend on the retail price of the integrated network, operator 1.

The profit maximization problem of the integrated network becomes

$$\max_{p_1} s_1(p_1, p_2)(p_1 - f_1) + (1 - s_1(p_1, p_2))(l - f_1^{\text{ll}}) + a(p_2)(l - f_1^{\text{ll}}) \tag{5}$$

Note that the third term in the sum is not affected by the decision of the integrated network. Consequently, the first-order condition is the same as in the previous section. The profit maximization problem of the non-integrated network is

$$\max_{p_2} [s_2(p_1, p_2) + a(p_2)](p_2 - l - f_2^{\text{lc}}) \tag{6}$$

An equilibrium (p_1^*, p_2^*) has to satisfy the system of first-order conditions

$$\begin{aligned} \frac{\partial s_1(p_1^*, p_2^*)}{\partial p_1}(p_1^* - f_1) + s_1(p_1^*, p_2^*) - \frac{\partial s_1(p_1^*, p_2^*)}{\partial p_1}(l - f_1^{\text{ll}}) &= 0 \\ \left[\frac{\partial s_2(p_1^*, p_2^*)}{\partial p_2} + \frac{\partial a(p_2^*)}{\partial p_2}\right](p_2^* - l - f_2^{\text{lc}}) + [s_2(p_1^*, p_2^*) + a(p_2^*)] &= 0. \end{aligned} \tag{7}$$

Suppose there is a unique solution to this system. Now consider a change in the lease price. We first show that generically the profit neutrality result for the non-integrated network breaks down.

Result 3. *With partial participation, profit of the non-integrated network are generically not neutral to the lease price of the local loop and the equilibrium demand of the integrated firm* s_1 *depends on the lease price* l*.*

[10] Note that heterogeneity is more likely to be relevant in the captive segment than in the competitive segment because in the competitive segment consumers can choose among alternative offerings so that they are more likely to be satisfied with one of them than in a monopoly situation.

Proof. Proof by contradiction. Suppose that after a change in the lease price of Δl, equilibrium retail prices are $p_1^{**} = p_1^* + \Delta l$ and $p_2^{**} = p_2^* + \Delta l$. Then, in equilibrium, the first-order condition of profit maximization for the non-integrated firm is

$$\left[\frac{\partial s_2(p_1^{**}, p_2^{**})}{\partial p_2} + \frac{\partial a(p_2^{**})}{\partial p_2}\right](p_2^* + \Delta l - (l + \Delta l) - f_2^{\mathrm{lc}}) + [s_2(p_1^{**}, p_2^{**}) + a(p_2^{**})] = 0.$$

which can be rewritten as

$$\left[\frac{\partial s_2(p_1^*, p_2^*)}{\partial p_2} + \frac{\partial a(p_2^{**})}{\partial p_2}\right](p_2^* - l - f_2^{\mathrm{lc}}) + [s_2(p_1^*, p_2^*) + a(p_2^{**})] = 0.$$

Comparing this equation with (7) it must hold that

$$\left[\frac{\partial a(p_2^* + \Delta l)}{\partial p_2} - \frac{\partial a(p_2^*)}{\partial p_2}\right](p_2^* - l - f_2^{\mathrm{lc}}) + [a(p_2^* + \Delta l) - a(p_2^*)] = 0.$$

Generically this equation is violated.[11] **Q.E.D.**

Clearly, it would be desirable to know in which way the equilibrium outcome changes. To answer this question in more detail, it is useful to consider for a moment the case that the non-integrated network could price discriminate between the two segments. In the non-captive market segment, the analysis of section 2 applies. Hence, prices have the same price levels as prices derived in the previous section; we denote these prices as p_1^{C*} and p_2^{C*}. In its captive market segment, the non-integrated network then would solve the following maximization problem $\max_{p_2} a(p_2)(p_2 - l - f_2^{\mathrm{lc}})$. Hence, it would set the monopoly price p_2^M in this segment which satisfies $a'(p_2^M)(p_2^M - l - f_2^{\mathrm{lc}}) + a(p_2^M) = 0$ or

$$-\frac{1}{a'(p_2^M)\frac{p_2^M}{a(p_2^M)}} = \frac{p_2^M - l - f_2^{\mathrm{lc}}}{p_2^M}.$$

This is the well-known inverse elasticity rule. Suppose the price elasticity of demand in the captive segment is a constant ε with $|\varepsilon| > 1$ (derived from $a(p_2) = kp_2^{\varepsilon}$). The inverse elasticity rule can be rewritten such that the profit-maximizing price is a linear function of the lease price.

$$p_2^M = \frac{1}{1 - \frac{1}{|\varepsilon|}}(l + f_2^{\mathrm{lc}})$$

Changes in the lease price by Δl translate into an increase of the price charged to the captive consumers by $(1 - (1/|\varepsilon|))\Delta l$. Hence, the price p_2^M increases always by more than Δl (since

[11] For instance, if a is linear the lease price is never neutral.

$|\varepsilon| > 1$).[12] In the limit as $|\varepsilon|$ goes to 1, we have $\lim_{|\varepsilon|\to 1}(1 - (1/|\varepsilon|)) = \infty$ and the smaller the demand elasticity the more sensitive reacts the price to a lease price increase.

The monopoly price in segment 2, p_2^M, may be higher or lower than the equilibrium price in segment 1. To fix ideas we call the former situation a *high-value situation* because overall there is a sufficient number of consumers attaching high value to the product of firm 2, (i.e. consumers with a willingness-to-pay above p_2^{C*}) so that the non-integrated network optimally sets its price above p_2^{C*}. We call the latter situation a *low-value situation* because overall there is an insufficient number of consumers attaching high value to the product of firm 2, so that the network optimally sets its price below p_2^{C*}. An alternative interpretation would be to look at the (imperfectly) competitive segment. Then the former situation can be called a competitive situation because competition in segment 1 is sufficiently strong to lead to an equilibrium price below the monopoly price in the captive segment. Similarly, the latter situation can be called an uncompetitive situation. In any case the captive segment is added value for the non-integrated network (and for the integrated network, provided the lease price is above costs).

In our setup in which the non-integrated network cannot price-discriminate between segments the qualitative results for the equilibrium prices depend on whether we are in a high-value or a low-value situation. From the definition of a high-value situation it follows that the profit maximizing price p_2 given p_1^* is between the equilibrium price in the competitive segment p_2^{C*} and the monopoly price in the captive segment p_2^M. Hence, in a high-value situation if networks offer strategic complements, equilibrium prices in our non-discrimination setup are higher than equilibrium prices in the competitive segment in the setup with price discrimination.[13] This implies that in a high-value situation the integrated network necessarily benefits from the existence of a captive segment because its profits in the competitive segment are higher than without the captive segment. The reason is that firm 1 can increase p_1^*. In addition, it makes revenues from selling wholesale-access to consumers in the captive segment of the non-integrated network. In a low-value situation equilibrium prices in our non-discrimination setup are lower than equilibrium prices in the competitive segment in the setup with price discrimination.

[12] This holds more generally since demand at the profit-maximizing price is always elastic, i.e. $|\varepsilon| > 1$.

[13] Note that in standard models of price competition with differentiated products, firms offer strategic complements (see e.g. Vives, 1990, and Milgrom and Roberts, 1990; for an application of the theory to telecommunications markets see Peitz, 2003). Consequently, best responses r_i are upward sloping. Comparing partial to full participation is a comparative statics exercise. Introducing a captive segment makes the best-response of non-integrated network 2 rotate clock-wise at the point $(\widetilde{p}_1, p_2^M)$ where $\widetilde{p}_1$ is defined by $r_2(\widetilde{p}_1) = p_2^M$.

How does the lease price affect equilibrium outcomes? First note that the qualitative result that a lease price increase leads to higher retail prices is robust to the introduction of partial participation. Formally, the result is shown by the fact that the best-response of both firms is shifted outward by a lease price increase, i.e. $\partial^2 \pi_i / \partial p_i \partial l > 0$, provided that networks offer strategic complements.

We also address the question whether the retail price increase is more pronounced under partial than under full participation. Suppose that initially we are in a low-value situation, that is, p_2^M is less than the competitive price under discrimination p_2^{C*}. Then, as argued above the equilibrium price must be $p_2^* < p_2^{C*}$. Consider now an increase in the lease price. With the (constant) elasticity ε greater than 1, the price in the captive segment p_2^M increases by more than Δl. As shown in section 3, the price in the competitive segment increases exactly by Δl. Hence, it is possible that we move from a low-value situation to a high-value situation. In other words, if the elasticity is sufficiently low, then a lease price increase leads to a regime shift from a low-value situation to a high-value situation. Hence, the presence of a captive segment amplifies the retail price increase. Starting from an initial situation in which prices are below the competitive price under discrimination, after a lease price increase they will be set above the corresponding prices if demand is sufficiently inelastic.

Result 4. *Suppose that the initial situation is a low-value situation. Then a retail price increase following from a lease price increase is greater with partial participation than with full participation, given that the demand in the captive segment is not too elastic.*

Clearly if the initial situation is a high value situation, the final situation after a lease price increase will also be a high-value situation. Similarly for a lease price reduction: either we move from a high-value situation to a low-value situation or we remain in a low-value situation.

Note that the level of the lease price is not welfare-neutral as it was in the case of full participation. A higher lease price translates into higher retail prices. This does not affect consumer participation in the competitive segment but it reduces consumer participation in the competitive segment. The mark-up charged by firm 2 leads to a deadweight loss. From a social point of view any retail price above the social costs $f_1^{\mathrm{ll}} + f_2^{\mathrm{lc}}$ is detrimental to social welfare. Since firms have market power, firm 2 charges a mark-up over its perceived marginal costs $l + f_2^{\mathrm{lc}}$. Hence, if the optimal regulation in a market in which firm 2 does not have market power (e.g. because it forms a competitive fringe together with other firms) implies that the lease price should be equal to costs, the optimal regulation in a market in which firm

2 *does* have market power is to set the lease price below costs. With respect to welfare in the captive segment and ignoring other welfare effects, optimal lease price regulation would have the property that the lease price is below costs and the resulting equilibrium price of firm 2 given this lease price is equal to costs $f_1^{\mathrm{ll}} + f_2^{\mathrm{lc}}$. Are there additional welfare effects which have to be considered? There is no welfare loss due to higher prices in the competitive segment due to inelastic demand. Hence, the lower lease price would be neutral to market share if firm 2 could price discriminate. However, without discrimination best responses are no longer symmetric. Also, a change in the lease price affects the firms' best-response functions differently. It depends on the exact change to determine whether firm 1 or firm 2 gains market share in the competitive segment after a change in lease price.

We can summarize the discussion up to this point by the following statement.

Result 5. *Suppose that the welfare effects of the captive segment dominate welfare effects in the competitive segment if they go in different directions. A regulator who only controls the lease price optimally sets its lease price below costs to control for the market power of firm 2.*

We can elaborate on this by considering a lease price increase that leads from a low-value to a high-value situation. For this consider the special case that the slope of firm 1's best response is globally greater than 1 (note that this is a natural assumption to make in the present context). If this is the case then in equilibrium with the initial lease price the equilibrium lies below the 45-degree line in the price-space (p_1, p_2), that is, $p_1 > p_2$ in equilibrium and consequently $s_1 < s_2$. In a high-value situation the reverse holds and consequently $s_1 > s_2$. From a social point of view, the optimal market share is 1/2 in the competitive segment (provided that the market is symmetric). Then a low lease price tends to lead to a socially excessive market share of the non-integrated network whereas a high lease price tends to lead to a socially excessive market share of the integrated network.

Laffont and Tirole (1994) consider a similar market environment in which also firm 2 enjoys market power. They are interested in the structure of Ramsey prices, that is the welfare-maximizing access and retail prices under the constraint that firm do not make losses. They show that the Ramsey pricing formulas in a market in which firm 2 does not have market power has to be modified. Since the retail price of firm 2 tends to be too high, the access price should reflect this type of inefficiency and therefore has to be set lower.

Finally, we would like to comment on investment and entry incentives. Clearly, if there are sunk costs to enter the industry, the regulator may have to guarantee a positive level of operating profits to the entrant. Clearly, ignoring strategic interaction in the competitive segment, a lower lease price leads to a higher profit of firm 2 in the captive segment because it can serve those consumers at a lower cost. In this sense a lower lease price stimulates entry. At the same time, a lower lease price tends to lead to lower retail prices overall since it makes firm 2 less interested in high prices in the captive segment. This indirect effect then leads to a lower profit of firm 2.

Also, we can consider firm 1's incentive to invest in quality, where firm 1 takes into account the dependence of lease price on quality. Here result 2, which is shown under full participation, appears to be robust to the addition of a captive segment for the non-integrated firm.

5 Discussion and Conclusion

In this paper, we extended existing insights on unbundling of the local loop in telecommunications markets to a more general setting. The extensions were in two dimensions: first, partial consumer participation, and second (more generally), imperfect competition. In particular, we looked at the effects of increases of the lease price of the local loop on retail prices. In addition, we derived implications related to the network operator's incentives to invest in quality or capacity of local connections to end-users. Although the analysis was framed in a telecommunications setting, the results have a more general applicability, extending to other markets as well. Further research should identify exactly when and to what extent this type of results apply to other sectors. For example, in sectors such as post and electricity it makes sense to model the particular characteristics of these markets, which may lead to more detailed results.

We believe that the analysis of one-way access situations that lead to imperfect competition in the retail market, such as in the model that we explored, needs further consideration. Our results, which focused on the effects of the access price on retail competition, provide some flavor of a broader research program. In future work we plan, for instance, to consider VoIP in more depth. As remarked in the introduction, an interesting feature of broadband internet access is that it allows for competition in voice telephony through VoIP. Whereas VoIP is sometimes implemented as a peer-to-peer application on end-users' computers (e.g. Skype), there exist also providers of VoIP that use 'gateways' to interconnect to the PSTN, that is, the public telephony network (an example of such a provider is Vonage in the US). The latter type of VoIP allows its users to connect to all (including 'traditional') telephony customers. Because of their different business model, such providers may provide very different pricing structures than those offered by former incumbents, which moreover face regulatory constraints on their pricing strategies. Thus, it may happen that a VoIP provider, offering a flat-rate scheme, competes with a telecommunications operator offering a two-part tariff.

A more general question related to the discussion above, which features prominently in current policy discussions, is whether a new technology, that allows entrants to make innovative use of unbundling agreements, should be regulated or not. With regard to VoIP in particular, an important question is whether a provider of VoIP services should be put under the regulatory umbrella or not.[14] Accordingly, it may be interesting to introduce asymmetric constraints on possible strategies, in particular with respect to retail pricing and quality requirements, that can be chosen by the integrated and non-integrated firm, and verify how welfare is affected.

[14]In the US, for instance, the Internet Policy Working Group of the Federal Comunnications Commission in the US, tries to identify the policy issues that arise as telecommunications moves to internet-based platforms.

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