A New, Simple and More-Efficient Access Pricing Rule

António Nogueira Leite Vasco Santos
Maria do Carmo Seabra

Universidade Nova de Lisboa, Faculdade de Economia
Travessa Estêvão Pinto (Campolide), P-1099-032 Lisboa, Portugal

April 1999

Abstract

The pricing of access to bottleneck facilities is often ruled by the Efficient Component Pricing Rule (ECPR) due to its simplicity even though, from an economic-efficiency standpoint, the ECPR is known to be other than optimal in most instances. We propose a new pricing rule that, while equally simple to implement and informationally undemanding, enhances economic efficiency beyond what is achieved with the ECPR whenever the entrants are no less efficient than the incumbent.

JEL Classification Numbers: D82, L22, L51
Keywords: Access price, Efficient Component Pricing Rule

Vasco Santos
Universidade Nova de Lisboa
Faculdade de Economia
Travessa Estêvão Pinto (Campolide)
P-1099-032 LISBOA
PORTUGAL
Telephone: (+351 1) 380 16 46
Fax: (+351 1) 388 60 73
E-mail: vascos@feunix.fe.unl.pt

A New, Simple and More-Efficient Access Pricing Rule*

António Nogueira Leite Vasco Santos†
Maria do Carmo Seabra

Universidade Nova de Lisboa, Faculdade de Economia
Travessa Estêvão Pinto (Campolide), P-1099-032 Lisboa, Portugal

April 1999

Abstract

The pricing of access to bottleneck facilities is often ruled by the Efficient Component Pricing Rule (ECPR) due to its simplicity even though, from an economic-efficiency standpoint, the ECPR is known to be other than optimal in most instances. We propose a new pricing rule that, while equally simple to implement and informationally undemanding, enhances economic efficiency beyond what is achieved with the ECPR whenever the entrants are no less efficient than the incumbent.

JEL Classification Numbers: D82, L22, L51
Keywords: Access price, Efficient Component Pricing Rule

1 Introduction

The opening of some formerly monopolized markets—frequently described in the past as natural monopolies—often entails the use of a bottleneck facility, i.e., an essential input without which operation would be impossible. Since its pricing constitutes an opportunity for strategic and often

*The first author acknowledges the funding of the EC Commission TMR network grant FMRX-CT98-0203, for which he is grateful. Work on this paper began while the second author was visiting the University of California, Berkeley on a grant from FLAD (Portuguese-American Foundation for Development) which is gratefully acknowledged. Remaining mistakes are the authors' responsibility.

†Corresponding author: Vasco Santos, Universidade Nova de Lisboa, Faculdade de Economia, Travessa Estêvão Pinto (Campolide), P-1099-032 Lisboa, Portugal, telephone no. (+351 1) 380 16 46, fax no. (+351 1) 388 60 73, e-mail: vascos@feunix.fe.unl.pt.

anti-competitive behavior on the part of the bottleneck-facility owner, regulators frequently set the access price to such facilities.

The benchmark currently used by regulators to price access to bottleneck facilities is the Efficient Component Pricing Rule (henceforth ECPR).[1] The ECPR's popularity springs not only from its simplicity but also from the fact that the Rule's informational requirements are quite mild, a feature of particular importance to regulatory authorities. Despite its name, the Rule basically enshrines the notion of *productive efficiency* rather than that of *economic efficiency*. Since one notion neither implies nor is implied by the other, and it is the latter that ought to guide regulatory policy, the search for a more efficient rule for pricing access is important.[2] This is the aim of the paper.

Rules better than the ECPR have been proposed, but at the cost of simplicity and informational requirements. For instance, second-best access prices—guaranteeing a positive transfer to the incumbent—have been advanced. These, though of theoretical interest, are of limited usefulness to regulatory authorities because their implementation requires detailed knowledge of demand and competitive conditions after access is opened to new firms. This drawback has repeatedly been recognized by regulators and economists alike.[3] This underscores the need to keep the information requirements of any access pricing rule to as few as possible.

We search for an alternative rule that (i) better promotes economic efficiency (ii) without being informationally more demanding than the ECPR

[1] The ECPR has already been used in several regulatory cases, some giving rise to litigation. The USA Interstate Commerce Commission adopted it in different situations involving the establishment of access rates in railroads (see Baumol and Sidak (1994)) and the California Public Utilities Commission has used it since 1989 for regulating access prices to Local Exchange Carriers. Its use was also the main point of litigation between Telecom Corporation of New Zealand and its rival, Clear Communications.

[2] The ECPR has not passed scrutiny unscathed. See, *inter alia*, Armstrong, Cave and Doyle (1996), Baumol and Sidak (1994), Economides and White (1995), Kahn and Taylor (1994) and Larson and Lehman (1997) on this topic.

[3] For instance, Baumol and Sidak (1994) and Laffont and Tirole (1996), have argued that rules using own- and cross-elasticities of demand are hard to implement. In effect, as referred to in Laffont and Tirole (p. 243), not only are demand elasticities difficult to obtain in rapidly changing sectors (such as telecommunications) but also "the discretion involved in the determination of these elasticities creates vast opportunities for capture as interest groups gain from influencing the regulator's determination of elasticities and cross-elasticities."

(iii) while still ensuring a transfer to the bottleneck-facility owner deemed satisfactory by regulatory authorities.

The last requirement needs explaining. Bottleneck facilities usually emerge in industries characterized by significant fixed costs, often associated with the investment necessary for setting up the bottleneck facility itself (stranded costs), but resulting also from universal-service obligations, contribution to common costs, and similar extraneous requirements. Concomitantly, access often involves negligible marginal cost. Together, these two aspects may require significant departures from pricing access at marginal cost due to dynamic-efficiency issues.

The new rule for pricing access to bottleneck facilities that we propose enhances economic efficiency when compared to the ECPR whenever entrants are no less efficient than the incumbent. The intuition is the following: access simultaneously constitutes a revenue to the former monopolist and a cost to entrants. Its pricing thus has a bearing on the aggressiveness with which the latter compete. This, in turn, impacts the economic performance of the industry as a whole. The new rule, by ensuring a more-level playing field between the incumbent and the entrants, gives incentive for more aggressive competition by entrants compared to the ECPR. This furthers economic efficiency when entrants are no less efficient than the incumbent.[4] Propositions 4 and 7 show this for two types of competition (Cournot and Bertrand) and are thus the main results of the paper.

The other results, while proving instrumental in achieving the former two, are also of importance. For instance, Proposition 2 shows that in markets where there is Cournot competition, the use of the ECPR for pricing access implies unduly protecting the incumbent, giving it a disproportionate market share even when such a firm is less efficient than the entrants. This lack of regulatory neutrality—to our knowledge never explicitly recognized in the literature—is independently important in its own right.

The paper is organized as follows. The next section briefly presents the main points of the paper through the use of specific market games that

[4] In the opposite case, a conflict arises between increased competition and productive efficiency that precludes comparison of the new rule proposed and the ECPR.

prove both simple to analyze and particularly illustrative. These motivational market games are set in a Bertrand framework because the usual discussion of the ECPR seems to have this type of competition in mind. They point out two problems associated with the ECPR that led us to think of an alternative rule. Section 3 presents this new rule. Section 4 compares our rule to the ECPR in the context of Cournot competition whereas Section 5 does so for Bertrand competition. The former is consistent with moderate after-entry competition while the latter (with two or more entrants) yields maximal post-entry competition. Section 6 draws conclusions.

2 The Problem

Let I denote the bottleneck-facility owner (also referred to, for short, as the incumbent), E its competitor, and R the regulator.[5] Firms I and E are both in the position of supplying a commodity whose provision requires access to the bottleneck facility. The demand for this commodity is represented by $p = p(q)$. Units are chosen such that one unit of the commodity requires the purchase of one unit of access.

Assume that the constant marginal cost of providing access is c. Suppose also that I has to incur a further firm-specific constant marginal cost of c_I to provide the commodity. Thus, the overall constant marginal cost incurred by I is $c + c_I$. The analogous firm-specific constant marginal cost for E is c_E. Thus, firm E's overall economic constant marginal cost of supplying the commodity is $c + c_E$. However, its perceived cost is $p_a + c_E$ where p_a is the access charge.

Suppose that the regulator allows I to produce the monopoly quantity of the commodity, q^M, and charge the associated monopoly price, p^M. In other words, assume that the monopoly profit is deemed by the regulator as both necessary and sufficient to compensate I for the investment on the bottleneck facility or any other extraneous costs (see Introduction).[6] As-

[5]In this motivational section we will consider the case of a single entrant. Our results deal with the more general case of a finite number of entrants.

[6]Such profit level is not crucial to the points we are making in this section. Its choice is purely expositional.

suming that demand is linear, this corresponds to equilibrium A in Figure 1. The profit of the bottleneck-facility owner is then given by $[p^M, A, a, c+c_I]$.

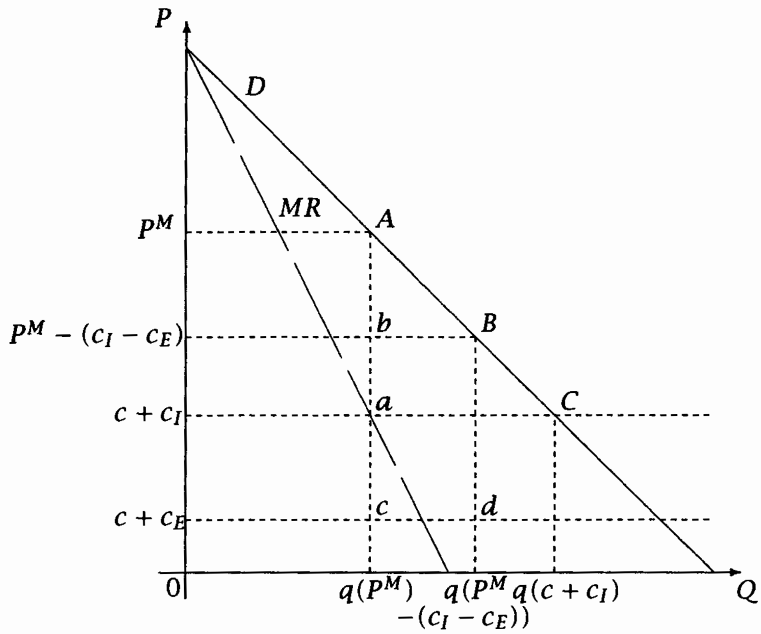

FIGURE 1. *The Problem.*

Suppose that access to the bottleneck facility is opened. Assume also that E is more efficient than I, i.e., $c_I > c_E$. Finally, assume that the two firms compete *à la* Bertrand in the output market after access becomes available.

The ECPR sets the access price, p_a, as the sum of the marginal cost of access, c, and the per-unit profit that I foregoes when it provides access, i.e.,

$$\begin{aligned} p_a &= c + [p^M - (c + c_I)] \\ &= p^M - c_I. \end{aligned}$$

2.1 Overcompensation Problem

Market equilibrium with this particular type of competitive behavior (Bertrand) and efficiency configuration ($c_I > c_E$) is as follows. From the ECPR, $p_a = p^M - c_I$. Thus, E has marginal cost $(p^M - c_I) + c_E = p^M - (c_I - c_E)$. Assume for simplicity that if both firms quote the same price, only firm I sells.[7] Suppose that I quotes price $p^M - (c_I - c_E) + \epsilon$, $\epsilon > 0$ and its opponent quotes $p^M - (c_I - c_E)$. In the proposed equilibrium, total quantity is $q\,(p^M - (c_I - c_E))$, firm E's profit is zero because it sells at marginal cost, and I sells access only, obtaining a profit equal to $q\,(p^M - (c_I - c_E))\,(p^M - c_I - c) = q\,(p^M - (c_I - c_E))\,[p^M - (c + c_I)] > q(p^M)\,[p^M - (c + c_I)] = \pi^M$. In Figure 1, the equilibrium is at B. It is easy to see that I's profit equals $q\,(p^M - (c_I - c_E))\,[p^M - c_I - c] = q\,(p^M - (c_I - c_E))\,[p^M - (c_I - c_E) - (c + c_E)]$, i.e., areas $[P^M - (c_I - c_E), b, c, c + c_E]$ plus $[b, c, d, B]$, and that the former equals π^M. Thus, when the monopoly is opened to competition and the ECPR is used to price access, the incumbent obtains a profit that exceeds the pre-opening profit.

It is easy to check that this is indeed an equilibrium: if firm I undercuts its opponent, I's profit will be at most π^M. Since in the proposed equilibrium I's profit is shown to exceed π^M, it loses by deviating and quoting a lower price. Quoting a higher price will not affect its profit since its sales to consumers will still be zero, all its revenue coming from selling access. Firm E has no incentive to raise its price above that quoted by firm I or matching it (in which case only I would sell due to the simplifying assumption made in footnote 7) since its profit will be zero, as in the proposed equilibrium. Selling at a lower price would make it incur a loss. Thus, firm E also has nothing to benefit from deviating.

The crucial point is that I's profit *exceeds that originally obtained when no competitor demanded access* when the ECPR is used to price access. If the regulator could reduce this excess transfer by means of a lower access price, thus inducing a lower output price, welfare could increase.

[7]This assumption is made for ease of exposition. It could be dropped without affecting the main conclusion of this subsection.

2.2 Marginal-cost Pricing Problem

Consider now another access pricing scheme. Assume that the regulator requires E to pay a fixed fee, equal to π^M, in order to have access to the bottleneck facility plus a fee c per unit of access bought. The regulator transfers π^M to I. The equilibrium is now such that E pays π^M to R and undercuts its opponent, offering a price slightly below $c + c_I$ and earning a profit (gross of π^M) essentially equal to $q(c + c_I)(c_I - c_E)$ as long as $q(c + c_I)(c_I - c_E) \geq \pi^M$.[8] This inequality is verified if (i) $c_I \gg c_E$ or (ii) demand is quite elastic such that $q(c + c_I) \gg q(p^M)$.[9] Market output thus equals $q(c + c_I) > q\left(p^M - (c_I - c_E)\right)$, firm I obtains a profit of π^M and E's profit is non-negative. In Figure 1, this equilibrium is represented by C.

Overall, social welfare surely increases because of the increment in consumer surplus. Crucially, this welfare increase results from *pricing access in accordance with its marginal cost, c, at the margin.* Again, by devising an alternative rule that does not depart from marginal-cost pricing of access as significantly as does the ECPR, a better access pricing rule may emerge.

These two observations clearly raise the issue of whether a better rule, alternative to the ECPR but equally simple and informationally undemanding, can be obtained under different types of competition and arbitrary levels of the transfer to be effected to the bottleneck-facility owner. The paper aims at this.[10]

[8]If the difference between c_I and c_E is very pronounced this inequality is replaced with one involving the monopoly profit at marginal cost $c+c_E$. The argument would be essentially the same in this case.

[9]Note that if the level of profit that the regulator wishes the bottleneck-facility owner to obtain is smaller, this inequality is concomitantly easier to fulfill (see footnote 6).

[10]The reader can argue that the pricing rule sketched in this subsection already seems to improve upon the ECPR. However, with more than one entrant, the problem of how to apportion π among entrants needs to be addressed. The two-part price scheme used in this subsection is thus merely instrumental in exposing the economic-efficiency reducing effects of the extreme departure from marginal-cost pricing implicit in the ECPR. A rule inducing a less extreme departure from marginal-cost pricing while still effecting the transfer of π to the bottleneck-facility owner would better promote economic efficiency.

3 A New Pricing Rule

An access pricing rule should have some properties that make it a desirable candidate for pricing access. It should (i) cover the marginal cost of providing access plus (ii) contribute to any common costs (or the like) to the extent reputed by the regulatory authority to be necessary for insuring dynamically-efficient investment in bottleneck facilities, while (iii) being informationally undemanding and (iv) nondiscriminatory either in favor of or against the incumbent *vis-à-vis* the entrant. This last property—not shared by the ECPR—will be at the root of our main results.

We propose the following alternative access pricing rule, which the subsequent discussion shows has the properties above:

$$p_a = c + \frac{\pi}{q_I + \sum_n q_E}, \tag{1}$$

where c and q_I have the same meaning as before, q_E refers to the quantity produced by each entrant, the summation thus being over the finite set of entrants, n, and π is the (minimum) amount that the regulator wants the bottleneck-facility owner to receive. Let us now discuss the rationale for and main features of this rule.

3.1 Rationale

First, by setting $q_I = 0$, i.e., by not selling directly to consumers and providing access only, the incumbent can earn a profit of π for certain. To see this, note that once $\sum_n q_E > 0$, i.e., at least one entrant does enter the market, entrants pay an access fee of $\left(c + \frac{\pi}{\sum_n q_E}\right) \sum_n q_E$ while inducing costs to the incumbent of $c \sum_n q_E$. This strategy by the incumbent insures it a profit of π *regardless* of the (positive) quantity chosen by entrants. The incumbent decides to produce a positive quantity in equilibrium, $q_I > 0$, only if its profit exceeds what it would earn by setting $q_I = 0$. Thus, π is indeed the minimum profit obtainable by the incumbent. Since efficiency differences between the incumbent and the entrants can be such that the incumbent may opt in equilibrium for leaving the output market altogether and selling access only (namely if it is significantly less efficient than the entrants) this minimum-profit property is a desirable one for any access pricing rule.

When the incumbent produces a positive quantity in equilibrium, $q_I > 0$, and its profit exceeds π, there is scope for lowering the access charge, p_a, thus reducing the discrepancy between the access charge and marginal-cost pricing (the latter requires access to be priced at c). This is the rationale for having q_I appearing in the denominator of (1). In fact, by the argument above, when the bottleneck-facility owner sets $q_I > 0$, it is being overcompensated, i.e., earning a profit in excess of π. The rule partly uses this slack brought about by the overcompensation problem (see Subsection 2.1) to lower the access charge, therefore alleviating the marginal-cost pricing problem (see Subsection 2.2).

Our rule has implicit a sharing of π among the firms using the bottleneck facility. Each entrant contributes to the coverage of π in proportion to its usage of the bottleneck facility, $\frac{q_E}{q}$. So too does the bottleneck-facility owner itself, insofar as it chooses to set $q_I > 0$: it "pays" $\frac{q_I}{q}\pi$.

When the incumbent opts for producing a positive quantity, we know that its profit is higher than π. Thus, our rule does not totaly eliminate the overcompensation problem. One could then argue that another rule, even better than the one proposed, would use such slack to lower the access price even more, thus further increasing efficiency. One could, for instance, think of a rule that transferred to the incumbent exactly the difference between π and whatever it earned in the post-entry game. However, by its own definition, such a rule would require the regulator to be sure of both demand and the type of competition prevalent after entry. This much is needed to solve the post-entry game, compute profits and effect the exact transfer. Such a rule would thus be very demanding in terms of the information that the regulator would have to muster. In case of error in the assessment of demand or the post-entry game, the regulator could be faced with an actual outcome that entailed an incumbent's profit of less than π, which would likely cause serious regulatory problems. On the other hand, a significant over-transfer could take place, with the associated efficiency loss. Our point is that any access pricing rule should be informationally undemanding, and able to ensure that at least π is indeed transferred, even if at a cost of some optimality loss.

3.2 Informational Requirements

The rule is based on the observation of c, a marginal cost whose knowledge should not be harder for the regulator to obtain than that of c_I, which is needed for setting the access price according to the ECPR. Also, q_E and q_I, simply being the access quantities required by the incumbent and the entrants, pose no significant observational difficulties for the regulator.[11] Finally, π is set by the regulator itself, corresponding simply to the profit deemed necessary to compensate the bottleneck-facility owner for having invested in the facility.[12] Thus, the proposed rule is not more demanding, from an informational viewpoint, than the ECPR. In particular, no use is made of direct- or cross-elasticities of demand.

Our rule differs from the ECPR in one important aspect of its implementation. The ECPR allows the setting of a given access price at the outset, whereas our rule, by making use of the quantity of access bought by market participants to "allocate" π among firms (incumbent and entrants), only allows the actual access price to be known *ex post*. This does not raise a problem as long as demand and costs are non-stochastic and known to market participants, as is the case in the model. Even if uncertainty about any parameters exists, it is only relevant as far as it affects quantities. This problem is much eased by making sure that firms continuously observe

[11] To see this, note that two particular examples of these quantities are the number of trains run by different firms using a common track, or the number of minutes a fixed-link telephone network is used by telecommunications firms providing other services that require the use of the fixed-link network. These are obviously easily observable, and thus hard to misrepresent by any party involved in the access market.

[12] Setting π at a level deemed socially optimal is in itself a theoretically important and empirically difficult issue. We can circumvent it by taking the level of profit associated with the price that the regulatory authority allows the incumbent to set before access is opened, and assuming that it results from solving the theoretical and empirical questions that optimally setting π raises. To put it another way, the incumbent's profit from exploiting the bottleneck facility before access is allowed, implicitly reveals the regulator's choice of π.

aggregate output, $q_I + \sum q_E$, thus allowing them to update their estimate of the denominator of the second term of (1). Moreover, choosing a short settling period after which the access charges are paid to the incumbent and a new round of access use is started, minimizes the possible adverse consequences that an unexpected access charge may have on market participants. In this sense, our rule is more informationally demanding than the ECPR, though in a sense different from the one mentioned above, but the problem raised does not seem to be insurmountable. More importantly, this problem does not give clear scope for regulatory capture since there are no demand or cost parameters to be argued over.

4 Cournot Competition

Even though we motivated the need for an improved access pricing rule in the context of Bertrand competition, we will first discuss its performance under Cournot competition since this is the typical framework used for analyzing imperfectly competitive markets. In fact, the process of deregulation alluded to in the Introduction is gradual, not leading to a total liberalization of entry. Regulatory authorities prefer to slowly allow entry, controlling the number of new firms, and thus limiting the amount of competition faced by the former monopolies. After opening, such markets tend to be imperfectly competitive.[13] Also, once opening takes place, regulators prefer not to directly regulate the market price, trusting competition instead to enhance market performance.

Furthermore, imperfectly competitive downstream markets are one of the problems that the ECPR does not properly take into account (see Baumol and Sidak (1994) and Kahn and Taylor (1994) on this issue). Since different access pricing rules affect downstream competition differently, comparing the performance of the ECPR and the new rule herewith proposed under imperfect downstream competition seems important.

[13] See Parker and Röller (1997) for empirical tests of the US telecommunications market indicating prices in significant excess of costs. This is attributed by the authors to the duopoly market structure imposed by the regulatory authority.

Assume that demand is represented by the inverse demand function $p(q)$, with $q = q_I + \sum_n q_E$. Profits of the incumbent and each entrant are then given by

$$\pi^I = pq_I + p_a \sum_n q_E - c(q_I + \sum_n q_E) - c_I q_I$$

$$\pi^E = pq_E - p_a q_E - c_E q_E.$$

Substituting the access pricing rule (1), we obtain

$$\pi^I = pq_I + \left(c + \frac{\pi}{q_I + \sum_n q_E}\right) \sum_n q_E - c(q_I + \sum_n q_E) - c_I q_I$$

$$\pi^E = pq_E - \left(c + \frac{\pi}{q_I + \sum_n q_E}\right) q_E - c_E q_E.$$

Optimizing to obtain the best-response functions, we get, after simple computations

$$\left\{ \begin{array}{l} \max\limits_{q_I} \pi^I \\ \\ \max\limits_{q_E} \pi^E \end{array} \right. \Leftrightarrow \left\{ \begin{array}{l} p - c - c_I + \frac{\partial p}{\partial q_I} q_I - \frac{\sum q_E}{(q_I + \sum_n q_E)^2} \pi = 0 \\ \\ p - c - c_E + \frac{\partial p}{\partial q_E} q_E - \frac{q - q_E}{(q_I + \sum_n q_E)^2} \pi = 0 \end{array} \right. \Leftrightarrow \tag{2}$$

$$\left\{ \begin{array}{l} \frac{p - c - c_I}{p} = \frac{\alpha}{\varepsilon} + (1 - \alpha) \frac{\pi}{pq} \\ \\ \frac{p - c - c_E}{p} = \frac{1 - \alpha}{n} \frac{1}{\varepsilon} + \frac{n - 1 + \alpha}{n} \frac{\pi}{pq}, \end{array} \right. \tag{3}$$

where $\varepsilon \equiv -\frac{\partial p}{\partial q} \frac{q}{p}$, $\alpha \equiv \frac{q_I}{q_I + \sum_n q_E} = \frac{q_I}{q}$ and $1 - \alpha = \frac{\sum_n q_E}{q_I + \sum_n q_E} = \frac{\sum_n q_E}{q}$.

The following results characterize the functioning of this market under the proposed rule, highlighting the features that are of interest from a regulatory viewpoint.

The first proposition shows that when all firms are equally efficient, they share the market equally, i.e., $q_I = q_E$ in equilibrium, whereas, if differences in efficiency exist, the more efficient firm(s) outproduce the other(s). This is desirable on its own because it shows that with Cournot competition, our rule preserves a level playing field, giving neither the incumbent nor the entrants a disproportionate share of the market when all firms are equally efficient, and inducing differences in market shares in accordance with efficiency advantages. We will later see that the ECPR induces a bias in favor of the incumbent. This feature is important because it affects productive (and, hence, economic) efficiency. It will later prove crucial for the main result in this section comparing the performance of the ECPR with our access pricing rule. Formally we have

Proposition 1 *When the bottleneck-facility owner and the entrants are equally efficient, they share the market equally in equilibrium. Otherwise, the more efficient firm(s) has (have) a bigger market share. Formally:*

$$c_I \gtreqless c_E \Rightarrow q_I \lesseqgtr q_E.$$

Proof See Appendix. □

We will now study the performance of the ECPR under the same framework. Before any entrant requests access, the regulator allows the bottleneck-facility owner to earn π, as a result of stranded costs or similar reasons. Let $\bar{p}$ be the lowest price such that $q(\bar{p})\,(\bar{p} - c - c_I) = \pi$ and $\bar{q} \equiv q(\bar{p})$ denote the associated quantity. In what follows, we will assume that $\bar{q}$ is small enough (implying that π is significantly high) that the outcome with access and competition induces an output higher than $\bar{q}$. Formally, we assume that $q > \bar{q}$ when at least one entrant seeks access whatever the access pricing rule chosen. We do so in order to separate the problem under analysis—comparison of two access pricing rules—from the issue of output-pricing regulation (more on this later).

Recall that the ECPR sets the access price $p_a = \bar{p} - c_I$.[14] Thus, profits are given by

$$\pi^I = pq_I + (\bar{p} - c_I)\textstyle\sum_n q_E - c(q_I + \sum_n q_E) - c_I q_I$$

$$\pi^E = pq_E - (\bar{p} - c_I)\, q_E - c_E q_E.$$

Optimizing to derive the best-response functions, we obtain, after simple but cumbersome computations,

$$\begin{cases} \max\limits_{q_I} \pi^I \\ \\ \max\limits_{q_E} \pi^E \end{cases} \Leftrightarrow \begin{cases} p - c - c_I + \frac{\partial p}{\partial q_I} q_I = 0 \\ \\ p - c_E - \bar{p} + c_I + \frac{\partial p}{\partial q_E} q_E = 0 \end{cases} \Leftrightarrow \tag{4}$$

[14]Our motivational examples assumed $\bar{p} = p^M$, i.e., that the monopoly profit was necessary to compensate the bottleneck-facility owner for its investment.

$$\begin{cases} p - c - c_I + \frac{\partial p}{\partial q_I} q_I = 0 \\ p - c_E - \bar{p} + c_I + c - c + \frac{\partial p}{\partial q_E} q_E = 0 \end{cases} \Leftrightarrow \begin{cases} \frac{p-c-c_I}{p} = \frac{\alpha}{\varepsilon} \\ \frac{p-c-c_E}{p} = \frac{1-\alpha}{n\varepsilon} + \frac{\bar{p}-c-c_I}{p} \end{cases} \Leftrightarrow$$

$$\begin{cases} \frac{p-c-c_I}{p} = \frac{\alpha}{\varepsilon} \\ \frac{p-c-c_E}{p} = \frac{1-\alpha}{n\varepsilon} + \frac{(\bar{p}-c-c_I)\bar{q}}{p\bar{q}} \end{cases} \Leftrightarrow \begin{cases} \frac{p-c-c_I}{p} = \frac{\alpha}{\varepsilon} \\ \frac{p-c-c_E}{p} = \frac{1-\alpha}{n\varepsilon} + \frac{\pi}{p\bar{q}}. \end{cases} \tag{5}$$

We can now analyze the performance of the ECPR in this setting and compare it with (1). The following proposition is the counterpart of Proposition 1.

Proposition 2 *Under the ECPR, if the incumbent is more efficient than the entrants ($c_I < c_E$), or the amount that the regulator is willing to transfer to the incumbent is relatively high compared to the efficiency advantage of the entrants over the incumbent ($0 \leq c_I - c_E < \frac{\pi}{\bar{q}}$), the latter outproduces each entrant in equilibrium. If $c_I - c_E > \frac{\pi}{\bar{q}}$, the opposite occurs. Formally,*

$$c_I - c_E \gtrless \frac{\pi}{\bar{q}} \Rightarrow q_I \lesseqgtr q_E.$$

Proof See Appendix. □

First, note that the ECPR is biased towards the incumbent, in the sense that when all firms are equally efficient, in equilibrium the incumbent produces more than each entrant. Moreover, note that there is a range of parameter values for which the ECPR allows the incumbent to outproduce its opponents even though it is less efficient. This is to be contrasted with the results in Proposition 1, where our rule was shown to yield, in equilibrium, an equal share for both the incumbent and the entrants when they are all equally efficient, and a higher share to the more efficient firm(s). Since market structure and parameters were kept constant, this shows that the bias in favor of the incumbent associated with the ECPR can be attributed to the incentives implicit in the access pricing rule. From an economic-efficiency viewpoint, this is a perverse consequence of the incentives implicit in the ECPR.

We can now compare the levels of output induced by the two rules. We do so in the following

Proposition 3 *Output is higher with rule (1) than with the ECPR.*

Proof See Appendix. □

The reader who reads the proof may think that we have assumed, rather than proved, the result, since it depends on the hypothesis made above that $q > \bar{q}$. This is not the case. Note that the assumption $q > \bar{q}$ amounts to saying that no regulatory intervention *concerning low output and high price* is deemed necessary by the regulatory authority, once entry by (at least) one firm occurs, since this is enough to induce a price below $\bar{p}$. Thus, the regulator, once it has forced the incumbent to provide access, needs only to be concerned with regulating its pricing.[15]

To put it another way, assuming otherwise ($q < \bar{q}$) would introduce the question of how to regulate price in the post-entry market alongside the problem of the economic efficiency of the access pricing rule. Our assumption amounts to assuming that the first problem is solved by the competition resulting from opening access, thus allowing the discussion to concentrate on the efficiency consequences of the access pricing rule adopted.

Once this is the case, Proposition 3 shows that the proposed rule gives firms incentive to compete more aggressively than does the ECPR. The intuitive reason for this is as follows. Our rule treats all firms symmetrically—recall Proposition 1—while the ECPR treats firms asymmetrically—see Proposition 2. The latter makes the entrants weak competitors, because of the burden associated with the way access is priced, therefore allowing for a more collusive outcome. In other words, access pricing according to the ECPR handicaps the entrants to an extent that is competitively detrimental, thereby reducing efficiency. Our rule does not do so, while still inducing the transfer of (at least) π to the bottleneck-facility owner.

Note that when the incumbent and the entrants are not equally efficient, besides the efficiency gains of a lower price, the issue of productive

[15] This seems realistic since in many markets dependent on a bottleneck facility, regulators are apparently satisfied that either two or a small number of competitors ensure low enough prices, since no regulatory decisions deemed explicitly concerned with high prices have emerged in such partially deregulated markets.

efficiency must be addressed. If a slightly lower price is achieved at a cost of having production being carried out in large part by the least-efficient producer(s), then welfare may decrease. We can now compare our rule and the ECPR, bearing in mind these two potentially conflicting aspects.

Proposition 4 *Economic efficiency is higher under our rule than under the ECPR when entrants are more efficient than, or as efficient as the incumbent,* $c_I \geq c_E$. *The comparison is ambiguous in the opposite case.*

Proof See Appendix. □

5 Bertrand Competition

In this section we characterize the equilibria of the game when firms compete *à la* Bertrand, both when access is priced according to the ECPR and the new rule we propose. We do so because even though imperfect competition seems to be more consistent with what is seen in recently-liberalized markets, most discussions of the ECPR seem to have in mind Bertrand competition, i.e., situations where the lowest-price firm(s) capture(s) all sales. When comparing the two rules, we conclude that our rule is better from an economic-efficiency viewpoint when entrants are more efficient than the incumbent, identical when all firms are equally efficient, and non-comparable when the incumbent is more efficient than the entrants. The result is thus identical to that obtained in the previous section.

We assume that there are at least two firms that seek entry after access to the bottleneck facility is opened. Post-entry competition is thus maximal. This is desirable because it allows the comparison of the two rules when competition is intense, as is the case with Bertrand competition and at least two entrants seeking access. Yet, the results prove qualitatively analogous to those in the previous section, where competition was less intense, as is the case with Cournot for any finite number of firms.

Proposition 5 *Let the access price be determined by the Efficient Component*

Pricing Rule, firms compete à la Bertrand and there be at least two firms seeking access. The equilibrium is as follows: (i) when the entrants are more efficient than the incumbent ($c_I > c_E$), the equilibrium price is $\bar{p} - (c_I - c_E)$ and is quoted by at least one entrant, while the bottleneck-facility owner sells access only. (ii) When the entrants are less efficient than the incumbent ($c_I < c_E$), the equilibrium price belongs to the interval $[\bar{p}, \bar{p} - (c_I - c_E)]$ and the incumbent serves the whole market while the entrants sell nothing. (iii) When the incumbent and the entrants are equally efficient ($c_I = c_E$), the equilibrium price equals $\bar{p}$ and firm I, one or more entrants, or both sell to consumers.

Proof See Appendix. □

The theorem shows that the equilibrium is such that only the more efficient firms sell under the different cost configurations. The ECPR does indeed ensure productive efficiency.

Let us now discuss the equilibrium when our rule is used. Before doing so, we need to define some additional notation. Let $\tilde{p}$ be the lowest price such that $(\tilde{p} - c - c_E)q(\tilde{p}) = \pi$. Thus $\tilde{p}$ is analogous to $\bar{p}$, except that it is calculated for marginal cost $c + c_E$ rather than $c + c_I$. Thus $c_I \gtreqless c_E$ implies $\bar{p} \gtreqless \tilde{p}$. Also, simplify notation by writing $\tilde{q} \equiv q(\tilde{p})$. Multiplying both sides of the equality defining $\tilde{p}$ by $\frac{q_E}{\tilde{q}}$ and rearranging yields $q_E\tilde{p} = cq_E + \frac{q_E}{\tilde{q}}\pi + c_E q_E$. Thus, when $\tilde{p}$ is the equilibrium price, any entrant selling a positive quantity makes zero profits. Crucially, any lower price induces a loss. Also, any higher price induces a profit, and the associated incentive for undercutting on the part of each entrant.

We can now state

Proposition 6 *Let the access price equal*

$$p_a = c + \frac{\pi}{q_I + \sum q_E},$$

firms compete à la *Bertrand and there be at least two firms seeking access. The equilibrium is such that (i) when the entrants are more efficient than the incumbent ($c_I > c_E$), the equilibrium price equals $\tilde{p}$ and is quoted by at least* *one entrant, while the bottleneck-facility owner sells access only. (ii) When the entrants are less efficient than the incumbent ($c_I < c_E$), the equilibrium price belongs to the interval $[\bar{p}, \tilde{p}]$ and the incumbent serves the whole market while the entrants sell nothing. (iii) When the incumbent and the entrants are equally efficient ($c_I = c_E$) the equilibrium price equals $\tilde{p} = \bar{p}$ and firm I, one or more entrants, or both sell to consumers.*

Proof See Appendix. □

Again, exactly as in the case of the ECPR, only the more efficient firms produce. Our rule ensures productive efficiency, too. However, the two rules differ from an economic-efficiency viewpoint. The rule yielding a lower price is more efficient. The following theorem formalizes the comparison.

Proposition 7 *Pricing entry according to*

$$p_a = c + \frac{\pi}{q_I + \sum q_E}$$

enhances economic efficiency beyond that which the ECPR does when the entrants are more efficient than the incumbent. When all firms are equally efficient, the two rules are equivalent. Finally, when the incumbent is more efficient than the entrants, the two rules cannot be compared.

Proof See Appendix. □

We underscore the fact that this result is qualitatively analogous to the one obtained in the previous section. Why is the comparison of the two rules clear-cut when the entrants are more efficient than the incumbent, but not so in the opposite case? To see this, note that opening of access has two effects: on the one hand, it introduces competition where formerly there was none, an effect that unequivocally increases economic efficiency; on the other hand, it allows entrants to steal business from the incumbent. This increases economic efficiency if the former are more efficient than the latter, but reduces economic efficiency in the opposite case. Our rule, because it establishes a level playing field between the incumbent and the entrants, induces more aggressive entry in equilibrium compared to the

ECPR, which we have seen to be biased in favor of the incumbent. Thus, when the incumbent is less efficient than the entrants, our rule better promotes economic efficiency when compared to the ECPR because it gives incentives for more aggressive production, and this is unequivocally desirable from an economic-efficiency viewpoint. When the incumbent is more efficient than the entrants, our rule, while inducing more aggressive competition after entry than the ECPR, does so at the cost of more business being obtained by the less-efficient entrants. The final balance of these two contradictory effects precludes a definite comparison of the two rules.

6 Conclusion

Opening of formerly monopolized markets to new entrants in the presence of a bottleneck facility raises the question of how the price of access to such facilities should be determined. Insofar as authorities refrain from directly regulating the price prevailing in such markets after they are opened—as is typically the case—the access pricing rule used to regulate access to bottleneck facilities becomes of the essence in enhancing economic efficiency. This is so because the access price, being the price of an input, impacts the final price prevailing in such markets, as well as the output shares of the firms operating therein, thus ultimately determining economic efficiency. We propose a new rule that better promotes economic efficiency than the Efficient Component Pricing Rule—the current benchmark used by regulators to price access—when the entrants are more efficient than the incumbent.

Moreover, our rule is as simple and informationally undemanding as the ECPR, and thus constitutes a good alternative to the current benchmark as far as simplicity and clarity of the regulatory process are concerned. This simplicity seems to render attempts at capture harder to effect: the simpler to estimate are the parameters involved, the less scope there is for capture.

The reader may notice that our rule attains its gains in efficiency compared to the ECPR by introducing non-linearity in the access price, while simultaneously keeping the rule simple. In this sense, it borrows heavily from the example presented in subsection 2.2, while addressing the problem of how to allocate π among firms buying access.

Our rule is totaly blind to demand parameters that other, more sophisticated rules proposed in the literature, incorporate. When such data are available, naive rules such as the ECPR and ours are less than optimal given the information available. This is an ineluctable counterpart of the simplicity and clarity alluded to above and in the Introduction. Proposing theoretically correct and possibly complicated rules is worthy in guiding our intuition as to the factors that should determine access pricing. However, when the information available does not allow for their implementation, the study of the efficiency performance of simple rules such as the ECPR and ours becomes paramount from a regulatory viewpoint. In this sense, investigating the economic efficiency of simple and apparently *ad hoc* rules should be regarded as a search for optimality in the pricing of access *given the informational constraints* faced by regulators. The fast-paced opening of formerly closed markets suggests that the search for simpler but even better access pricing rules should be a task for future research.

Appendix

Proof of Proposition 1 To see this, subtract one of the Lerner indices in (3) from the other to obtain

$$\frac{c_I - c_E}{p} = \frac{1-(n+1)\alpha}{n}\left(\frac{1}{\varepsilon} - \frac{\pi}{pq}\right).$$

The last term in parentheses needs to be signed. In order to do so, note that $\frac{1}{\varepsilon} - \frac{\pi}{pq} > \frac{1}{\varepsilon} - \frac{q_I(p-c-c_I)}{pq} = \frac{1}{\varepsilon} - \frac{q_I}{q}\frac{p-c-c_I}{p} > \frac{1}{\varepsilon} - \frac{p-c-c_I}{p} = \frac{1}{\varepsilon} - \frac{\alpha}{\varepsilon} - (1-\alpha)\frac{\pi}{pq} = (1-\alpha)\left(\frac{1}{\varepsilon} - \frac{\pi}{pq}\right)$, where the first inequality results from noting that the incumbent sets $q_I > 0$ if doing so yields it more than π, which can be obtained by setting $q_I = 0$. Noting that $1-\alpha < 1$, we conclude that $\frac{1}{\varepsilon} - \frac{\pi}{pq} > 0$. Thus, $c_I = c_E \Rightarrow \frac{1-(n+1)\alpha}{n} = 0 \Rightarrow 1-(n+1)\alpha = 0 \Rightarrow \alpha = \frac{1}{n+1}$. Also, the signs of $c_I - c_E$ and $\frac{1-(n+1)\alpha}{n}$ are the same, implying $c_I \gtreqless c_E \Leftrightarrow \alpha \lesseqgtr \frac{1}{n+1}$.

Proof of Proposition 2 Subtract one of the Lerner indices in (5) from the other to obtain

$$\frac{c_I - c_E}{p} = \frac{1-(n+1)\alpha}{n}\frac{1}{\epsilon} + \frac{\pi}{p\bar{q}} \Leftrightarrow c_I - c_E - \frac{\pi}{\bar{q}} = \frac{1-(n+1)\alpha}{n}\frac{p}{\epsilon}.$$

Thus, $c_I - c_E \gtreqless \frac{\pi}{\bar{q}} \Rightarrow \frac{1-(n+1)\alpha}{n} \gtreqless 0 \Rightarrow 1-(n+1)\alpha \gtreqless 0 \Rightarrow \alpha \lesseqgtr \frac{1}{n+1}$. In particular, $c_I = c_E \Rightarrow q_I > q_E$.

Proof of Proposition 3 We can create a composite Lerner index by summing the Lerner indices of all the firms operating in the market. To do this, use the first-order conditions in (3) and (5) to obtain the following composite Lerner indices

$$\frac{(n+1)p - (n+1)c - c_I - nc_E}{p} = \frac{1}{\varepsilon} + \frac{n\pi}{pq}$$

$$\frac{(n+1)p - (n+1)c - c_I - nc_E}{p} = \frac{1}{\varepsilon} + \frac{n\pi}{p\bar{q}}.$$

Thus, $q > \bar{q}$ implies the desired result.

Proof of Proposition 4 First consider the case where $0 \le c_I - c_E < \frac{\pi}{\bar{q}}$. By Proposition 2, our rule implies $q_E \ge q_I$ whereas by Proposition 4, the ECPR implies the opposite. Also, by the previous proposition, our rule implies a higher output. Thus, we can be sure that welfare is higher with rule (1) than with the ECPR because output is higher and production is concentrated in the more efficient firms.

When $c_I - c_E = \frac{\pi}{q} > 0$, we have $q_I = q_E$ under the ECPR, and $q_E > q_I$ under our rule. Again, welfare is higher with the proposed rule than with the ECPR because output is higher and production is concentrated in the more efficient firms.

Consider now the case where $c_I - c_E > \frac{\pi}{q}$. Now, under both our rule and the ECPR, we have $q_E > q_I$. The following argument allows the comparison of the ratios $\frac{q_I}{q_E}$ under the two rules. Begin by manipulating the two Lerner indices in (3), to obtain

$$\frac{q_I}{q_E} = \frac{\alpha}{1-\alpha} = \frac{p - c - c_I - (1-\alpha)\frac{\pi}{q}}{p - c - c_E - \frac{n-(1-\alpha)}{n}\frac{\pi}{q}}.$$

This expression can be altered as follows

$$\frac{p - c - c_I - (1-\alpha)\frac{\pi}{q}}{p - c - c_E - \frac{n-(1-\alpha)}{n}\frac{\pi}{q}} < \frac{p - c - c_I}{p - c - c_E - \frac{\pi}{q}} < \frac{p - c - c_I}{p - c - c_E - \frac{\pi}{\bar{q}}}.$$

For the last expression to be equal to $\frac{q_I}{q_E}$ under the ECPR, we need to take into account that the price, p, is higher under the ECPR than under our alternative pricing rule. Note that $\frac{\partial\left(\frac{p-c-c_I}{p-c-c_E-\frac{\pi}{q}}\right)}{\partial p} = \frac{c_I - c_E - \frac{\pi}{q}}{\left(p-c-c_E-\frac{\pi}{q}\right)^2} > 0$ to conclude that $\frac{q_I}{q_E}$ is lower under (1) than under the ECPR. Thus, economic efficiency under our rule is also higher since not only does it induce a lower price, but productive efficiency is increased.

When $c_I < c_E$ nothing can be concluded in general. To see this, suppose that the incumbent has a small competitive advantage, $c_I < c_E$, in which case our rule will induce the incumbent to produce slightly more than each entrant. The ECPR, on the other hand, leads the incumbent to produce significantly more than each entrant. Thus, the ECPR, while inducing a higher price, concentrates production in the more efficient producer, precluding a general conclusion.

Proof of Proposition 5 Setting the access price according to the ECPR implies $p_a = \bar{p}-c_I$. Thus, entrants have marginal cost $\bar{p}-c_I+c_E = \bar{p}-(c_I-c_E)$.

Note that, by quoting $\bar{p}$, the incumbent can secure a profit not inferior to π. To see this, note that, by following this strategy, the incumbent obtains a per-unit profit of $\bar{p} - c - c_I$ when selling directly to consumers, the same margin that it obtains by selling access to entrants, while ensuring that quantity traded in the market is not inferior to $\bar{q}$, since the equilibrium price cannot exceed the incumbent's quoted price. Quoting $\bar{p}$ thus yields at least π to firm I.

(i) When the entrants are more efficient than the incumbent, we claim that the equilibrium price is $\bar{p}-(c_I-c_E)$, with one or more entrants quoting it, and firm I either quoting a higher price or matching $\bar{p} - (c_I - c_E)$ and selling nothing.

To see this, first consider (ia) all price profiles such that the lowest price quote is by one or more entrants. If such price is lower than $\bar{p}-(c_I-c_E)$, any firm quoting it and selling a positive quantity realizes a loss, which could be avoided by quoting $\bar{p} - (c_I - c_E)$, for example. If such price exceeds $\bar{p} - (c_I - c_E)$, then at least one of the entrants will gain by slightly undercutting such price and serving the whole market.

(ib) Suppose now that the lowest price is quoted by firm I. If it exceeds $\bar{p} - (c_I - c_E)$, then an entrant can profit by slightly undercutting it. If it is less than or equal to $\bar{p} - (c_I - c_E)$, firm I earns less than π, since $c_I > c_E \Rightarrow \bar{p} - (c_I - c_E) < \bar{p}$ and $\bar{p}$ is, by definition, the lowest price at which firm I can earn π while serving the whole market. By quoting $\bar{p}$, firm I can earn at least π.

(ic) Finally, consider the case where the lowest price is quoted simultaneously by firm I and at least one of the entrants. If such price is lower than $\bar{p} - (c_I - c_E)$ and one of the entrants sells a positive quantity, such entrant is making a loss which it can eliminate by increasing its quote and selling nothing. If only firm I is selling, it earns less than π because $c_I > c_E \Rightarrow \bar{p} - (c_I - c_E) < \bar{p}$ and $\bar{p}$ is, by definition, the lowest price at which firm I can earn π while serving the whole market. It can then quote $\bar{p}$ and earn π. If such price exceeds $\bar{p} - (c_I - c_E)$, an entrant can slightly undercut it, serve the whole market and increase its profits. Finally, if the lowest price quoted equals $\bar{p} - (c_I - c_E)$ and firm I sells a positive quantity, it earns $\bar{p} - (c_I - c_E) - c - c_I$ per unit sold. By quoting a higher price and selling nothing directly to consumers, it ensures that whatever it was selling will now be sold by entrants, who buy access from I at a per-unit margin of $\bar{p} - c - c_I > \bar{p} - (c_I - c_E) - c - c_I$ to firm I. Thus, firm I can unilaterally deviate.

(ii) Consider now the case where the incumbent is more efficient than the entrants ($c_I < c_E$). The entrants' marginal cost equals $\bar{p} - c_I + c_E = \bar{p} - (c_I - c_E) > \bar{p}$. We claim that the equilibrium price belongs to the interval $[\bar{p}, \bar{p} - (c_I - c_E)]$ and the incumbent serves the whole market while the entrants sell nothing.

(iia) To see this, first consider all price profiles such that the lowest price quote is by one or more entrants. If such price is lower than $\bar{p} - (c_I - c_E)$, any firm quoting it and selling a positive quantity realizes a loss, which could be avoided by quoting $\bar{p} - (c_I - c_E)$, say. If such price exceeds $\bar{p} - (c_I - c_E)$, then at least one of the entrants gains by slightly undercutting such price and serving the whole market. If such price equals $\bar{p} - (c_I - c_E)$, then the entrants are buying less than $\bar{q}$ of access at a profit margin of $\bar{p} - c - c_I$ to the access provider whose profit is thus less than π. By quoting $\bar{p}$, firm I can capture the whole market and earn π, thus increasing its profit.

(iib) Consider now all price profiles such that the lowest price quote is by one or more entrants as well as firm I. If such price is lower than $\bar{p} - (c_I - c_E)$, any entrant quoting it and selling a positive quantity realizes a loss, which could be avoided by quoting $\bar{p} - (c_I - c_E)$, say. If only firm I sells a positive quantity and the price is lower than $\bar{p}$, firm I earns less than π: quoting $\bar{p}$ would then increase its profit to π.

If such price exceeds $\bar{p} - (c_I - c_E)$ then at least one of the entrants gains by slightly undercutting it and serving the whole market.

If such price equals $\bar{p} - (c_I - c_E)$ and the entrants are selling a positive quantity and thus buying access, they do so at a profit margin to the access provider of $\bar{p} - c - c_I$. By slightly lowering its quote, firm I can then capture the sales of the entrants at a margin essentially equal to $\bar{p} - (c_I - c_E) - c - c_I > \bar{p} - c - c_I$ and thus increase its profit.

(iic) Finally consider now all price profiles such firm I quotes the lowest price. If such price is lower than $\bar{p} - (c_I - c_E)$, firm I can increase it slightly, thereby increasing its profit without losing sales to entrants. If such price exceeds $\bar{p} - (c_I - c_E)$ then at least one of the entrants gains by slightly undercutting such price and serving the whole market.

(iii) Consider finally the case where the incumbent and the entrants are equally efficient. In this case, the entrants' marginal cost equals $\bar{p}$. Now we claim the equilibrium price equals $\bar{p}$, and firm I, one or more entrants, or both sell to the public.

To see this, first consider all price profiles such that the lowest price quote exceeds $\bar{p}$. Then, at least one entrant can slightly undercut it and increase its profit by capturing the whole market. Consider now the case where the lowest price quoted is lower than $\bar{p}$. If an entrant is quoting it and selling a positive quantity, it is incurring a loss that it can avoid by increasing its quote to $\bar{p}$. If only firm I is selling a positive quantity, it is making a profit of less than π since $\bar{p}$ is, by definition, the lowest price that yields firm I a profit of π when serving the whole market. Firm I can thus deviate to quoting $\bar{p}$ and earn at least π.

Proof of Proposition 6 Note that, by quoting $\bar{p}$, firm I can secure a profit of π irrespective of whether it sells access only (in which case we have seen that (1) yields a profit of exactly π to the incumbent), serves the whole market by selling $\bar{q}$ to consumers, or shares the market with one or more entrants. Note that in the latter case, firm I's profit equals $(\bar{p} - c - c_I)q_I + (p_a - c)\sum q_E = (\bar{p} - c - c_I)q_I + (c + \frac{\pi}{q_I + \sum q_E} - c)\sum q_E = \frac{q_I}{q_I + \sum q_E}\pi + \frac{\pi}{q_I + \sum q_E}\sum q_E = \pi$. Note that $(\bar{p} - c - c_I)q_I = \frac{q_I}{q_I + \sum q_E}\pi$ since, by selling q_I at price $\bar{p}$, firm I obtains a share of π equal to $\frac{q_I}{q_I + \sum q_E}$. Thus, quoting $\bar{p}$ earns firm I a profit of π irrespective of the entrants' price quotes.

(i) When the entrants are more efficient than the incumbent, we claim that the equilibrium price is $\bar{p}$, with one or more entrants quoting it, and firm I either quoting a higher price or matching $\tilde{p}$ and selling nothing.

To see this, first consider (ia) all price profiles such that the lowest price quote is by one or more entrants. If such price is lower than $\tilde{p}$, any firm quoting it and selling a positive quantity realizes a loss, which could be avoided by quoting $\tilde{p}$, for example. If such price exceeds $\tilde{p}$, then at least one of the entrants will gain by slightly undercutting such price and serving the whole market.

(ib) Suppose now that the lowest price is quoted by firm I. If it exceeds $\tilde{p}$, then an entrant can profit by slightly undercutting it. If it is less than or equal to $\tilde{p}$, firm I earns less than π, since $c_I > c_E \Rightarrow \tilde{p} < \bar{p}$. By quoting $\bar{p}$, firm I can earn π.

(ic) Finally, consider the case where the lowest price is quoted simultaneously by firm I and at least one of the entrants. If such price is lower than $\tilde{p}$ and one or more entrants sell a positive quantity, such firms are realizing a loss which can be eliminated by increasing the price quote and selling nothing. If only firm I is selling, it earns less than π since $c_I > c_E \Rightarrow \tilde{p} < \bar{p}$. It can then quote $\bar{p}$ and earn at least π. If such price exceeds $\tilde{p}$, an entrant can slightly undercut it and serve the whole market. Finally, if such price equals $\tilde{p}$ and firm I sells a positive quantity, its profit equals $(\tilde{p} - c - c_I)q_I + (p_a - c)\sum q_E < (\bar{p} - c - c_I)q_I + (p_a - c)\sum q_E = (\bar{p} - c - c_I)q_I + (c + \frac{\pi}{q_I + \sum q_E} - c)\sum q_E = \frac{q_I}{q_I + \sum q_E}\pi + \frac{\pi}{q_I + \sum q_E}\sum q_E = \pi$ and is thus less than π. Thus, firm I can unilaterally deviate by raising its price, sell access only and earn π.

(ii) Consider now the case where the incumbent is more efficient than the entrants ($c_I < c_E$). Recall that $c_I < c_E \Rightarrow \bar{p} < \tilde{p}$. We claim that the equilibrium price belongs to the interval $[\bar{p}, \tilde{p}]$ and the incumbent serves the whole market while the entrants sell nothing.

(iia) To see this, first consider all price profiles such that the lowest price quote is by one or more entrants. If such price is lower than $\tilde{p}$, any entrant quoting it and selling a positive quantity does so at a loss, which could be avoided by quoting $\tilde{p}$, for example. If such price exceeds $\tilde{p}$, then at least one of the entrants gains by slightly undercutting such price and serving the whole market. If such price equals $\tilde{p}$, firm I can slightly undercut $\tilde{p} > \bar{p}$, capture the whole market and earn more than π, rather than just π, which is firm I's profit from selling access only.

(iib) Consider now all price profiles such that the lowest price quote is by one or more entrants as well as firm I. If such price is lower than $\tilde{p}$, any entrant quoting it and selling a positive quantity realizes a loss, which could be avoided by quoting $\tilde{p}$, for example. If only firm I sells a positive quantity and the price is lower than $\tilde{p}$, firm I earns less than π: quoting $\tilde{p}$ would then increase its profit to π.

If such price exceeds $\tilde{p}$, then at least one of the entrants gains by slightly undercutting it and serving the whole market. If such price equals $\tilde{p}$ and the entrants are selling a positive quantity, firm I's profit from selling access equals $\frac{\sum q_E}{q_I + \sum q_E}\pi$. By slightly undercutting $\tilde{p}$ and capturing the whole market, firm I can capture the entrants' sales, earning on them $(\tilde{p} - c - c_I)\sum q_E > (\bar{p} - c - c_I)\sum q_E = \frac{\sum q_E}{q_I + \sum q_E}\pi$, thereby increasing its profit.

(iic) Consider now all price profiles in which firm I quotes the lowest price. If such price is lower than $\tilde{p}$, firm I can increase it slightly without losing sales to entrants, thereby increasing its profit. If such price exceeds $\tilde{p}$, an entrant gains by slightly undercutting such price and serving the whole market.

(iii) Consider finally the case where the incumbent and the entrants are equally efficient. Now we claim that the equilibrium price equals $\tilde{p} = \bar{p}$, and firm I, one or more entrants, or both sell to the public.

To see this, first consider all price profiles such that the lowest price quote exceeds $\bar{p}$. Then, at least one entrant can slightly undercut it and increase its profit by capturing the whole market. Consider now the case where the lowest price quoted is lower than $\bar{p}$. If an entrant is quoting it and selling a positive quantity, it is incurring a loss that it can avoid by increasing its quote to $\bar{p}$, for example. If firm I is quoting it and serving the whole market, it is making a profit of less than π. By quoting $\bar{p}$, firm I can increase its profit to π.

This exhausts all price profiles for which there is a unilateral deviation. The remainder constitute the equilibria of the game.

Proof of Proposition 7 When $c_I > c_E$, the ECPR yields an equilibrium price of $\bar{p} - (c_I - c_E)$ whereas our accessing-pricing rule yields $\tilde{p}$. From the definition of $\bar{p}$ and $\tilde{p}$ we have $c_I > c_E \Rightarrow \bar{p} > \tilde{p} \Rightarrow \bar{q} < \tilde{q}$. Write $\tilde{q} = \bar{q} + \Delta$, and note that $\Delta > 0$. Also from the definition of $\bar{p}$ and $\tilde{p}$, we have

$$(\bar{p} - c - c_I)\,\bar{q} = \pi = (\tilde{p} - c - c_E)\,\tilde{q}.$$

Manipulation of this expression yields

$$\bar{p} - (c_I - c_E) - \tilde{p} = \frac{(\tilde{p} - c - c_E)\,\Delta}{\bar{q}} > 0.$$

Since our rule yields a lower price, it better promotes economic efficiency.

When all firms are equally efficient ($c_I = c_E$), both rules yield the same price.

When the incumbent is more efficient than the incumbent, the ECPR yields a price in the interval $[\bar{p}, \bar{p} - (c_I - c_E)]$, whereas our rule results in a price belonging to $[\bar{p}, \tilde{p}]$. The two intervals have the same lower bound and overlap in part, thus precluding a definitive price comparison.

References

ARMSTRONG, M, C. DOYLE AND J. VICKERS. 1996. "The Access Pricing Problem: A Synthesis." *The Journal of Industrial Economics* 44(2): 131-150.

BAUMOL, W. AND G. SIDAK. 1994. *Towards Competition in Local Telephony.* AEI Studies in Telecommunications Deregulation, Cambridge and London: MIT Press.

BAUMOL, W. AND G. SIDAK. 1994. "The Pricing of Inputs Sold to Competitors." *Yale Journal on Regulation* 11(1): 171-202.

ECONOMIDES, N. AND L. WHITE. 1995. "Access and Interconnection Pricing: How Efficient is the ECPR?" *Antitrust Bulletin* 40(3): 557-579.

KAHN, A. AND W. TAYLOR. 1994. "The Pricing of Inputs Sold to Competitors: A Comment." *Yale Journal on Regulation* 11(1): 225-240.

LAFFONT, J.-J. AND J. TIROLE. 1996. "Creating Competition Through Interconnection: Theory and Practice." *Journal of Regulatory Economics* 10(3): 227-256.

LARSON, A., AND D. LEHMAN. 1997. "Essentiality, Efficiency, and the Efficient Component-Pricing Rule." *Journal of Regulatory Economics* 12(1): 71-80.

PARKER, P. AND L.-H. RÖLLER. 1997. "Collusive Conduct in Duopolies: Multimarket Contact and Cross-Ownership in the Mobile Telephone Industry." *Rand Journal of Economics*, 28(2): 304-322.