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A Retail Benchmarking Approach to Efficient Two-way Access Pricing: Two-Part Tariffs *

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Abstract

We study a retail benchmarking approach to determine access prices for interconnected networks. Instead of considering fixed access charges as in the existing literature, we study access pricing *rules* that determine the access price that network i pays to network j as a linear function of the marginal costs and the retail prices set by both networks. In the case of competition in two-part tariffs, we consider a class of access pricing rules, similar to the optimal one under competition in linear prices, derived by Jeon (2005), but based on average retail prices. We show that firms choose the variable price equal to the marginal cost under the class of rules. Therefore, the regulator can choose one among the rules to pursue additional objectives such as consumer surplus, network coverage or investment: in particular, we show that the regulator can achieve static and dynamic efficiency at the same time.

Keywords: Networks, Access Pricing, Interconnection, Competition Policy, Telecommunications, Investment, Two-part Tariff

JEL numbers: D4, K21, L41, L51, L96

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1 Introduction

Access pricing constitutes the core of the policy issues regarding interconnected networks. More precisely, studying how access prices affect competition between networks and determining the optimal access prices form the central questions of the seminal papers on two-way network interconnection in Telecommunication Industry (Armstrong 1998, Laffont-Rey-Tirole (LRT, hereafter), 1998a,b) and the papers that followed.[1] Although the papers vary in terms of the retail prices they consider (linear versus non-linear prices, with or without network based price discrimination), the degree of customer heterogeneity and whether or not they explicitly consider receivers' surplus, all the papers have a common trait in that they consider a fixed access price, which is either negotiated bilaterally between two networks or is fixed by a regulatory agency. In this paper, we make a departure from this standard approach and consider what we call a retail benchmarking approach. In our approach, we study access pricing *rules* that determine the access price that network i pays to network j as a (linear) function of the marginal costs and the retail prices set by both networks. Using this approach, Jeon (2005) considers the case of competition in linear prices and derives the optimal access pricing rule that implements the Ramsey outcome. In this paper, we consider the case of competition in two-part tariffs and study an adaptation of the optimal rule discovered in Jeon (2005). It turns out that the adapted rule has some remarkable properties that we explain below.

In the case of competition in linear prices, Jeon (2005) considers a set of linear access pricing rules that includes any fixed access price and the well-known Efficient Component Pricing Rule (ECPR) as particular rules. He shows that within this set, there is a unique rule that implements the Ramsey outcome as the unique equilibrium, *independently of the underlying demand conditions*, as long as there exists at least a mild degree of substitutability between networks' services. This optimal rule is such that the mark-up of the access price that network i pays to network j is equal to the mark-up of network i's retail price multiplied by $n/(n-1)$ where n represents the number of competing networks. This rule promotes competition in retail prices as network i can decrease its access payment by reducing its retail price. Since access pricing rules are much more general than fixed access prices, it is perhaps not that surprising that some rule is able to implement the Ramsey outcome. What is a very remarkable feature of the optimal access pricing rule is that it does not depend on

[1]See, for instances, Carter and Wright (1999, 2003), Dessein (2003, 2004), Gans and King (2000, 2001), Hahn (2004), Hermalin and Katz (2001, 2004), Jeon-Laffont-Tirole (2004), Laffont-Marcus-Rey-Tirole (2003), Valletti and Cambini (2005) and Wright (2002).

the demand structure[2] so that the regulator only needs to observe marginal costs and retail prices and does not need to know anything about the demand side.[3] Furthermore, the model and access pricing rules allow for more than two competing networks.[4]

This paper considers the case of competition in two-part tariffs. We adapt the access pricing rule that is optimal in the case of linear prices such that the mark-up of the access price above the termination cost that network i pays to network j is equal to network i's *average retail price* mark-up multiplied by a factor κ.[5] We show that under the adapted rules each network finds it optimal to charge its variable price equal to the true marginal cost for any market share and for any $\kappa \leq 1$: in fact, when $\kappa = 0$, the access price is equal to the termination cost and LRT (1998a) show that in this case, the variable price is equal to the marginal cost. When $\kappa = 0$, network i's profit is equal to its market share multiplied by profit per customer (net of the fixed cost per customer). Therefore, maximizing network i's profit with respect to its variable price, while maintaining its market share constant, is equivalent to maximizing its profit per customer, which leads to the marginal cost pricing. When $\kappa \neq 0$, under our access rule, the access payment per customer that network i makes to its rival networks is equal to a fraction (smaller than one) of its profit per customer (as long as $\kappa \leq 1$). Therefore, our rule generates the marginal cost pricing as long as $\kappa = 0$ does it. For instance, we show that our rule achieves the marginal cost pricing even when networks face heterogeneous customers and compete with a menu of two-part tariffs.

Therefore, the regulator (or the competition authority) can properly choose κ to pursue another goal while achieving the efficient pricing in terms of variable price. For instance, since the equilibrium profit decreases with κ (*i.e.*, the profit neutrality result does not hold within our framework), κ can be chosen to increase consumer surplus at the expense of firms'

[2] Under the LRT assumption of full coverage

[3] In contrast, under the standard approach of fixed access price (LRT,1998a), (i) the Ramsey access price must be lower than the termination cost but no equilibrium exists if the access price is different from the termination cost and the services provided by different networks are substitutable enough; (ii) if access prices are determined through private negotiations, networks can achieve the monopoly outcome by coordinating on a certain level of access price; (iii) the Ramsey access price is informationally demanding since it requires the regulator to possess precise information regarding both the cost and the demand structure.

[4] Stennek and Tangerås (2006) also consider a model that allows for more than two networks. Their analysis accounts for the fact that the bilaterally agreed upon reciprocal access price between two networks affects their competitiveness with respect to other rivals. Since network based price discrimination is not allowed for in the model, the equilibrium retail price set by one particular network will be influenced by all negotiated access prices. It is shown that, in the absence of regulation, this competition in access prices has no effect and networks will be able to sustain monopoly retail prices. However, a light-handed form a regulation (setting a maximum access price) induces networks to set retail prices close to marginal cost when networks are sufficiently close substitutes.

[5] It turns out that the rule that implements the Ramsey outcome in case of linear prices gives firms incentives to set variable price below cost and high fixed fees, generating a high volume of (off-net) calls for which negative access charges would have to be paid.

profits. This also suggests that κ can be chosen to promote penetration in markets where no full coverage equilibrium exists with fixed access charges. Very interestingly, κ can also be chosen to increase firms' profits so as to create incentives for socially optimal investment in network quality (*i.e.*, to achieve static and dynamic efficiency at the same time).

Making access prices depend on retail prices is an old idea in the case of one-way access. The well-known ECPR[6] achieves the efficient entry by equalizing the access price that an entrant should pay to the incumbent with the sum of the cost of providing the access and the latter's opportunity cost (*i.e.*, the incumbent's retail price mark-up) when the incumbent's retail price is regulated. However, the ECPR is not good at promoting competition in retail prices when the retail prices are not regulated since the access price that the incumbent receives increases with its retail price.[7] This motivated Sibley et al. (2004) to consider the Generalized Efficient Component Pricing Rule (GECPR) in which the access price that an entrant pays is, roughly speaking, equal to the sum of the cost of providing the access and the entrant's opportunity cost (*i.e.*, the entrant's retail price mark-up). They find that since the entrant can reduce its access charge payment by lowering its retail price, the GECPR is good at intensifying retail competition.

In the case of two-way access, LRT (1998a) examine various interpretations of the ECPR in a duopoly framework and show that when networks can privately negotiate on a fixed level of access price, the ECPR allows them to collude and achieve the monopoly outcome. More importantly, Mialon (2007) studies the GECPR, considered by Sibley et al. (2004) in one-way access, in LRT's framework of duopoly with linear pricing.[8] Under the GECPR, the mark-up of the access price that network i pays to the rival network is equal to the former's retail price mark-up. Jeon (2005) shows that there exists a unique rule achieving the Ramsey outcome in the set of linear access pricing rules which includes the GECPR as a special case. Since the optimal rule is different from the GECPR, the GECPR does not achieve the Ramsey outcome.[9]

In practice, there are cases in which access prices (or termination charges) depend on

[6]See Baumol (1983), Baumol and Sidak (1994) and Willig (1979). For an introduction to the ECPR, see Armstrong (2002) and Laffont and Tirole (2000).

[7]Moreover, as Economides and White (1995) point out, the ECPR avoids entry by less efficient entrants and thus achieves productive efficiency, but this social gain may be more than outweighed by the loss in consumer surplus by means of foregone competition and high retail prices.

[8]Doganoglu and Tauman (2002) also consider a linear access pricing rule which depends on retail price. More precisely, in their paper, the access price that network i receives from network j is a (positive and) constant fraction of the linear retail price that network i charges. This rule is included as a special case in the set of the access pricing rules that we consider. As is explained in section 3, this kind of rule cannot be optimal since network i has an incentive to increase (rather than reduce) its retail price in order to receive a higher access payment.

[9]In fact, the equilibrium price under the GECPR is higher than the Ramsey price.

retail tariffs. In the context of termination charges for mobile phone service, the Australian competition and consumer commission (2001) adopted what they call "retail benchmarking approach" (the title of our paper comes from this report), which means that "access prices for GSM termination will fall at the same rate as retail prices for mobile services provided by a mobile carrier (p.89)." Some other countries use a "retail-minus" approach to set access prices on the basis of a fixed discount off the corresponding retail prices. (See OECD, 2004.) [10]

Our result in Section 6 that there is a class of access pricing rules which achieve efficiency when networks face heterogeneous consumers and compete in menus of two-part tariffs is interesting in its own right. Previously, Dessein (2003) and Hahn (2004) find that when the access price is equal to the termination cost (*i.e.*, $\kappa = 0$), network competition achieves efficiency. However, in this case, access price disappears from the profit function and the profit function becomes the same as the one in a standard Hotelling model without interconnection. This is why they rediscover the efficient two-part tariff result obtained by Armstrong and Vickers (2001) and Rochet and Stole (2002) in the context of competitive price discrimination without interconnection. In other words, in Dessein (2003) and Hahn (2004), efficiency is achieved by making the case with interconnection similar to the case without interconnection. What we show is that in the presence of interconnection, there is a class of access pricing rules which achieve efficiency; interconnection provides additional instruments to achieve efficiency with respect to no interconnection.

Section 2 presents the general model, defines the set of linear access pricing rules and characterizes the Ramsey outcome. Section 3 briefly reviews the results in the case of competition in linear prices obtained by Jeon (2005). Section 4 considers how the optimal rule in section 3 can be adapted in a context where firms compete in non-linear prices by benchmarking the access price to the *average* retail price. It shows that a whole class of benchmarking rules lead to marginal cost pricing. Section 5 shows that by choosing adequately among these rules the regulator can pursue another goal. In particular, section 5.2 shows that the regulator can achieve both static and dynamic efficiency at the same time. Section 6 considers the case of heterogeneous consumers in which firms compete with menu of two-part tariffs and shows that the main result derived in section 4 is robust. Section 7 concludes.

[10] Another example of pegging access price to retail tariffs can be found in the international postal service. For instance, access prices (*i.e.*, what they call "termination dues") among European countries should be set at 80% of domestic tariffs (Ghosal, 2002).

2 Framework

2.1 The model

We present a general model of n-network competition which includes the duopoly model of LRT (1998a) as a special case. There is a mass one of consumers.

• *Individual demand*:

Let $u(q)$ be the utility that a consumer derives from placing q volume of calls. The utility function $u(\cdot)$ is twice continuously differentiable, with $u' > 0, u'' < 0$, which implies that demand function is differentiable. Let $q(\cdot)$ denote the demand function, given by $u'(q(p)) = p$ where p is the variable retail price. When network i charges p_i, the volume of calls placed by a customer of network i is given by $q(p_i)$. Let $v(p)$ be the indirect utility function, *i.e.*,

$$v(p) = \max_q\{u(q) - pq)\}.$$

Let $R(p) \equiv (p - c)q(p)$ represent the revenue per consumer. We assume that $R(p)$ has a unique maximum at $p = p^m$, is strictly increasing when $p < p^m$ and strictly decreasing when $p > p^m$. Therefore, p^m denotes the monopoly price. Let R^m denote the monopoly revenue per consumer (*i.e.*, $R^m = R(p^m)$). We assume $\lim_{p\to\infty} R(p) = 0$.

• *Firm's demand (or market share):*

The networks (*i.e.*, firms) provide horizontally differentiated services and each network can cover all the consumers. Under competition in two-part tariffs, firm i chooses tariff $T_i = F_i + p_i q$. Given (p_i, F_i), the net surplus of a consumer of network i is given by:

$$w_i = v(p_i) - F_i.$$

Let $\mathbf{w} \equiv (w_1, ...w_n)$ and $\mathbf{w}_{-i} \equiv (w_1, .., w_{i-1}, w_{i+1}, ..., w_n)$. Let $\alpha_i(w_i; \mathbf{w}_{-i})$ denote the measure of consumers subscribing to network i. We assume that $\alpha_i(\mathbf{w})$ satisfies the following properties:

Property 1 (symmetry): For any vector $\mathbf{w}$ with $w_i = w_j$ for some i and j, we have $\alpha_i(\mathbf{w}) = \alpha_j(\mathbf{w})$.

Property 2 (monotonicity): For any $i, j = 1, ..., n$ and $i \neq j$, $\alpha_i(w_i; \mathbf{w}_{-i})$ is differentiable with respect to each w_j and increases with w_i and decreases with w_j; it strictly increases with w_i and strictly decreases with w_j for $\alpha_i \in (0, 1)$.[11]

Property 3 (full coverage): $\sum_{i=1}^{n} \alpha_i(w_i; \mathbf{w}_{-i}) = 1$ for all relevant $\mathbf{w} \in \Re_+^n$.

Properties 1, 2, and 3 are satisfied by the Hotelling model of LRT (1998a) and the circular city model with $n = 2$ or 3 (Salop, 1979). For $n > 3$, our model is more natural than the circular city model since in the latter, a (minor) price change of network i affects only the demands of its direct neighbors (network $i - 1$ and network $i + 1$) but does not affect the demands of other networks. In the context of telecommunication markets all networks compete directly with each other for all customers, and not only with two artificial "neighbors" for a specific subset of consumers. The symmetry and the full coverage imply $\alpha_i = \frac{1}{n}$ for all $i = 1, ..., n$ if $w_i = w$ for all $i = 1, ..., n$. Regarding the full coverage property, LRT (1998a) assume that each consumer derives, in addition to $u(q)$, a constant utility v_0 from subscribing to one of the networks, which is large enough to ensure that all consumers always choose to join one of the networks. Since the total mass of consumers is equal to one, under full coverage, the mass of consumers subscribing to network i (*i.e.*, α_i) is equal to network i's market share.

In the case of competition in linear prices, let $\mathbf{p} \equiv (p_1, ..., p_n) \in \Re_+^n$ represent the vector of retail prices and let $\mathbf{p}_{-i} \equiv (p_1, .., p_{i-1}, p_{i+1}, ..., p_n)$. Since w_i strictly decreases with p_i, it is more convenient to work with $\alpha_i(p_i; \mathbf{p}_{-i})$ than with $\alpha_i(w_i; \mathbf{w}_{-i})$. Obviously, properties 1-3 imply that similar properties hold for $\alpha_i(p_i; \mathbf{p}_{-i})$. Of course, $\alpha_i(p_i; \mathbf{p}_{-i})$ *decreases* with p_i and *increases* with p_j.

• *Cost*:

Concerning the cost side, we use the same technology that is used in LRT (1998a). Serving a customer involves a fixed cost $f > 0$, say of connecting the customer's home to the network and of billing and serving her. We assume $R^m > f$. A network also incurs a marginal cost c_0 per call at the originating and terminating ends of the call and marginal cost c_1 in between. Therefore, the total marginal cost of a call is

$$c \equiv 2c_0 + c_1.$$

[11]Property 2 can be more rigorously defined as follows. Given $\mathbf{w}_{-i}$, let $\overline{w}_i$ be the minimum w_i making $\alpha_i(w_i; \mathbf{w}_{-i}) = 1$ and let $\underline{w}_i$ be the maximum $w_i \in \Re_+$ making $\alpha_i(w_i; \mathbf{w}_{-i}) = 0$. Then, α_i strictly increases with w_i for $w_i \in [\underline{w}_i, \overline{w}_i]$. Similarly, given $\mathbf{w}_{-j}$ with $j \neq i$, let $\overline{w}_j$ be the minimum $w_j \in \Re_+$ making $\alpha_i(w_i; \mathbf{w}_{-i}) = 0$ and let $\underline{w}_j$ be the maximum $w_j \in \Re_+$ making $\alpha_i(w_i; \mathbf{w}_{-i}) = 1$. Then, α_i strictly decreases with w_j for $w_j \in [\underline{w}_j, \overline{w}_j]$.

2.2 Access pricing rules

We consider simple access pricing rules which are not informationally demanding. More precisely, the informational constraint that the regulator faces is defined as follows.

- *The regulator's informational constraint*:

On the one hand, we assume that the regulator (or the competition authority) has limited information about the market such that she is not informed about the individual demand function $q(p)$, each firm's demand function and the value of the fixed cost f. On the other hand, she knows the marginal cost c and the termination cost c_0. Furthermore, she and consumers observe retail prices $(p_1, F_1), ..., (p_n, F_n)$. Moreover, the regulator can observe average retail prices,[12] which means that she must be able to observe realized demand.

The firms are assumed to know all the relevant information regarding both the demand and the cost sides.

- *The linear access pricing rules*:

Let a_{ij} with $i \neq j$ denote the access charge that network i pays to network j. In Jeon (2005) which considers competition in linear prices, in order to consider simple rules, he limits attention to the following linear access pricing rules:

$$a_{ij} - c_0 = h(p_i, p_j, c) = h_1 p_i + h_2 p_j + h_3 c + h_4 \text{ for any } i, j = 1, ..., n \text{ and } i \neq j, \tag{1}$$

where $(h_1, h_2, h_3, h_4) \in \Re^4$ is a vector of constants. Note that the rule is reciprocal since the coefficients (h_1, h_2, h_3, h_4) do not depend on firms' identities. This is without loss of generality given that networks are symmetric.[13] Let Λ_n^L be the set of linear access pricing rules satisfying the above form (1). Some special cases of linear access pricing rules are:

- Cost based access pricing rule: $a_{ij} = c_0$.
- Efficient component pricing rule (ECPR): $a_{ij} - c_0 = p_j - c$.
- Generalized efficient component pricing rule (GECPR): $a_{ij} - c_0 = p_i - c$.
- Bill and keep: $a_{ij} = 0$.

[12]For instance, the Spanish telecommunication agency (Comisión del Mercado de las Telecomunicaciones) publishes data on each network's average price.

[13]In the case of asymmetric networks, we need to consider non-reciprocal rules such that the coefficients depend on the firms' identities. See Carter and Wright (2003) for the study of asymmetric networks.

In the case of the ECPR, the access price that network i pays to network j is the sum of the termination cost and network j's retail price mark-up. In contrast, in the case of the GECPR, the access price that network i pays to network j is the sum of the termination cost and network i's retail price mark-up (Sibley *et al.* 2004, Mialon 2007).

2.3 Ramsey benchmark

For future reference, we derive the social optimum in the ideal case in which the regulator knows all the relevant information and can dictate the prices under the constraint that the industry breaks even. Under linear pricing, consumer variable welfare is

$$W(\mathbf{p}) = \sum_{i=1}^{n} \alpha_i(\mathbf{p})v(p_i) - T\left[\alpha_1(\mathbf{p}), ..., \alpha_n(\mathbf{p})\right] \tag{2}$$

where $T(\alpha_1, ..., \alpha_n)$ denotes the average consumer's utility from not being able to consume her preferred service. We assume that $T(\boldsymbol{\alpha})$ is minimized at equal market share $\alpha_i = \frac{1}{n}$. The industry budget constraint is

$$\sum_{i=1}^{n} \alpha_i(\mathbf{p})R(p_i) = f. \tag{3}$$

Maximizing (2) subject to (3) yields a symmetric solution, $p_i = p^R$ for all $i = 1, ..., n$, where the Ramsey price p^R is the lowest price that satisfies the budget constraint:

$$R(p^R) = f.$$

Since we assume $R^m > f$, we have $p^R < p^m$. Let $q(p^R) \equiv q^R$.

Clearly, in the case of competition in two-part tariffs, it is socially optimal to set a two-part tariff with variable price c and fixed fee $F \geq f$. $T(\boldsymbol{\alpha})$ is minimized at equal market share $\alpha_i = \frac{1}{n}$.

2.4 Timing

The timing of the game we consider is the following:

1. The regulator chooses a linear access pricing rule in Λ_n^L.
2. All networks simultaneously choose retail prices.
3. Consumers make subscription and consumption decisions.

3 Summary of the Results under Competition in Linear Prices

In this section, we summarize the results in the case of competition in linear prices in Jeon (2005). This is because the rules we consider in the case of competition in two-part tariff is derived from the optimal rule in the case of competition in linear prices.

Under competition in linear prices, two more properties are assumed. Property 4 is about the degree of substitutability among the networks. Because of our assumptions on $R(p)$, there exists a $\overline{p} > p^m$ such that $R(\overline{p}) = f$. We assume in this section:

Property 4 (substitutability): $\alpha_i(p) = 0$ if $p_i \geq \bar{p}$ and $p_j = p^m$ for some $j \neq i$.

The property says that a firm charging a high price yielding negative revenue per costumer will have no market share if there is at least one competitor charging no more than the monopoly price. Hence the property guarantees that there is at least some mild level of substitutability.

Property 5 is a technical assumption to eliminate asymmetric equilibria for $n \geq 3$:

Property 5 (proportional market share increases): Let i, j and k be three different firms and consider price vectors $\mathbf{p}$ and $\hat{\mathbf{p}}$ with $p_k < \hat{p}_k$ and $p_m = \hat{p}_m$ for all $m \neq k$. If $\alpha_j(\mathbf{p}) > 0$, then $\alpha_i(\hat{\mathbf{p}})/\alpha_j(\hat{\mathbf{p}}) = \alpha_i(\mathbf{p})/\alpha_j(\mathbf{p})$.

Property 5 says that the *ratio* of market shares of any two firms is not affected by a price increase by a third firm. It is automatically satisfied when $n = 2$ and is introduced to exclude asymmetric equilibria when $n \geq 3$.

The following proposition shows the main result for the case of competition in linear prices.

Proposition 1 *(Competition in linear prices, Jeon, 2005) For any demand structure satisfying Properties 1-5 and for $n \geq 2$, there is a unique linear access pricing rule in Λ_n^L defined by $a_{ij} - c_0 = \frac{n}{n-1}(p_i - c)$ that implements, independently of the underlying demand conditions, the Ramsey outcome ($p_i = p^R$ for all $i = 1, ..., n$) as the unique equilibrium, which is symmetric.*

Note the remarkable result that the optimal rule implementing the Ramsey outcome does not depend on the demand structure as long as it satisfies Properties 1-5.

The following corollary compares different access pricing rules in the case of $n = 2$. Suppose that the regulator should choose an access pricing rule without knowing the demand structure while she only knows the marginal cost structure (c, c_0). Consider duopolistic competition[14] and, for simplicity, let a_i denote the access charge that network i pays to the rival network. Then, from Proposition 1, we have the following corollary.

Corollary 2 *(Jeon, 2005) Under Properties 1-5, the social welfare is strictly higher under the access pricing rule $a_i - c_0 = 2(p_i - c)$ than under any other fixed access price (including $a_i = c_0$), under the ECPR ($a_i - c_0 = p_j - c$, for $i \neq j$) and under the GECPR ($a_i - c_0 = p_i - c$).*

4 The main result

Although linear prices are used in practice, especially for pre-paid cards in the mobile telecommunication market, we cannot deny that non-linear prices are also heavily used. Moreover, the literature has embraced two-part tariff competition as the standard. In this section we study competition in two-part tariffs when our rule is adapted to make access charges depend (linearly) on average retail prices. We show in this section that the class of rules we consider induces networks to choose the marginal cost pricing in a general setting.

It is clear that firms would prefer to use two-part tariffs rather than linear prices. Namely, when firms are allowed to use a two-part tariff, they will in general find it optimal to set a strictly positive fixed fee to extract consumer surplus. If one would naively use the access pricing rule that is optimal in the case of linear prices (*i.e.*, $a_{ij} = c_0 + 2(p_i - c)$) when firm i uses tariff $T_i = F_i + p_i q$, no symmetric equilibrium would exist.[15] Therefore, the rule needs to be adapted to give sensible and satisfactory results. Inspired by the previous discussion, we propose to make the access charge to be paid by firm i to depend linearly on its average retail price as follows:

$$a_i = c_0 + \kappa \left(\frac{F_i + p_i q(p_i)}{q(p_i)} - c \right), \tag{4}$$

where a_i represents the access charge that firm i pays to each rival firm. Since it only depends on firm i's retail prices, we use a_i instead of a_{ij} for simplicity.

[14] The intuition obtained in this section applies to the case of $n > 2$ as well.

[15] More precisely, firms would have incentives to reduce variable price below cost (for example, to zero if negative prices are not allowed) so that access charge becomes negative. Each network would then receive money from its rival for each off-net call made by its subscribers. This then leads the firms to compete for market share by reducing fixed fees resulting in huge losses.

Under the standard full coverage assumption, we find that firms always will set variable price equal to marginal cost c, independently of κ and their market shares, for all $\kappa \leq 1$. In what follows, we first explain intuitively why the class of access pricing rules we consider generates the marginal cost pricing.

Given (p_i, F_i), the net surplus of a consumer of network i is given by:

$$w_i = v(p_i) - F_i.$$

Let $\mathbf{w} \equiv (w_1, ...w_n)$. The market share of network i is given by $\alpha_i(\mathbf{w})$. For instance, in the Hotelling model of duopoly (LRT, 1998a,b), we have

$$\alpha_i = \frac{1}{2} + \sigma(w_i - w_j),$$

where $\sigma \equiv 1/(2t)$ and t is the transportation cost in the Hotelling model. We first consider the case of $\kappa = 0$ which corresponds to $a_i = c_0$. Then, network i's profit is given by:

$$\Pi_i(p_i, F_i) = \alpha_i \left[(p_i - c)q(p_i) + F_i - f\right] = \alpha_i \pi_i - \alpha_i f.$$

where $\pi_i \equiv (p_i - c)q(p_i) + F_i$ represents network i's retail profit per customer gross of the fixed cost f when $\kappa = 0$. It is useful to think that network i chooses (p_i, w_i) instead of (p_i, F_i). Then, we have:

$$\begin{aligned} \Pi_i(p_i, w_i) &= \alpha_i \left[(p_i - c)q(p_i) + v(p_i) - w_i - f\right] \\ &= \alpha_i \left[u(q(p_i)) - cq(p_i) - w_i - f\right]. \end{aligned}$$

Given w_i (hence, given α_i), maximizing Π_i with respect to p_i is equivalent to maximizing total surplus, which leads to the marginal cost pricing (*i.e.*, $p_i = c$) for any α_i as LRT (1998a) show.

Consider now $\kappa \neq 0$. Then, we have the following expression for network i's profit:

$$\Pi_i(p_i, F_i) = \alpha_i \left[(p_i - c - (1 - \alpha_i))(a_i - c_0)q(p_i) + F_i - f + \Sigma_{j \neq i} \alpha_j (a_j - c_0) q(p_j)\right].$$

In particular, from (4) the total access payment mark-up that network i makes to network j is given by:

$$\alpha_i(1 - \alpha_i)(a_i - c_0)q(p_i) = \alpha_i \kappa (1 - \alpha_i)\pi_i.$$

The above equation shows that network i's access payment mark-up per customer is a fraction $(1-\alpha_i)\kappa$ of its retail profit per customer π_i. Inserting the above expression into the profit function leads to

$$\Pi_i(p_i, F_i) = \alpha_i \left[(1-\kappa(1-\alpha_i))\pi_i - f + \kappa\Sigma_{j\neq i}\alpha_j\pi_j\right], \tag{5}$$

which is equivalent to

$$\Pi_i(p_i, w_i) = \alpha_i \left[(1-\kappa(1-\alpha_i))(R(p_i)+v(p_i)-w_i)\right] - \alpha_i f + \alpha_i\kappa\Sigma_{j\neq i}\alpha_j\pi_j \tag{6}$$

Therefore, as long as $(1-\kappa(1-\alpha_i)) \geq 0$ (which is satisfied when $\kappa \leq 1$), the profit maximization with respect to p_i for given w_i leads to the marginal cost pricing (*i.e.*, $p_i = c$) for any α_i and for any $\kappa \leq 1$. The intuition is clear from (6). Given w_i (hence, given α_i), when we maximize Π_i with respect to p_i, only the first term matters in (6) and therefore maximizing Π_i is equivalent to maximizing the profit per customer π_i as is the case when $\kappa = 0$. This is because, under our access pricing rule, network i's access payment mark-up per customer is just a fraction of its retail profit per customer.

The above intuition suggests that our access pricing rule gives the marginal cost pricing under various circumstances; as long as $a_j = c_0$ generates the marginal cost pricing, our access pricing rule generates the marginal cost pricing as well. In fact, we show this later on when firms can invest to improve quality of their networks or when firms compete by providing a menu of two-part tariffs to heterogeneous customers.

The following proposition presents our main result:

Proposition 3 *Assume Properties 1-3. (i) For any $n \geq 2$ and $\kappa \leq 1$, all networks choose the same variable price $p = c$.*

(ii) More specifically, in the case of the Hotelling duopoly model (LRT, 1998a,b), when $\kappa \leq 1$ and for small enough $\sigma > 0$, there exists a unique equilibrium, which is symmetric. In the equilibrium, networks charge variable price $p = c$ and fixed fee $F = f + (2-\kappa)/(4\sigma)$. Equilibrium profits per firm equal $(2-\kappa)/(8\sigma)$.

Hence, for any $\kappa \leq 1$ we obtain efficient pricing. By varying κ we can address and achieve further objectives, without distorting the efficient marginal cost pricing result. Furthermore, proposition 3(ii) shows that the profit is not neutral and decreases with κ. An increase in κ promotes competition in terms of the fixed fee and thereby decreases the profit. Therefore, by increasing κ, the regulator or competition authority can improve consumer welfare at the expense of firms' profits.

However, we cannot push firms' profits all the way to zero. Namely, this would require firms to set the competitive schedule $T = f + cq$, which in turn requires setting $\kappa = 2$. But this cannot be an equilibrium since the average price at this equilibrium is strictly above c, so that access charge is above marginal cost. A network could deviate by offering a schedule $\tilde{T} = \tilde{F} + \tilde{p}q$, where $0 < \tilde{p} < c$ and $\tilde{F} = -(\tilde{p} - c)q(\tilde{p})$, such that its average price is exactly equal to marginal cost c and such that its market share $\tilde{\alpha}_i$ is positive but less than one half. The deviating firm then pays an access fee equal to termination cost c_0 so that both on-net and off-net calls are at marginal cost c, which in turn equals average price. It thus would earn zero net profits from calls made by her own subscribers but would then make strictly positive profits because the net access revenue exceeds the incurred fixed costs: $2(1 - \tilde{\alpha}_i)\tilde{\alpha}_i f > \tilde{\alpha}_i f$.

Proof.

Since (i) is proven in the text before the proposition, we only need to prove (ii). We first derive the unique symmetric equilibrium candidate. We will then derive conditions under which this candidate equilibrium is indeed an equilibrium.

Using $v'(p_i) = -q(p_i)$ we obtain

$$\partial \Pi_i / \partial p_i = \alpha_i q'(p_i)(p_i - c)(1 - \kappa(1 - \alpha_i)). \tag{7}$$

When $1 - \kappa(1 - \alpha_i) > 0$ and $\alpha_i > 0$, this derivative is negative (positive) when $p_i > c$ ($p_i < c$, respectively). Hence, the equilibrium price in a symmetric equilibrium must be equal to marginal cost c.

We now focus on the derivative of profit with respect to w_i.

$$\frac{\partial \Pi_i}{\partial w_i} = \sigma \left[\frac{\Pi_i}{\alpha_i} \right] + \alpha_i(-1 + \kappa(1 - \alpha_i) + \kappa\sigma[F_i + R(p_i) - F_j - R(p_j)]). \tag{8}$$

In a symmetric interior equilibrium we have $p_i = c$ and thus $\Pi_i = (F - f)/2$. Hence, the first order condition gives

$$0 = \sigma(F_i - f) + \frac{1}{2}(-1 + \kappa/2).$$

The symmetric equilibrium candidate has thus

$$F = f + \frac{2 - \kappa}{4\sigma}.$$

Symmetric equilibrium profit per firm equals

$$\Pi^* = \frac{2-\kappa}{8\sigma}.$$

We see that a necessary condition is $\kappa \leq 2$. The second order derivative yields

$$\frac{\partial^2 \Pi_i}{\partial w_i^2} = 2\sigma[-1 + \kappa\sigma(R(p_i) + v(p_i) - 3w_i - R(p_j) - v(p_j) + 3w_j)].$$

At the symmetric equilibrium candidate this is equal to -2σ and thus strictly negative for all κ.

We now derive sufficient and necessary conditions for the symmetric equilibrium candidate $T = F + cq$ to be indeed an equilibrium.

Hence, let $p_2 = c$ and $F_2 = F$. That is, $w_2 = v(c) - F = v(c) - f + (\kappa - 2)/(4\sigma)$. First, we know from (7) that, as long as $1 - \kappa(1 - \alpha_1) > 0$, it is optimal to set $p_1 = c$. This is the case when $\kappa \leq 1$ and $\alpha_i > 0$. The optimal w_1 is then found by the first order condition at $w_1 = w_2$, since the second order derivative $(2\sigma(-1 + 3\kappa\sigma(w_2 - w_1)))$ is strictly negative for all $w_1 \geq 0$ as long as σ is small enough.

On the other hand, if $\kappa > 1$, network 1 can obtain unbounded profits by choosing w_1 such that $1 - \kappa(1 - \alpha_1) < 0$ by letting $p_1 \approx 0$. (Namely, if demand is as in LRT, then $\lim_{p_1 \to 0} v(p_1) + R(p_1) = -\infty$, and profit is unbounded from equation (6)).

It is not hard to see that there cannot be an asymmetric equilibrium. Namely, from (7) we know that both firms will set $p_j = c$. Substituting these prices and taking derivatives with respect to w_i yields

$$\frac{\partial \Pi_i}{\partial w_i} = \sigma v(c) - w_i - \sigma f + \sigma\kappa(1 - 2\alpha_i)(w_i - w_j) - \alpha_i(1 - \kappa(1 - \alpha_i)).$$

Subtracting the first order derivative for firm j from that for firm i yields

$$0 - 0 = \frac{\partial \Pi_i}{\partial w_i} - \frac{\partial \Pi_j}{\partial w_j} = -3\sigma(w_i - w_j),$$

so that $w_i = w_j$. ∎

5 Pursuing additional goals

In this section, we consider the Hotelling model à la LRT (1998a). We show how the degree of freedom in the class of access pricing rules that achieve static efficiency can be used to pursue an additional goal.

5.1 Expanding coverage

In this subsection we take the participation condition of consumers seriously. In the previous section, and in most of the related literature, one typically assumes that σ is small enough, which implies that transportation cost t is very large. This would lead consumers in the center of the Hotelling model to forego subscribing to a network. In order to maintain the full coverage assumption one needs to assume that consumers have a high enough valuation for being subscribed to the network, even if no one else subscribes or when hardly any calls are made (typically, v_0, introduced in section 2, is assumed to be large enough). A reason for this could be that then one can call 911 in emergencies. In this subsection, we relax this assumption and assume that v_0 is not large and smaller than f. Hence, the number of subscribers in equilibrium will depend on the net surplus consumers obtain, which in turn depends on the degree of competition between two networks.

Assume that consumers' valuation from subscribing to a network when in total ρ consumers are subscribing to one of the networks is such that a consumer at distance x from his network that charges $T = F + pq$, receives utility $v_0 + \rho v(p) - F - xt$.

Let us denote

$$\lambda = \frac{v_0 + v(c) - f}{t}.$$

When total coverage by two networks charging $T = f + cq$ equals $2\alpha \leq 1$, social welfare equals

$$W(\alpha) = 2\alpha(v_0 + 2\alpha v(c) - f - t\alpha/2).$$

$W'(\alpha) = 2(\alpha(4v(c) - t) + v_0 - f)$ and $W''(\alpha) = 2(4v(c) - t)$. If $t \geq 4v(c)$, $W'(\alpha) < 0$ for all positive α and consumer welfare is maximized at $\alpha = 0$. If $t < 4v(c)$, $W(\alpha)$ is convex and maximized at zero or 1/2. Since $W(0) = 0$ and $W(1/2) = v_0 + v(c) - f - t/4$, we find that the full coverage is optimal when $\lambda > 1/4$ and that no coverage is optimal when $\lambda \leq 1/4$. However, also note that when networks charge the very competitive schedule $T = f + cq$, the consumer in the middle only receives positive net surplus if $v_0 + v(c) - f - t/2 > 0$. Hence, implementing the consumer surplus maximizing network prices when $\lambda \in (1/4, 1/2)$

is incompatible with voluntary participation. We will henceforth assume that $\lambda > 1/2$ so that full coverage is both feasible and desirable.

We now consider the necessary condition for a full coverage equilibrium to exist. Recall from Proposition 3 that equilibrium prices are $T = f + t - \kappa t/2 + cq$. To have full coverage and voluntary participation in such an equilibrium, one needs the consumer in the center of the interval to be willing to subscribe when anticipating that everyone will subscribe to one of the networks. This condition reads $v_0 + v(c) - t/2 - (f + t - \kappa t/2) > 0$, or equivalently,

$$\lambda = \frac{v_0 + v(c) - f}{t} > \frac{3 - \kappa}{2}.$$

In particular, for $\kappa = 0$ there is no equilibrium in which the market is fully covered when $(v_0+v(c)-f)/t < 3/2$. By increasing κ one relaxes the full coverage constraint. In particular, as long as $\lambda \in (1/2, 1)$, no full coverage equilibrium exists when subscription is voluntary and cost based access price regulation ($\kappa = 0$) is applied. However, when using our rule with $\kappa = 1$, existence of the full coverage equilibrium is restored when consumers anticipate that the market will be covered. An increase in κ intensifies competition between the networks and thereby make them leave a larger surplus to consumers, which make the full coverage more likely. Summarizing, we have:

Proposition 4 *In the Hotelling model of LRT (1998a), assume $v_0 < f$. Then, an increase in κ makes full coverage more likely. For $\lambda \in (1/2, 1)$ where $\lambda \equiv [v_0 + v(c) - f]/t$, no full coverage equilibrium exists under the cost based access price regulation (*i.e., *when $\kappa = 0$) but existence of the full coverage equilibrium is restored when $\kappa = 1$.*

5.2 Investment

Valletti and Cambini (2005) analyze the effects of fixed access fees on firms' incentives to invest in the quality of their network. They find that the profit neutrality result breaks down when quality of networks is determined endogenously. If access charge is fixed at or above marginal cost of termination, firms underinvest in quality in order to avoid running an access deficit, since the network with the highest quality will have more calls going out to the other network than calls coming in from the other network.

Valletti and Cambini (2005) also find that if firms can freely negotiate reciprocal access charges they will set it above marginal cost which would imply even lower investment levels and inefficiently high usage fees. To induce efficient investment levels one needs to set access charges below marginal cost of termination. In order to calculate this optimal access fee the regulator needs information about demand. Moreover, when access fee is set in this way, usage fee will be inefficiently low (below marginal cost). That is, to induce dynamic efficiency one is forced to lose static efficiency.

In this subsection we adopt Valletti and Cambini's (2005) framework of investment but access charges are defined by our retail benchmarking rule (4). We show that for any $\kappa \leq 1$ the rule induces firms to set usage fee equal to marginal cost. Moreover, by choosing κ appropriately (below zero), one can induce socially efficient investment. Moreover, setting the appropriate κ does not require knowledge of the demand function. Finally, it is shown that firms may obtain higher net profits under this socially optimal rule than with any fixed access fee.

Following Valletti and Cambini (2005) we assume that firms in a first stage invest in quality $\rho_i \geq \bar{\rho} > 0$, and that they afterwards compete in two-part tariffs $T_i = F_i + p_i q$. The cost of investment is given by the convex function $I(\rho_i)$. Each subscriber subscribes to exactly one of both networks and a subscriber to network i makes $\rho_i q(p_i)$ calls and receives indirect utility $\rho_i v(p_i)$. We first find the socially optimal investment in a symmetric equilibrium $\rho_i = \rho_j = \rho$. Assume $p_i = p_j = c$, which is required by static efficiency. Then, the socially optimal ρ is determined by maximizing $\rho v(c) - 2I(\rho)$, which gives $v(c) = 2I'(\rho)$.

Now we turn to the competition between the two networks. Since we will need to know which two-part tariffs firms set when they are of different quality, we will not be able to restrict attention at the pricing stage to symmetric equilibria. Given ρ_1 and ρ_2, gross profit of network i (not including investment costs) is given by

$$\Pi_i(p, w) = \alpha_i \left[(1 - \kappa(1 - \alpha_i))(\rho_i R(p_i) + \rho_i v(p_i) - w_i - f) + \kappa(1 - \alpha_i)(\rho_j R(p_j) + \rho_j v(p_j) - w_j - f) \right].$$

Thus

$$\frac{\partial \Pi_i}{\partial p_i} = \alpha_i (1 - \kappa(1 - \alpha_i)) \rho_i (p_i - c) q'(p_i)$$

and we obtain again the marginal cost pricing result, independently of κ, ρ_i and ρ_j.

Fixed fees will turn out to depend on networks' qualities. Namely, given $p_1 = p_2 = c$, we have

$$\begin{aligned}\frac{\partial \Pi_i}{\partial w_i} &= \sigma[(1 - \kappa(1 - \alpha_i))(\rho_i v(c) - w_i - f) + \kappa(1 - \alpha_i)(\rho_j v(c) - w_j - f)] \\ &\quad + \alpha_i[-1 + \kappa(1 - \alpha_i) + \kappa\sigma[(\rho_i - \rho_j)v(c) - w_i + w_j]].\end{aligned}$$

The first order conditions can be solved explicitly to yield

$$w_i = \frac{-6 + 3\kappa + 4\sigma v(c)(2\rho_i + \rho_j) + 4\kappa(\sigma v(c))^2(\rho_i - \rho_j)^2}{12\sigma} - f$$

and

$$\alpha_i = \frac{3 + 2\sigma v(c)(\rho_i - \rho_j)}{6}. \tag{9}$$

Net profits in the second stage are then given by

$$\Pi_i(\rho_i, \rho_j) = \frac{(3 + 2\sigma v(c)(\rho_i - \rho_j))^2(6 - \kappa(3 + 2\sigma v(c)(\rho_i - \rho_j)))}{216\sigma} - I(\rho_i).$$

Taking first order derivatives and looking for a symmetric equilibrium in qualities yields $\rho_i = \rho$ where the latter solves

$$I'(\rho) = v(c)(4 - 3\kappa)/12.$$

Since $I(\cdot)$ is convex and $v(c)$ is positive, it follows immediately that equilibrium investment is decreasing in κ. Letting $\kappa = 0$ corresponds exactly to Valletti and Cambini's (2005) case of cost based access price regulation where firms invest at the inefficiently low level determined by $I'(\rho) = v(c)/3$. By setting $\kappa = -2/3$ one obtains $2I'(\rho) = v(c)$, which corresponds to the efficient level of investment. The negative factor κ means that access charges are below marginal cost. The intuition for the result that κ should be set below zero is similar to the one underlying the result of Valletti and Cambini (2005) that a fixed access price should optimally set below the termination cost, but is even clearer. Namely, in our case marginal prices in the second stage are always equal to marginal cost. Since consumers at the higher quality network make more calls, the higher quality network will have more outgoing than incoming calls (independently of the market shares), so that when access charge is above marginal cost (that is, $\kappa > 0$), it will suffer from an access revenue deficit. This reduces firms' incentives to invest in the quality of their network in comparison with the situation where access charge is equal to marginal cost ($\kappa = 0$). When access charge is below marginal cost (that is, $\kappa < 0$), the effect is opposite and this increases firms' incentives to invest.

An important difference with respect to Valletti and Cambini (2005) is that here we can induce efficient investment without distorting efficient pricing, since for any $\kappa \leq 1$, marginal usage prices will be set to true marginal cost, independently of the qualities of the networks. Under any fixed access charge $a \neq c_0$, marginal usage price will be set equal to perceived marginal cost, which is not equal to true marginal cost, and is thus necessarily inefficient. Moreover, it makes the computation of equilibria in the investment stage very cumbersome. Indeed, Valletti and Cambini (2005) main results are about marginal deviations from cost based access charges.

Summarizing, we have:

Proposition 5 *In the Hotelling model of LRT (1998a), suppose that networks invest in quality* $(\rho_1, \rho_2)\,(\geq (\bar{\rho}, \bar{\rho}))$ *after the access pricing rule is determined and before they engage in competition in two-part tariffs.*

(i) For any $(\rho_1, \rho_2) \geq (\bar{\rho}, \bar{\rho})$ *and for any* $\kappa \leq 1$*, each network chooses the variable price equal to the marginal cost.*

(ii) When $\kappa = -2/3$*, each network has a socially efficient incentive to invest. In other words,* $\kappa = -2/3$ *achieves both the static efficiency and the dynamic efficiency.*

It is worthwhile to compare the profits of firms in the symmetric equilibrium under our optimal benchmarking rule with $\kappa = -2/3$ with those under cost based access charges ($\kappa = 0$). In the first case they are equal to $1/(3\sigma) - I(\rho^*)$ (where ρ^* denotes the socially efficient level of investment determined by $I'(\rho^*) = v(c)/2$), while in the second case they are equal to $1/(4\sigma) - I(\rho)$ (where ρ is determined by $I'(\rho) = v(c)/3$). Depending on the parameters, profits in the first case may be higher, despite the higher investments made. For example, when $I(\rho) = \rho^2/2$, $v(p) = (10-p)^2/2$, $\sigma = 0.001$, $c_0 = 1$ and $c = 2$, and a minimum level of investment is set at $\bar{\rho} = 10$. In this case the socially efficient investment level equals $\rho^* = 16$ and profit per firm equals 205.33. On the other hand, cost based access charges ($\kappa = 0$) would lead to an investment level $\rho = 10.67$ and per firm profit of 193.

Finally, in case of bilateral negotiations about the reciprocal access charge, firms may be able to agree on such high access charges that investment will be set at the minimum $\bar{\rho} = 10$. In this case profits would be equal to 200. This illustrates that our socially optimal retail benchmarking approach may provide higher profits for firms than any bilaterally agreed upon fixed access charge.

6 Heterogeneous consumers and competition in menu

In this section, we consider the case of heterogeneous consumers as in Dessein (2003) and Hahn (2004) and show that our main result obtained in section 4 is robust. There is a fraction $\mu > 0$ of light consumers and a fraction $1 - \mu > 0$ of heavy consumers: let θ denote the type of a consumer with $\theta = H, L$.[16] From consuming q, a θ-type consumer obtains gross utility $u_\theta(q)$ in which

$$u'_H(q) > u'_L(q) > 0 \text{ and } u''_\theta(q) < 0 \text{ for } \theta = H, L.$$

Given a price p, let $q^\theta(p)$ denote the volume of calls chosen by a consumer of type θ; we have $q^H(p) > q^L(p)$ for any $p > 0$. Network i offers a menu of two-part tariffs $\left\{F_i^\theta, p_i^\theta\right\}$ for $\theta = H, L$. For simplicity, $q_i^H = q^H(p_i^H)$ and $q_i^L = q^L(p_i^L)$. Let $v_\theta(p)$ be the indirect utility function of type θ.

$$\begin{aligned}
w_i^H &\equiv v_H(p_i^H) - F_i^H, w_i^L \equiv v_L(p_i^L) - F_i^L; \\
\alpha_i^H &= \frac{1}{2} + \sigma\left(w_i^H - w_j^H\right), \alpha_i^L = \frac{1}{2} + \sigma\left(w_i^L - w_j^L\right).
\end{aligned}$$

Let $\alpha_i \equiv \mu\alpha_i^L + (1-\mu)\alpha_i^H$ for $i = 1, 2$.

We consider again the access pricing rule in which the markup of the access price that network i pays to the rival network is κ times its average price mark up:

$$a_i - c_0 = \kappa\left(\frac{\mu\alpha_i^L\left[F_i^L + p_i^L q_i^L\right] + (1-\mu)\alpha_i^H\left[F_i^H + p_i^H q_i^H\right]}{\mu\alpha_i^L q_i^L + (1-\mu)\alpha_i^H q_i^H} - c\right)$$

We will first consider the complete information case in which each consumer's type is known by both networks and networks can apply third degree price discrimination. We show that in this case firms will offer exactly the same two-part tariffs to light and heavy users. This then implies that the equilibrium under the complete information case is the equilibrium under incomplete information.

Network i's profit is given by:

$$\begin{aligned}
\Pi_i &= \mu\alpha_i^L\left[(p_i^L - c)q_i^L + F_i^L - f\right] + (1-\mu)\alpha_i^H\left[(p_i^H - c)q_i^H + F_i^H - f\right] \qquad (10) \\
&\quad -(a_i - c_0)(\mu\alpha_i^L q_i^L + (1-\mu)\alpha_i^H q_i^H)\alpha_j \\
&\quad +(a_j - c_0)\left(\mu\alpha_j^L q_j^L + (1-\mu)\alpha_j^H q_j^H\right)\alpha_i.
\end{aligned}$$

[16] We consider the case with two types merely for expositional simplicity. Our result can be easily extended to m types with $m > 2$.

We have

$$
\begin{aligned}
&(a_j - c_0)\left(\mu\alpha_j^L q_j^L + (1-\mu)\alpha_j^H q_j^H\right) = \\
&\qquad \kappa\left\{\mu\alpha_j^L\left[F_j^L + (p_j^L - c)q_j^L\right] + (1-\mu)\alpha_j^H\left[F_j^H + (p_j^H - c)q_j^H\right]\right\}.
\end{aligned}
$$

Therefore,

$$
\begin{aligned}
\Pi_i &= \mu\alpha_i^L(1-\kappa\alpha_j)\left[(p_i^L - c)q_i^L + F_i^L\right] + (1-\mu)(1-\kappa\alpha_j)\alpha_i^H\left[(p_i^H - c)q_i^H + F_i^H\right] \\
&\quad -\alpha_i f + \alpha_i\kappa\left\{\mu\alpha_j^L\left[F_j^L + (p_j^L - c)q_j^L\right] + (1-\mu)\alpha_j^H\left[F_j^H + (p_j^H - c)q_j^H\right]\right\}.
\end{aligned}
$$

It is convenient to maximize Π_i with respect to (p_i^θ, w_i^θ) instead of (p_i^θ, F_i^θ). Then, we have:

$$
\begin{aligned}
\Pi_i &= \mu\alpha_i^L(1-\kappa\alpha_j)\left[(p_i^L - c)q_i^L - v_L(p_i^L) + w_i^L\right] \\
&\quad +(1-\mu)(1-\kappa\alpha_j)\alpha_i^H\left[(p_i^H - c)q_i^H - v_H(p_i^H) + w_i^H\right] - \alpha_i f \\
&\quad +\alpha_i\kappa\mu\alpha_j^L\left[-v_L(p_j^L) + w_j^L + (p_j^L - c)q_j^L\right] \\
&\quad +\alpha_i\kappa(1-\mu)\alpha_j^H\left[-v_H(p_j^H) + w_j^H + (p_j^H - c)q_j^H\right].
\end{aligned}
$$

Maximizing π_i with respect to p_i^θ given w_i^θ leads to the marginal cost pricing for all α_i^θ as long as $\kappa \leq 1$. When $p_i^\theta = p_j^\theta = c$ for $\theta = H, L$, we have

$$
\begin{aligned}
\Pi_i &= \mu\alpha_i^L(1-\kappa\alpha_j)\left[v_L(c) - w_i^L\right] + (1-\mu)(1-\kappa\alpha_j)\alpha_i^H\left[v_H(c) - w_i^H\right] \\
&\quad -\alpha_i f + \alpha_i\kappa\left\{\mu\alpha_j^L\left[v_L(c) - w_j^L\right] + (1-\mu)\alpha_j^H\left[v_H(c) - w_j^H\right]\right\}.
\end{aligned}
$$

Taking derivatives and solving for a symmetric solution ($i.e.$, $w_i^\theta = w_j^\theta$ for $\theta = L, H$) yields

$$
w_i^\theta = v_\theta - f + \frac{\kappa - 2}{4\sigma},
$$

so that

$$
F_i^\theta = f + \frac{2-\kappa}{4\sigma}.
$$

Since the optimal fixed fee is identical for both consumer types when firms can discriminate between types, it will be optimal in the case of incomplete information to offer only one two-part tariff $T = F + cq$ where

$$F = \frac{2-\kappa}{4\sigma}.$$

Summarizing, we have:

Proposition 6 *In the Hotelling model of LRT (1998a), suppose that consumers are heterogeneous (some are light consumers and others are heavy consumers) and that networks compete in menus of two-part tariffs without knowing each consumer's type.*

(i) For any $\kappa \leq 1$, each network chooses the variable price equal to the marginal cost for all types of consumers.

(ii) Given $\kappa \leq 1$, in symmetric equilibrium, both networks offer an identical two-part tariff ($p = c, F = \frac{2-\kappa}{4\sigma}$) for all types of consumers.

Dessein (2003) and Hahn (2004) find that when $a = c_0$ (*i.e.*, $\kappa = 0$), both networks offer an identical two-part tariff ($p = c$, $F = \frac{1}{2\sigma}$) for all types of consumers. In fact, if $a = c_0$, as can be seen in (10), access price disappears from the profit function and the profit function becomes the same as the one in a standard Hotelling model without interconnection. This is why they rediscover the efficient two-part tariff result obtained by Armstrong and Vickers (2001) and Rochet and Stole (2002) in the context of competitive price discrimination without interconnection between firms. In other words, $a = c_0$ achieves efficiency by making the case with interconnection similar to the case without interconnection. What we show is that in the presence of interconnection, there is a class of access pricing rules which achieve efficiency. Hence, interconnection provides extra instruments to achieve the static efficiency.

7 Conclusion

We studied a retail benchmarking approach to determine efficient access prices for interconnected networks when they compete in two-part tariffs. Our approach is simple since we consider a set of access pricing rules that linearly links the mark-up of the access price that network i pays to its rivals with network i's retail price mark-up. Our approach is not informationally demanding since the regulator only needs to know the marginal costs of communication. We showed that the efficient access pricing rules that we found can significantly improve social welfare with respect to what we can achieve with the standard approach of fixed access prices.

More precisely, when networks compete in two-part tariffs, the literature has obtained a static efficiency and a profit neutrality result. The static efficiency result says that setting access price equal to the termination cost leads to marginal cost pricing. The profit neutrality result says that firms' equilibrium profits are equal to the Hotelling profits for any access price. These two results provide a rationale for letting firms choose collectively the access price as they do not have strict incentives to set a higher access price. However, Valletti and Cambini (2005) find that when firms can invest in the quality of their networks prior to setting prices, firms have an incentive to choose an access charge larger than the termination cost in order to reduce investment incentives. The reason is that their equilibrium profits gross of the investment costs are equal to the Hotelling profits, because of the profit neutrality result. Furthermore, they show that static efficiency is in conflict with dynamic efficiency since firms under-invest in quality when access price is equal to the termination cost.

We considered a particular class of access pricing rules under which the mark-up of the access price that network i pays to its rivals is a fraction of network i's average retail price mark-up. We first showed that all of the rules in the class lead to static efficiency (*i.e.*, marginal cost pricing) while the profits vary depending on the degree with which the average retail price mark-up influences the access price mark-up. Therefore, by properly choosing this degree, the regulator can pursue additional objectives such as improving consumer surplus or inducing full coverage. The most interest result is that the regulator can achieve both static efficiency and dynamic efficiency at the same time. We also showed that the result that the class of access pricing rules lead to static efficiency holds when networks compete in menu of two-part tariffs. The general message of our paper is that creating the link between access charge and retails prices provides extra instruments to promote competition and to enhance efficiency.

References

Armstrong, M. "Network Interconnection." *Economic Journal*, Vol. 108 (1998): 545-564.

Armstrong, M. "The Theory of Access Pricing and Interconnection." in M. Cave, S. Majumdar and I. Vogelsang, eds., *Handbook of Telecommunications Economics*, chap. 8, North Holland, 2002.

Armstrong, M. and J. Vickers. "Competitive Price Discrimination", *Rand Journal of Economics*, Vol. 32 (2001): 579-605.

Australian Consumer and Competition Commission (2001). *Pricing Methodology* *for the GSM Termination: Final Report.*

Baumol, W. “Some Subtle Issues in Railroad Regulation,” International Journal of Transport Economics Vol. 10 (1983): 341-355.

Baumol, W. and G. J. Sidak. “The Pricing of Inputs sold to Competitors,” Yale Journal on Regulation, Vol. 11 (1994): 171-202.

Carter, M. and J. Wright. “Interconnection in Network Industries.” *Review of Industrial Organization*, Vol. 14 (1999): 1-25.

Carter, M. and J. Wright. “Asymmetric Network Interconnection.” *Review of Industrial Organization*, Vol. 22 (2003): 27-46.

Dessein, W. “Network Competition in Nonlinear Pricing.” *Rand Journal of Economics*, Vol. 34 (2003): 593-611.

Dessein, W. “Network Competition with Heterogeneous Customers and Calling Patterns.” *Information Economics and Policy*, Vol. 16 (2004): 323-345.

Doganoglu, T. and Y. Tauman. “Network Competition and Access Charge Rules.” *The Manchester School*, Vol. 70 (2002): 16-35.

Economides, N. and L.J. White. “Access and Interconnection Pricing: How Efficient is the ”Efficient Component Pricing Rule”?” *Antitrust Bulletin*, Vol. XL, (1995): 557-579.

Gans, J. S., and S. P. King. “Mobile Network Competition, Customer Ignorance and Fixed-to-Mobile Call Prices.” *Information Economics and Policy*, Vol. 12 (2000): 301-327.

Gans, J. S., and S. P. King. “Using ‘Bill and Keep’ Interconnect Arrangements to Soften Network Competition.” *Economics Letters*, Vol. 71 (2001): 413-420.

Ghosal, V. “Competition in International Postal Markets: Should the Universal Postal Union’s Anti-remail Provisions Be Repealed?” *World Competition Law and Economics Review*, Vol. 26 (2002): 205-222.

Hahn, J.-H. “Network Competition and Interconnection with Heterogeneous Subscribers.” *International Journal of Industrial Organization*, Vol. 22 (2004): 611-631.

Hermalin, B. and M. Katz. “Network Interconnection with Two-Sided User Benefits.” Mimeo, UC Berkeley, 2001.

Hermalin, B. and M. Katz. "Sender or Receiver: Who Should Pay to Exchange an Electronic Message?" *Rand Journal of Economics*, Vol. 35 (2004): 423-448.

Jeon, D.S. "A Simple Access Pricing Rule to Achieve the Ramsey Outcome for Interconnected Networks." UPF Working Paper 808, 2005.

Jeon, D.S., J.J. Laffont and J. Tirole. "On the "Receiver-Pays" Principle." *Rand Journal of Economics, Vol.* 35 (2004), pp. 85-110.

Laffont, Jean-Jacques, Scott Marcus, Patrick Rey and Jean Tirole. "Internet Interconnection and the Off-Net-Cost Pricing Principle", *Rand Journal of Economics*, Vol. 34 (2003): 370-390.

Laffont, J.J., P. Rey and J. Tirole. "Network Competition I: Overview and Nondiscriminatory Pricing." *Rand Journal of Economics*, Vol. 29 (1998a): 1-37.

Laffont, J.J., P. Rey and J. Tirole. "Network Competition II: Price Discrimination." *Rand Journal of Economics,* Vol. 29 (1998b): 38-56.

Laffont, J.J. and J. Tirole. *Competition in Telecommunications*, MIT, 2000.

Mialon, S. H. "Pricing Access in Network Competition." *Journal of Regulatory Economics*, Vol. 31 (2007): 109-123.

OECD. "Access pricing in telecommunications."

http://www.oecd.org/dataoecd/26/6/27767944.pdf. Paris, 2004.

Rochet, J.C. and L.A. Stole. "Nonlinear Pricing with Randome Participation." *Review of Economic Studies*, Vol. 69 (2002): 277-311.

Salop, S. "Monopolistic Competition with Outside Goods." *Bell Journal of Economics,* Vol. 10 (1979): 141-156.

Sibley, David S., Michael J. Doane, Michael A. Willams and Shu-Yi Tsai. "Pricing Access To a Monopoly Input." *Journal of Public Economic Theory*, Vol. 6 (2004) pp. 541-555.

Stennek, J. and T.P. Tangerås. "Competition vs. Regulation in Mobile Telecommunications", mimeo RIIE. 2006.

Valletti, Tommaso M. and Carlo Cambini. "Investments and Network Competition." *Rand Journal of Economics*, Vol. 36 (2005): 446-467.

Willig, R. "The Theory of Network Access Pricing," in *Issues in Public Utility Regulation*, ed. by H. Trebing. Michigan State University Press, East Lansing, MI. 1979.

Wright, J. "Access Pricing under Competition: An Application to Cellular Networks." *Journal of Industrial Economics,* Vol. 50 (2002): 289-315.