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# Network interconnection with competitive transit

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**Abstract**

We examine the interaction between two interconnected networks (e.g., two local exchange carriers (LECs)) and a third network (e.g., an interexchange carrier (IXC)) seeking access to their customer base. The IXC could either interconnect with both LECs or interconnect with only one LEC and transit calls to the other LEC via the first LEC's network. We show that there is a wide set of cases in which competitive transit could justify partial or even complete deregulation of access to a network's customer base.


*JEL classification:* L51; L96

*Keywords:* Interconnection; Access pricing; Transit; Telecommunication; Bill and keep

## 1. Introduction

As network industries continue to open up to competition around the world, the terms under which various networks interconnect have increasingly become the subject of public and regulatory debate. Interconnections are particularly important in the telecommunications industry where competition has developed faster than in other network industries. In the US, current regulation of interconnection among telecommunication carriers may be classified into interconnections among competing local exchange carriers (LECs) and interconnections between LECs and interexchange

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carriers (IXCs). The first type of interconnections is, pursuant to the 1996 Telecommunications Act, mandatory, and requires LECs to negotiate reciprocal compensation rates for calls made by subscribers of one LEC to subscribers of another LEC. The second type of interconnections is regulated pursuant to a series of Federal Communications Commission (FCC) orders and rules. These orders and rules mandate interconnection between LECs and IXCs while placing a cap on the interconnection fees that LECs charge IXCs. Strict regulation of access to a network's subscriber base also characterizes other network industries such as cable TV and electricity. [1]

The idea behind the reforms in network industries was to replace regulation with competition. In the case of telecommunications, US courts and the FCC have stressed "Congress's directive that the [FCC] replace regulation with competition to the greatest extent possible consistent with the public interest ... competitive markets are far better than regulatory agencies at allocating resources and services efficiently for the maximum benefit of consumers." [2] At the same time, regulators remain concerned that competitive forces would not suffice to restrain the rates and conditions that networks set for granting other networks access to their customer base.

This paper examines a simple and extremely effective market force that could justify (either partial or complete) deregulation of interconnections: The ability of one network, seeking access to another network's customer base, to transit traffic to and from the other network via a third network. For example, when two LECs are interconnected, an IXC can transit long-distance calls to and from the subscribers of one LEC via the other LEC's network. Likewise, an ISP can reach the customer base of one LEC or cable carrier via another LEC or cable carrier with which the first carrier is interconnected. [3]

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[1] For example, the FCC has been considering requiring cable operators to furnish nondiscriminatory cable transmission capacity to unaffiliated Internet Service Providers (ISPs) (See In re inquiry concerning high-speed access to the Internet over cable and other facilities, FCC Record, vol. 17, p. 4798, 7 (Declaratory Ruling and Notice of Proposed Rulemaking) (2002)). Similarly, in the course of restructuring the US electricity markets, the Federal Energy Regulatory Commission (FERC) reinforced open access and unbundling requirements to insure undiscriminatory access to public utilities' transmission facilities by independent retailers and generators of electricity. For a recent discussion of such regulation, see http://www.ferc.gov/press-room/pr-current/07-23-03-interconnect1.pdf.

[2] See *Southwestern Bell Telephone Company v. Federal Communications Commission*, 153 F.3d 523, 547, 549 (8th Cir. 1998).

[3] The practice of sending traffic to one network via another network is very common and is often referred to as "least cost routing." Transit arrangements are common between Internet backbones: when backbone A purchases transit access from backbone B, it typically gains access to all backbones interconnected with backbone B (see Crémer et al., 2000; Kende, 2000). Transit arrangements are also common in international telecommunication. Two countries can interconnect by transiting calls through a third country (see, e.g., FCC Releases 1996 International Traffic Data, 1998 FCC LEXIS 363, *12–13, 1998). Transit also exists in local telecommunication markets (see, e.g., In re Developing a Unified Intercarrier Compensation Regime, CC Docket No. 01-92, 2001 FCC LEXIS 2339 (Notice of Proposed Rulemaking, 2001) albeit it is not common in the context of interconnection with IXCs, presumably because direct interconnection between LECs and IXCs is mandated under regulated rates. Transit currently exists in cases where a network, typically a cellular or paging network, does not have direct interconnection with a certain LEC, see e.g., Texcom, Inc. v. Bell Atlantic Corp., FCC Record, vol. 17, p. 6275 (2002) (discussing a dispute between a cellular network and a LEC that transited calls flowing between the competing LEC and the cellular network).

Our model focuses on an IXC that faces two interconnected LECs and needs to pay them interconnection fees for long-distance calls that either originate or terminate at their networks. Contrary to the current regime, in which interconnection between LECs and IXCs is heavily regulated, interconnection between the LECs and the IXC in our model is completely deregulated. This is because we are interested in finding out whether competitive transit can replace regulation. An important feature of the model is that the IXC need not interconnect directly with both LECs; instead it can interconnect with a single LEC and transit calls to and from the other LEC via the first LEC. Anticipating their dealings with the IXC, the LECs negotiate either a positive or a negative reciprocal access fee for transited traffic that flows between their networks so as to boost their access revenue from dealing with the IXC. [4] We therefore examine how, if at all, the reciprocal access fee that the two LECs negotiate should be regulated in order to restrain the interconnection fees that LECs charge the IXC with no need for further regulatory intervention.

We show that if the volumes of inbound and outbound long-distance traffic are equal, both LECs will voluntarily interconnect with the IXC at no charge, irrespective of the value of the reciprocal access fee that the LECs have negotiated before dealing with the IXC. Interestingly, this outcome is equivalent to that under mandatory interconnection with a "bill and keep" regime which was recently proposed by the FCC. Under this regime, all LEC interconnection charges are regulated down to zero, unless the interconnecting networks agree otherwise. [5] Transit has the obvious advantage that it leads to voluntary interconnection at no charge without a need for any regulatory intervention.

In contrast, when the volumes of inbound and outbound long-distance traffic are unequal, the two LECs would strategically set the reciprocal access fee for transited long-distance traffic so as to force the IXC to offer them higher interconnection fees. This strategic behavior on the LECs' part may force the IXC to pay the two LECs excessively high interconnection fees. Nonetheless, we show that it is still possible to achieve the same outcome as in a "bill and keep" regime by mandating that the LECs will transit long-distance calls to one another at no charge. Given this requirement, the two LECs will voluntarily agree to interconnect with the IXC at no charge without a need for directly regulating their interconnection with the IXC. We also show that when the IXC can price discriminate between direct and transited long-distance calls (and has all the bargaining power vis-a-vis the two LECs) then the IXC will be able to interconnect with both LECs at cost without a need for any type of regulation.

The literature on access pricing is relatively new but is rapidly growing (see Armstrong, 2002; for a comprehensive literature survey). Economides et al. (1996a,b) examine competition between interconnected networks and find that a dominant network can price squeeze an entrant by setting a higher price for off-net calls than for

[4] Throughout the paper we refer to the price that the LECs pay one another for transited long-distance traffic as "access fee" and refer to the prices that the IXC pays the two LECs as "interconnection fees."

[5] For details, see Intercarrier Compensation Proposal FCC Record vol. 16, p. 9610, (2001). The FCC's Proposal is based mainly on two FCC working papers: Atkinson and Barnekov (2000) and DeGraba (2002).

on-net calls. But, when access charges must be reciprocal, the price difference between on-net and off-net calls disappears and monopoly becomes less likely. Armstrong (1998) and Laffont et al. (1998a) show that whenever networks compete with one another by setting uniform per-call prices, an above-cost reciprocal access fee can be used as an instrument of tacit collusion. The reason for this is that an above-cost access fee induces each network to raise its per-call price above its rivals' price in order to induce its subscribers to make fewer off-net calls than they receive and thereby ensure that the network enjoys an access surplus. Laffont et al. (1998a,b) show that this conclusion no longer holds when networks can either use nonlinear prices and/or price discriminate between on-net and off-net calls. Carter and Wright (2003) extend the Laffont et al. (1998a,b) model and consider the case of asymmetric networks. They show that under two-part tariffs, the larger network will always prefer a reciprocal access fee equal to cost, while the smaller network may prefer an above-cost reciprocal access fee for moderate levels of asymmetry. Valletti and Cambini (2003) endogenize the potential asymmetry between the networks by introducing a preliminary stage in which the networks invest in their quality of service. Since in their model subscribers make more calls when the network's quality is higher, an above-cost reciprocal access fee will give the higher quality network an access deficit vis-a-vis the lower quality network. As a result, the networks prefer to set an above-cost access fee in order to soften the competition between them in the investment stage. Peitz (in press) shows that regulating access prices to ensure that only an entrant enjoys an access markup enhances the likelihood of entry and, given entry, makes competition between the entrant and incumbent more intense.

None of these papers, however, studied the interaction between two interconnected networks and a third network which is the main focus of our paper. Moreover, in our paper, the reciprocal access fee does not affect competition between the interconnected networks but rather affects their interaction with a third network that seeks access to their subscribers. The closest papers to ours are Carter and Wright (1999) and Wright (2002). They consider two networks that compete for customers and set access fees that a third network must pay them for access. They show that when the competing networks set unilateral access fees and use two-part retail tariffs, they both wish to raise their access fees and use the resulting revenue as a way to subsidize their fixed retail charges in an attempt to attract more subscribers and boost their respective market share. This will lead to escalation of the unilateral access fees. This escalation can be mitigated or even completely eliminated if the two networks must agree on a common access fee. These papers, however, do not consider the possibility of competitive transit, which is the main focus of our paper. Finally, Gilo (2003) discusses the legal and regulatory implications of relying on transit as a market force that could restrain access charges.

The paper is organized as follows. Section 2 presents the basic framework. Section 3 derives the interconnection fees that the IXC would offer and characterizes the reciprocal access fee that the two LECs would choose in anticipation of the IXC's offer. Access price discrimination is examined in Section 4 and the case in which the LECs offer interconnection fees to the IXC is examined in Section 5. Concluding remarks appear in Section 6.

## 2. The model

Consider two interconnected networks facing a third network that seeks access to their customer base. For the sake of concreteness, we refer to the two interconnected networks as LECs and to the third network as an IXC although our analysis may also apply to other cases. For instance, the third network could be an ISP or an internet backbone seeking access to the LECs' or to cable carriers' customer base, or an electricity generator or retailer seeking access to the transmission grids of interconnected electric utilities.

In order to focus on the interaction between the two LECs and the IXC, we abstract from competition in the local exchange market and consider the following three-stage game: In the first stage, the two LECs negotiate a reciprocal per-call access fee $a$ for transited traffic that flows between their networks. [6] The access fee $a$ is paid by the sending network to the receiving network. In the second stage, the IXC offers the two LECs contracts, $(p_1, \widehat{p}_1)$ and $(p_2, \widehat{p}_2)$, where $p_1$ and $p_2$ are the per-call interconnection fees that the IXC will pay the two LECs for inbound and outbound long-distance calls if both LECs interconnect with the IXC, and $\widehat{p}_i$ is the per-call interconnection fee for inbound and outbound calls that the IXC will pay LEC $i = 1, 2$ if only LEC $i$ interconnects with the IXC. In the third and last stage of the game, the two LECs simultaneously decide whether to accept or reject the IXC's offer. If LEC $j$ rejects the IXC's offer while LEC $i$ accepts it, long-distance calls to and from LEC $j$'s customers will be transited via LEC $i$'s network. [7] If both LECs reject the IXC's offers, the customers of the two LECs cannot receive or make long-distance calls (in equilibrium of course this is never the case).

Let $Q_1$ and $Q_2$ be the volumes of inbound long-distance calls that customers of LECs 1 and 2 receive and $mQ_1$ and $mQ_2$ the corresponding volumes of outbound long-distance calls. That is, we assume that there is a constant ratio, $m \geqslant 0$, between outbound and inbound long-distance calls and that this ratio is the same for both LECs. Although in general $m$ is strictly positive, there are important cases in which $m = 0$ (i.e., no outbound traffic). Examples for such "one-way-access" situations include ISPs seeking access to LECs' or cable carriers customers base and electricity generators or retailers seeking access to electric utilities' transmission grids. To simplify matters, we assume that $Q_1$ and $Q_2$ are independent of the interconnection fees that the IXC pays the two LECs. Admittedly, this assumption is restrictive and should be relaxed in future research. However, at least in the case of the US, this assumption can be partly justified on the grounds that IXCs are required by the FCC to average their costs across all of their subscribers regardless of the LEC they

[6] In Michigan Bell Telephone Company v. Chappelle, 222 F. Supp. 2d 905, 917–918 (2002), the federal district court held that federal law does not deal with the issue of access that a LEC provides for transited calls and that this issue is left to the state law governing the operations of the LEC. Hence, the access fee $a$ need not be equal to the access fee that the LECs set for local calls made between their respective customers.

[7] For call termination, the IXC can simply route the calls to LEC $j$ via LEC $i$'s network. In the case of call origination, the IXC can ask its LEC $j$'s customers to dial up a special access code that routes their outbound calls via LEC $i$'s network.

subscribe to. [8] Consequently, the interconnection fees of one LEC, especially if it is relatively small, will have only a small impact on the retail long-distance tariffs and hence on the volume of long-distance traffic. Without a loss of generality, we will assume that $Q_1 \geqslant Q_2$: the volume of long-distance calls is greater in LEC 1 than in LEC 2. Accordingly, we will often refer to LEC 1 as the "big LEC" and LEC 2 as the "small LEC."

The LECs incur per-call costs $c$ for trunk transmission, $c_o$ for call origination, and $c_t$ for call termination. Hence, when a LEC is directly interconnected with the IXC, the costs of originating and terminating long-distance calls, respectively, are $c + c_o$ and $c + c_t$. When long-distance calls are transited, there is an additional trunk transmission cost $c$ since the transited calls are routed through the networks of both LECs. Hence, transit is inefficient. Yet, as we shall see, transit may arise if the access fee, $a$, that the LECs negotiate for transited traffic that flows between their networks is relatively high.

We now turn to the LECs' profits. The profit of LEC $i$ when both LECs are interconnected with the IXC is

$$\pi_i(Y, Y) = Q_i(p_i - c - c_t) + mQ_i(p_i - c - c_o). \tag{1}$$

The first term represents LEC $i$'s profit on inbound long-distance calls while the second term represents its profit on outbound calls. In both cases, LEC $i$ collects from the IXC per-call interconnection fee, $p_i$, and bears the associated costs.

If LEC $i$ interconnects with the IXC while LEC $j$ does not, then LEC $i$'s profit is

$$\pi_i(Y,N) = Q_i(\widehat{p}_i - c - c_t) + mQ_i(\widehat{p}_i - c - c_o) + Q_j(\widehat{p}_i - a - c) + mQ_j(\widehat{p}_i + a - c). \tag{2}$$

In the opposite case where only LEC $j$ interconnects with the IXC, LEC $i$'s profit is

$$\pi_i(N, Y) = Q_i(a - c - c_t) - mQ_i(a + c + c_o). \tag{3}$$

The first two terms in $\pi_i(Y, N)$ represent LEC $i$'s profit on long-distance calls that terminate and originate at its own network, while the last two terms represent LEC $i$'s profit on calls that are transited to and from LEC $j$'s network. LEC $i$ then pays LEC $j$ a per-call access fee $a$ on inbound calls that terminate at LEC $j$'s network but receives from LEC $j$ a per-call access fee $a$ on outbound calls that originate at LEC $j$'s network. $\pi_i(N, Y)$ has a corresponding interpretation.

## 3. Equilibrium

To characterize the (subgame perfect) equilibrium of the three-stage game described in the previous section, we first solve the third stage of the game in which the two LECs

[8] See In re Policy and Rules Concerning the Interstate, Interexchange Marketplace Implementation of Section 254(g) of the Communications Act of 1934, as amended, CC Docket No. 96-61, FCC Rcd., vol. 11, p. 9564 (Report and Order) (1996).

simultaneously decide whether or not to accept the IXC's offer. We then turn to the second stage of the game in which the IXC makes offers to the two LECs in anticipation of their responses in the third stage. Finally we consider the first stage of the game in which the two LECs determine their reciprocal access fee, $a$, for transited traffic.

### 3.1. The interconnection fees

Given the IXC's offers, $(p_1, \widehat{p}_1)$ and $(p_2, \widehat{p}_2)$, the payoff matrix in the third stage of the game is given by

| | | LEC 2 Accept | LEC 2 Reject |
|---|---|---|---|
| LEC 1 | Accept | $\pi_1(Y,Y)$, $\pi_2(Y,Y)$ | $\pi_1(Y,N)$, $\pi_2(N,Y)$ |
| | Reject | $\pi_1(N,Y)$, $\pi_2(Y,N)$ | 0, 0 |

If the IXC wishes to interconnect with both LECs, it must induce a unique Nash equilibrium at (Accept, Accept). To this end, the IXC's offers $(p_1, \widehat{p}_1)$ and $(p_2, \widehat{p}_2)$ must satisfy the conditions (i) $\pi_1(Y,Y) \geqslant \pi_1(N,Y)$, (ii) $\pi_2(Y,Y) \geqslant \pi_2(N,Y)$, and either (iii) $\pi_1(Y,N) > 0$, or (iv) $\pi_2(Y,N) > 0$ (we assume that when indifferent, LECs accept the IXC's offer). Conditions (i) and (ii) ensure that (Accept, Accept) is a Nash equilibrium, while conditions (iii) and (iv) ensure that (Reject, Reject) is not a Nash equilibrium. Conditions (i) and (ii) require that

$$p_i \geqslant \left(\frac{1-m}{1+m}\right)a, \quad i = 1, 2, \tag{4}$$

while conditions (iii) and (iv) require that $\widehat{p}_1$ and $\widehat{p}_2$ are sufficiently large.

On the other hand, if the IXC wishes to interconnect exclusively with LEC 1, then it must induce a unique Nash equilibrium at (Accept, Reject). Therefore, $(p_1, \widehat{p}_1)$ and $(p_2, \widehat{p}_2)$ must be such that (i) $\pi_2(Y,Y) < \pi_2(N,Y)$, (ii) $\pi_1(Y,N) \geqslant 0$, and either (iii) $\pi_1(Y,Y) \geqslant \pi_1(N,Y)$, or (iv) $\pi_2(Y,N) < 0$. Conditions (i) and (ii) ensure that (Accept, Reject) is a Nash equilibrium, while either conditions (iii) or (iv) ensures that (Reject, Accept) is not a Nash equilibrium. Condition (i) and (iii) are equivalent to $p_2 < \left(\frac{1-m}{1+m}\right)a < p_1$, condition (iv) requires that $\widehat{p}_2$ would be sufficiently small (say 0), and condition (ii) is equivalent to

$$\widehat{p}_1 \geqslant \widehat{p}_1^* \equiv c + \gamma K + (1-\gamma)\left(\frac{1-m}{1+m}\right)a, \tag{5}$$

where $K \equiv \frac{c_t + mc_o}{1+m}$ is a weighted average of the cost of call origination, $c_o$ and call termination, $c_t$, and $\gamma \equiv \frac{Q_1}{Q_1+Q_2}$ is the share of long-distance calls that originate and terminate at LEC 1's network. The fee $\widehat{p}_1^*$ is equal to the average cost of LEC 1 when it interconnects exclusively with the IXC. These average costs consist of the transmission cost, $c$, plus a weighted average of $K$ (the cost of originating and terminating calls) and $a$ (the cost of access), with the weights being equal to the proportion of calls that terminate in LEC 1's own network and the proportion of calls that are transited to LEC 2's network.

Analogously, to interconnect exclusively with LEC 2, the IXC's offer must be such that $p_1 < \left(\frac{1-m}{1+m}\right)a < p_2$, $\widehat{p}_1$ should be sufficiently small (say 0), and $\widehat{p}_2$ should be such that

$$\widehat{p}_2 \geqslant \widehat{p}_2^* \equiv c + (1-\gamma)K + \gamma\left(\frac{1-m}{1+m}\right)a, \tag{6}$$

where $\widehat{p}_2^*$ is the average cost of LEC 2 when it interconnects exclusively with the IXC.

Using (4)–(6) we establish the following result:

**Proposition 1.** (*The interconnection fees*) *The IXC will interconnect with both LECs and will pay them a per-call fee* $\left(\frac{1-m}{1+m}\right)a$ *if*

$$\left(\frac{1-m}{1+m}\right)a \leqslant K + \frac{c}{\gamma}.$$

*Otherwise, the IXC will interconnect exclusively with LEC* 1 *and will pay it a per-call fee* $\widehat{p}_1^* < \left(\frac{1-m}{1+m}\right)a$.

**Proof.** Since the IXC wishes to minimizes its per-call access charges, it will offer $\left(\frac{1-m}{1+m}\right)a$ if it wishes to interconnect with both LECs and $\widehat{p}_i^*$ if it wishes to interconnect exclusively with LEC $i$. Using (5) and (6),

$$\widehat{p}_1^* - \widehat{p}_2^* = (2\gamma - 1)\left[K - \left(\frac{1-m}{1+m}\right)a\right].$$

Since $Q_1 \geqslant Q_2$, $\gamma \equiv \frac{Q_1}{Q_1+Q_2} \geqslant \frac{1}{2}$. Hence, $\widehat{p}_1^* \geqslant \widehat{p}_2^*$ if $K \geqslant \left(\frac{1-m}{1+m}\right)a$ and $\widehat{p}_1^* < \widehat{p}_2^*$ otherwise. There are now two possibilities:

(i) If $K \geqslant \left(\frac{1-m}{1+m}\right)a$, then the IXC will either interconnect with both LECs or will interconnect exclusively with LEC 2. But since $K \geqslant \left(\frac{1-m}{1+m}\right)a$,

$$\widehat{p}_2^* - \left(\frac{1-m}{1+m}\right)a = c + (1-\gamma)\left[K - \left(\frac{1-m}{1+m}\right)a\right] \geqslant 0,$$

so the IXC will interconnect with both LECs and will pay them $\left(\frac{1-m}{1+m}\right)a$.

(ii) If $K < \left(\frac{1-m}{1+m}\right)a$, then the IXC will either interconnect with both LECs or will interconnect exclusively with LEC 1. Noting that

$$\widehat{p}_1^* - \left(\frac{1-m}{1+m}\right)a = c + \gamma\left[K - \left(\frac{1-m}{1+m}\right)a\right],$$

the IXC will either interconnect with both LECs and will pay them $\left(\frac{1-m}{1+m}\right)a$ if $\left(\frac{1-m}{1+m}\right)a \leqslant K + \frac{c}{\gamma}$ but will interconnect exclusively with LEC 1 and will pay it $\widehat{p}_1^*$ if $\left(\frac{1-m}{1+m}\right)a > K + \frac{c}{\gamma}$. □

The intuition behind Proposition 1 is as follows. To interconnect with both LECs, the IXC needs to offer the two LECs an interconnection fee $\left(\frac{1-m}{1+m}\right)a$ since this is the net per-call access revenue that each LEC can receive by rejecting the IXC's offer and transiting all inbound and outbound long-distance calls via the rival LEC's network. [9] On the other hand, if the IXC wishes to interconnect exclusively with LEC $i$, then rejecting the IXC's offer means that neither LEC will be interconnected with the IXC. Hence, to induce LEC $i$ to agree to an exclusive interconnection, the IXC must offer LEC $i$ an interconnection fee $\widehat{p}_i^*$ equal to LEC $i$'s average cost and ensures that the LEC just breaks even on long-distance calls. When $\left(\frac{1-m}{1+m}\right)a$ is small (or even negative), it is cheaper to interconnect with both LECs than interconnect exclusively with one of them. But since $\widehat{p}_1^*$ and $\widehat{p}_2^*$ increase with $\left(\frac{1-m}{1+m}\right)a$ at a rate of less than 1, it is clear that as $\left(\frac{1-m}{1+m}\right)a$ increases, there eventually exists a critical value of $\left(\frac{1-m}{1+m}\right)a$ above which an exclusive interconnection with one LEC is cheaper than interconnection with both LECs. Noting that since $\gamma \geqslant \frac{1}{2}$, $\left(\frac{1-m}{1+m}\right)a$ receives a smaller weight in $\widehat{p}_1^*$ than in $\widehat{p}_2^*$ (the volume of transit calls is smaller when the large LEC has to transit long-distance calls to the small LEC than vice versa), it follows that when $\left(\frac{1-m}{1+m}\right)a$ is relatively large, it is cheaper for the IXC to interconnect exclusively with LEC 1.

Proposition 1 has at least two important implications. First, transit is inefficient since each transited call is transmitted through the networks of both LECs and hence involves an additional trunk transmission cost of $c$. Hence,

**Corollary 1.** (*Efficiency*) *The equilibrium is ex post efficient only when* $\left(\frac{1-m}{1+m}\right)a \leqslant K + \frac{c}{\gamma}$. *Otherwise, long-distance calls to and from LEC* 2*'s customers are inefficiently transited via LEC* 1*'s network.*

Second, as mentioned in Section 1, the FCC has recently proposed a new "bill and keep" regime according to which all LECs' interconnection charges will be regulated to 0 unless the interconnecting networks agree otherwise. Proposition 1 shows that whenever $m = 1$ (the volumes of inbound and outbound long-distance calls are equal), competitive transit induces the LEC to interconnect with the IXC at no charge without any need for regulatory intervention. Intuitively, if LEC $i$ refuses to interconnect with the IXC, then its long-distance calls are transited via LEC $j$'s network. But since $m = 1$, the resulting access revenue (on inbound calls if $a > 0$ and

[9] Note that $\left(\frac{1-m}{1+m}\right)a$ could be negative in which case the LECs pay the IXC for interconnection rather than vice versa. $\left(\frac{1-m}{1+m}\right)a$ will be negative if either $m > 1$ (more outbound than inbound long-distance calls) and $a > 0$, or when $m < 1$ (more inbound than outbound long-distance calls) and $a < 0$.

outbound calls if $a < 0$) is just equal to the access expenditure (on outbound calls if $a > 0$ and inbound calls if $a < 0$). That is, LEC $i$ just breaks even on long-distance calls if it does not interconnect with the IXC. Consequently, the IXC can induce both LECs to interconnect with it at 0 interconnection fee.

By contrast, when the volumes of inbound and outbound long-distance calls are unequal (i.e., $m \neq 1$), Proposition 1 shows that in general, the IXC will have to pay the LECs interconnection fees that are different than 0. However, if the reciprocal access fee, $a$, is regulated to 0, then the two LECs would be willing to interconnect with the IXC at no charge. Again, the intuition for this is that by refusing to interconnect with the IXC, the net income of each LEC from long-distance calls (that are now transited through the network of the rival LEC) is 0. Once again, it is possible to replicate the outcome of a "bill and keep" regime for LEC–IXC interconnection without having to directly regulate the interconnection fees that the LECs charge the IXC.

**Corollary 2.** (*Replicating a "bill and keep" regime with competitive transit*) *The IXC will interconnect with both LECs at* 0 *fees if either the volumes of inbound and outbound long-distance calls are equal* (*i.e.*, $m = 1$) *or if the reciprocal access fee that the LECs charge one another*, $a$, *is equal to* 0.

In practice, direct regulation of LEC–IXC interconnection should address not only the interconnection fees that IXCs pay the LECs, but also an array of additional factors, such as the quality of interconnection, technical standards, and repair services (see Gilo, 2003 for details). Corollary 2 suggests that in order to achieve a "bill and keep outcome" there is no need to regulate LEC–IXC interconnection: instead, it is enough to add an additional provision to the regulation of LEC–LEC interconnections (which is regulated anyway for various reasons) stating that LECs should transit long-distance calls to one another at no charge. [10] Clearly then, competitive transit can lower the regulatory burden needed to enforce "bill and keep" outcomes.

### *3.2. The choice of the reciprocal access fee*

In this subsection we turn to the first stage of the game in which the two LECs negotiate their reciprocal access fee, $a$. Our main purpose is to examine the preferences of the two LECs over $a$ – we will not postulate a particular bargaining game and attempt to solve for a specific value of $a$. Using Eq. (1) and Proposition 1, the profits of the two LECs, as functions of $a$, are

[10] In fact, the rates that incumbent LECs charge new LECs for transited calls are typically regulated anyway. See, e.g., US West Communications v. TCG Seattle,1998 US Dist. Lexis 22271, at p. 9, 10; In re Petition of WorldCom, Inc. Pursuant to Section 252(e)(5) of the Communications Act for Preemption of the Jurisdiction of the Virginia State Corporation Commission Regarding Interconnection Disputes with Verizon Virginia Inc., CC Docket No. 00-218, 2003 FCC LEXIS 6879, at p. 76; Texcom, Inc. v. Bell Atlantic Corp., FCC Record, vol. 17 p. 6275 (2002); and Michigan Bell Telephone Company v. Chapelle, 222 F. Supp. 2d 905 (2002).

$$\pi_1(a) = \begin{cases} \pi_1(N, Y), & \text{if} \left(\frac{1-m}{1+m}\right) a \leqslant K + \frac{c}{\gamma}, \\ 0, & \text{otherwise}, \end{cases} \tag{7}$$

and

$$\pi_2(a) = \pi_2(N, Y). \tag{8}$$

With Eqs. (7) and (8) in place, we are ready to examine the preferences of the two LECs for the reciprocal access fee, $a$.

**Proposition 2.** (*The LECs' preferences for the reciprocal access fee*)

- *If* $m = 1$, *the two LECs are indifferent to the value of the reciprocal access fee*, $a$.
- *If* $m \neq 1$, *the big LEC, LEC 1 will prefer to set a such that*

$$a = \left(\frac{1+m}{1-m}\right)\left(K + \frac{c}{\gamma}\right),$$

*which in turn induces the IXC to interconnect with both LECs at* $K + c/\gamma$. *By contrast, the small LEC, LEC 2, will prefer to set a as negative as possible if* $m > 1$ *and as large as possible if* $m < 1$.

- *The equilibrium is efficient only if* $|a| \leqslant \left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$.

When the IXC interconnects with both LECs, it offers them a per-call interconnection fee $\left(\frac{1-m}{1+m}\right)a$ to ensure that the profit of each LEC $i$ is just equal to $\pi_i(N, Y)$ which is LEC $i$'s profit from rejecting the IXC's offer and transiting all inbound and outbound long-distance calls via LEC $j$'s network. As (3) shows, $\pi_i(N, Y)$ is independent of $a$ when $m = 1$, implying that in this case the LECs are indifferent to the value of $a$. When $m > 1$ ($m < 1$), $\pi_i(N, Y)$ is decreasing (increasing) with $a$ since the LEC's total expenditure on outbound calls is larger (smaller) than its total revenue from inbound calls. Hence, the two LECs wish to set a negative (positive) $a$ to boost their profits from long-distance traffic. But, as $|a| > \left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$, the IXC offers interconnection fees such that LEC 2 refuses to interconnect with the IXC. In this case, if LEC 1 rejects the IXC's offer as well, no LEC will interconnect with the IXC and LEC 1's profit will be 0. The IXC can therefore offer LEC 1 a fee $\widehat{p}_1^*$ that leaves LEC 1 with a 0 profit. Obviously then, LEC 1 does not want $|a|$ to exceed $\left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$. On the other hand, LEC 2 prefers to raise $|a|$ as much as possible. [11] Interestingly, Carter and Wright (2003) also find that a large network will prefer a low reciprocal access fee while the smaller network may prefer a high reciprocal

[11] Of course, if the demand for long-distance calls is price elastic, then an increase in $|a|$ (that raises the interconnection fees that the IXC pays the two LECs), will lead to higher retail prices for long-distance calls and hence will depress the demand for long-distance calls. Hence, even LEC 2 will wish to raise $|a|$ only up to a certain point.

access fee. Their model however only considers traffic between the two networks: there are no calls to and from a third network as in our model.

Proposition 2 has several interesting implications. First, at LEC 1's ideal $a$, the IXC interconnects with both LECs and pays them an interconnection fee of $K + \frac{c}{\gamma}$ per-call. This fee decreases with $\gamma$ which is the share of long-distance traffic that originates and terminates at the big LEC, LEC 1. To the extent that a low ideal $a$ for LEC 1 will translate to a low $a$, we can draw the following conclusion:

**Corollary 3.** (*The effect of the shares of the two LECs in the long-distance traffic*) *The IXC is better-off as the gap between the sizes of the two LECs grows.*

Second, up to now we have implicitly assumed that transit is mandatory. A natural question to ask is what happens if the two LECs can refuse to transit calls to one another? To address this question, note that absent transit, the IXC needs to interconnect with both LECs so the profit of each LEC $i$ is given by $\pi_i(Y, Y)$ (see Eq. (1)). To induce LEC $i$ to interconnect, the IXC needs to offer LEC $i$ an interconnection fee such that $\pi_i(Y, Y) \geqslant 0$. The lowest fee that ensures LEC $i$ a nonnegative profit is $K + c$. With transit, the LECs lose money on long-distance calls if $m = 1$ since by Proposition 1, the IXC interconnects with both LECs at no charge. Hence, the two LECs are better-off committing not to transit long-distance calls to one another. In contrast, if $m \neq 1$, then the two LECs make a positive profit on long-distance calls if they agree to transit calls and set $|a| = \left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$. This reciprocal access fee induces the IXC to offer both LECs an interconnection fee of $K + \frac{c}{\gamma}$ which, given that $\gamma < 1$, exceeds the interconnection fee absent transit, $K + c$. Consequently, both LECs can benefit from transit.

Moreover, unless $m = 1$, the small LEC, LEC 2, would like to raise $|a|$ as much as possible, whereas the big LEC, LEC 1, would like to raise $|a|$ only up to $\left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$. But, if transit is not mandatory (each LEC can refuse to transit calls to the rival LEC), then LEC 1 can threaten LEC 2 that if $|a| > \left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$, LEC 1 will refuse to transit long-distance calls to LEC 2. This threat is credible since whenever $|a| > \left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$, the IXC offers LEC 1 an interconnection fee $\widehat{p}_1^*$ such that LEC 1 just breaks even on long-distance calls and hence gains nothing from transiting calls to LEC 2. In contrast, if transit is mandatory, then (at least in principle) LEC 2 might be able to force LEC 1 to agree to set $|a|$ above $\left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$. Hence,

**Corollary 4.** (*Voluntary transit*)

- *If $m = 1$ then the LECs are better-off committing not to transit long-distance calls to one another.*
- *If $m \neq 1$, then both LECs can benefit from agreeing to transit long-distance calls to one another. Moreover, allowing LEC 1 to refuse to transit long-distance calls to and from LEC 2 enables LEC 1 to force LEC 2 to agree to set the access fee, $a$, equal to $\left(\frac{1+m}{1-m}\right)\left(K + \frac{c}{\gamma}\right)$ which is LEC 1's ideal access fee when $m \neq 1$.*

To the extent that it is socially desirable to keep $|a|$ (and thereby the interconnection fees) low, Corollary 4 suggests that it may be a poor idea to force the LECs to transit long-distance calls to each other: under mandatory transit, the reciprocal access fee may be set such that $|a| > \left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$, in which case the IXC will inefficiently interconnect exclusively with LEC 1. By contrast, when LEC 1 can refuse to transit long-distance calls to LEC 2, $|a| \leqslant \left|\frac{1+m}{1-m}\right|\left(K + \frac{c}{\gamma}\right)$ and the IXC interconnects with both LECs.

## 4. Access price discrimination

In this section we consider the case in which the IXC can offer the LECs interconnection fees that depend on whether calls originate or terminate at a LEC's network or are transited to and from the rival LEC. That is, we consider the case where the IXC can price discriminate between calls depending on their destination. Specifically, let $p_{11}$ and $p_{22}$ be the interconnection fees that the IXC offers the two LECs for calls that originate or terminate at their own networks, and $p_{ij}$ be the interconnection fee that the IXC offers LEC $i$ for calls that originate or terminate at LEC $j$ and are transited via LEC $i$'s network. Let $\widehat{p}_{ii}$ and $\widehat{p}$ be the corresponding interconnection fees when only LEC $i$ accepts the IXC's offer.

**Proposition 3.** (*Price discrimination*) *Suppose that the IXC can price discriminate between long-distance calls that terminate in a LEC's network and calls that are transited to the rival LEC. Then, the two LECs will set a reciprocal access fee* $a = \left(\frac{1+m}{1-m}\right)(K + c)$ *and the IXC will interconnect with both LECs and will pay each LEC an interconnection fee* $K + c$ *per-call.*

**Proof.** We begin by considering the IXC's offer to the two LECs given the reciprocal access fee $a$ that the two LECs have negotiated in stage 1. If $\left(\frac{1-m}{1+m}\right)a < K + c$, the IXC offers $p_{11} = p_{22} = \left(\frac{1-m}{1+m}\right)a$, $\widehat{p}_{11} = \widehat{p}_{22} = K + c$, and $\widehat{p}_{12} = \widehat{p}_{21} = \left(\frac{1-m}{1+m}\right)a + c$. If both LECs accept the offer, then the profit of LEC $i$ is $Q_i(p_{ii} - c - c_t) + mQ_i(p_{ii} - c - c_o)$. If LEC $i$ rejects the offer, then LEC $j$ will surely accept it since with $\widehat{p}_{jj} = K + c$ and $\widehat{p}_{ji} = \left(\frac{1-m}{1+m}\right)a + c$, LEC $j$'s profit is

$$Q_j(K - c_t) + mQ_j(K - c_o) + Q_i\left(\left(\frac{1-m}{1+m}\right)a - a\right) + mQ_i\left(\left(\frac{1-m}{1+m}\right)a + a\right) = 0,$$

exactly as in the case where LEC $j$ rejects the IXC's offer as well (in which case no LEC is interconnected with the IXC); we assume that when indifferent, a LEC accepts the IXC's offer. Since LEC $j$ accepts the IXC's offer, LEC $i$ will receive its long-distance calls via LEC $j$'s network and its profit is given by $\pi_i(N, Y)$ (see Eq. (3)). Equating $Q_i(p_{ii} - c - c_t) + mQ_i(p_{ii} - c - c_o)$ and $\pi_i(N, Y)$ reveals that $p_{ii} = \left(\frac{1-m}{1+m}\right)a$ is the minimal interconnection fee that will induce both LECs to accept the IXC's offer.

If $\left(\frac{1-m}{1+m}\right)a \geqslant K + c$, then the IXC would concede rents to the LECs if it were to make the above offers. Therefore, the IXC can modify its offer by setting $p_{11} = p_{22} = K + c$ and $\widehat{p}_{12} = \widehat{p}_{21} = \infty$. Now, if a LEC refuses to interconnect with the IXC, its profit will be 0 since with $\widehat{p}_{12} = \widehat{p}_{21} = \infty$, the IXC will never transit calls to this LEC via the rival LEC's network. With $p_{11} = p_{22} = K + c$, both LECs will accept the IXC's offer since at these interconnection fees, they both break even on long-distance calls.

Given the IXC's offer, the LECs lose money on long-distance calls if $\left(\frac{1-m}{1+m}\right)a < K + c$ and break even otherwise. Hence the two LECs will set $\left(\frac{1-m}{1+m}\right)a = K + c$ in the first stage of the game, or $a = \left(\frac{1+m}{1-m}\right)(K + c)$. In the resulting equilibrium, the IXC will interconnect with both LECs and will pay an interconnection fee $K + c$ on each call. □

Proposition 3 shows that under access price discrimination, the interconnection fees that the IXC pays the two LECs are equal to those that would obtain in the absence of transit. The idea behind this result is as follows. To induce a LEC to interconnect with the IXC at minimal fees, the IXC must offer each LEC $i$ an interconnection fee that leaves LEC $i$ as well off as in the case where it rejects the IXC's offer. If $\left(\frac{1-m}{1+m}\right)a < K + c$, LEC $i$ would lose money by refusing to interconnect with the IXC and transiting all long-distance calls via LEC $j$'s network. The minimal interconnection fee that the IXC needs to offer LEC $i$ in this case is $\left(\frac{1-m}{1+m}\right)a$, which by design, leaves LEC $i$ with a loss on each long-distance call. However when $\left(\frac{1-m}{1+m}\right)a \geqslant K + c$, transiting long-distance calls via LEC $j$'s network is not a losing proposition anymore for LEC $i$. Hence, if transit is an option, the IXC must offer each LEC $i$ an interconnection fee that leaves the LEC a positive rent. But, when the IXC can price discriminate between direct and transited long-distance calls, it can credibly commit not to send or receive such calls by raising the interconnection fee on transited calls to a prohibitive level. [12] As a result, a LEC can offer its customers access to long-distance calls only if it interconnects directly with the IXC: transit is not a viable option anymore. Since the IXC can make take-it-or-leave-it offers to the two LECs, it can offer them interconnection fees that just cover their costs but leave them no rent. A similar strategy is impossible in the no discrimination case since the IXC must set the same interconnection fee for direct and transited long-distance calls and therefore has no way of credibly committing to block transited calls. The two LECs can therefore take advantage of that and set up a high $|a|$ that forces the IXC to offer them higher interconnection fees.

By revealed preferences, it is not surprising that the ability to price discriminate between direct and transited calls benefits the IXC. Proposition 3 shows however

[12] Alternatively, if a LEC can unilaterally refuse to transit calls, then the IXC can offer a price of 0 on such calls in which case, it will not pay a LEC to transit calls to and from a rival LEC and the same outcome will emerge.

that access price discrimination may also be welfare enhancing by leading to lower interconnection fees and by ensuring that the IXC will eventually interconnect with both LECs. The reason why price discrimination leads to a lower reciprocal access fee, $a$, is that if the LECs would try to set a high $|a|$ as in the no discrimination case, the IXC would set a prohibitively high fee on transit calls and would thereby commit not to send or receive such calls. This lowers the disagreement payoffs of the two LECs and would force them to accept lower interconnection fees.

## 5. The LECs make offers

Thus far, we have assumed that the IXC has all the bargaining power vis-a-vis the two LECs and can make them take-it-or-leave-it offers. In this section we examine the opposite polar case in which the LECs have all the bargaining power vis-a-vis the IXC.

Let $(r_1, \widehat{r}_1)$ and $(r_2, \widehat{r}_2)$ be the contracts that the two LECs offer the IXC, where $r_i$ is the per-call interconnection fee that LEC $i$ demands in case each LEC receives its long-distance calls directly from the IXC, and $\widehat{r}_i$ is the per-call interconnection fee if the IXC interconnects exclusively with LEC $i$. We assume that the LECs do not price discriminate between direct and transited calls. [13] The IXC can either accept or reject each offer. If it accepts both offers, its total expenditure on interconnection fees is $(1+m)(Q_1 r_1 + Q_2 r_2)$, while if it interconnects only with LEC $i$, its total expenditure is $(1+m)(Q_1+Q_2)\widehat{r}_i$. Recalling that $\gamma \equiv \frac{Q_1}{Q_1+Q_2}$, it follows that the IXC will interconnect with both LECs if and only if

$$\gamma r_1 + (1-\gamma) r_2 \leqslant \min\{\widehat{r}_1, \widehat{r}_2\}. \tag{12}$$

If (12) fails, the IXC will interconnect exclusively with the LEC that demands the minimum between $\widehat{r}_1$ and $\widehat{r}_2$. If $\widehat{r}_1 = \widehat{r}_2$, the IXC will pick one of the two LECs at random and will interconnect exclusively with that LEC. Consequently, LEC $i$'s expected profit is

$$\pi_i = \begin{cases} Q_i(r_i - c - c_t) + mQ_i(r_i - c - c_o), & \text{if (12) holds,} \\ Q_i(\widehat{r}_i - c - c_t) + mQ_i(\widehat{r}_i - c - c_o) \\ \quad + Q_j(\widehat{r}_i - a - c) + mQ_j(\widehat{r}_i + a - c), & \text{if (12) fails and } \widehat{r}_i < \widehat{r}_j, \\ (Q_i(\widehat{r}_i - c - c_t) + mQ_i(\widehat{r}_i - c - c_o) \\ \quad + Q_j(\widehat{r}_i - a - c) + mQ_j(\widehat{r}_i + a - c))/2, & \text{if (12) fails and } \widehat{r}_j = \widehat{r}_i, \\ Q_i(a - c - c_t) - mQ_i(a + c + c_o), & \text{if (12) fails and } \widehat{r}_i > \widehat{r}_j. \end{cases} \tag{13}$$

[13] In a previous version of this paper we showed that when the LECs have all the bargaining power vis-a-vis the IXC, the LECs' ability to price discriminate between direct and transited long-distance calls is immaterial in the sense that the results do not change in the presence of price discrimination.

Using (13) we now characterize the equilibrium offers of the two LECs and the IXC's response.

**Proposition 4.** (*The interconnection fees when the LECs make offers to the IXC*) *Suppose that the LECs can simultaneously make offers to the IXC. Then the equilibrium offers,* $(r_1^*, \widehat{r}_1^*)$ *and* $(r_2^*, \widehat{r}_2^*)$ *will be such that* $\left(\frac{1-m}{1+m}\right)a \leqslant r_1^* \leqslant \left(\frac{1-m}{1+m}\right)a + c$, $\left(\frac{1-m}{1+m}\right)a \leqslant r_2^* \leqslant \left(\frac{1-m}{1+m}\right)a + c$, *and* $\widehat{r}_1^* = \widehat{r}_2^* = \gamma r_1^* + (1-\gamma)r_2^*$. *The IXC will accept both offers and will transfer long-distance calls directly to each LEC. The resulting equilibrium will therefore be efficient.*

**Proof.** First note that in equilibrium, (12) must hold with equality, otherwise each LEC $i$ can make more money by raising $r_i$ slightly. Second, note that (12) cannot fail: if it does and $\widehat{r}_i < \widehat{r}_j$, then LEC $i$ can make more money by raising $\widehat{r}_i$ slightly. If (12) fails and $\widehat{r}_1 = \widehat{r}_2$, then LEC $i$'s expected profit is given by the expression in the third line of (13). If this expression falls short of the expression in the fourth line of (13), it pays LEC $i$ to raise $\widehat{r}_i$. If the expression in the third line of (13) is at least as large as that in the fourth line of (13), then it pays LEC $i$ to lower $\widehat{r}_i$ slightly. Hence, in equilibrium, (12) must hold with equality and LEC $i$'s profit is given by the expression in the top line in (13).

Since (12) holds with equality, we will restrict attention to cases in which $\widehat{r}_1^* = \widehat{r}_2^* = \widehat{r}^*$, where (12) implies that $\widehat{r}^* = \gamma r_1^* + (1-\gamma)r_2^*$. We do so because given $r_1$ and $r_2$, there exists a continuum of equilibria that differ only with respect to the value of $\max\{\widehat{r}_1, \widehat{r}_2\}$. But since all of these equilibria are payoff equivalent, it is natural to focus on symmetric cases in which $\widehat{r}_1 = \widehat{r}_2 = \widehat{r}$. Now, note that raising $r_i$ and $\widehat{r}_i$ will violate (12); since $\widehat{r}_i$ will exceed $\widehat{r}^*$, the IXC will interconnect exclusively with LEC $j$ so LEC $i$'s profit will become $Q_i(a-c-c_t) - mQ_i(a+c+c_o)$. To ensure that this deviation is unprofitable, it must be that in equilibrium,

$$Q_i(r_i^* - c - c_t) + mQ_i(r_i^* - c - c_o) \geqslant Q_i(a-c-c_t) - mQ_i(a+c+c_o), \quad i = 1, 2,$$

or equivalently, $r_1^* \geqslant \left(\frac{1-m}{1+m}\right)a$ and $r_2^* \geqslant \left(\frac{1-m}{1+m}\right)a$. Likewise, lowering $\widehat{r}_i$ slightly will violate (12) and induce the IXC to interconnect exclusively with LEC $i$, in which case its profit will be almost $Q_i(\widehat{r}^* - c - c_t) + Q_j(\widehat{r}^* - a - c)$. To ensure that this deviation is unprofitable, it must be that in equilibrium

$$\begin{aligned} &Q_i\left(r_i^* - c - c_t\right) + mQ_i\left(r_i^* - c - c_o\right) \\ &\geqslant Q_i(\widehat{r}^* - c - c_t) + mQ_i(\widehat{r}^* - c - c_o) + Q_j(\widehat{r}^* - a - c) + mQ_j(\widehat{r}^* + a - c) \\ &= Q_i\left(r_i^* - c - c_t\right) + mQ_i\left(r_i^* - c - c_o\right) + Q_j\left(r_j^* - a - c\right) + mQ_j\left(r_j^* + a - c\right), \end{aligned} \tag{14}$$

where the last equality follows because (12) holds with equality. Inequality (14) requires that $r_j^* \leqslant \left(\frac{1-m}{1+m}\right)a + c$, $j = 1, 2$.

We complete the proof by showing that any triplet $(r_1^*, r_2^*, \widehat{r}^*)$ such that $\left(\frac{1-m}{1+m}\right)a \leqslant r_1^* \leqslant \left(\frac{1-m}{1+m}\right)a + c$, $\left(\frac{1-m}{1+m}\right)a \leqslant r_2^* \leqslant \left(\frac{1-m}{1+m}\right)a + c$, and $\widehat{r}^* = \gamma r_1^* + (1-\gamma)r_2^*$ can be an equilibrium. In equilibrium, LEC $i$'s profit is given by the top line of (14). Fixing LEC $j$'s offer, let's consider possible deviations for LEC $i$. Raising both $r_i$ and $\widehat{r}_i$ will induce the IXC to interconnect exclusively with LEC $j$, so LEC $i$'s profit will be given by the fourth line in (13); since $r_i^* \geqslant \left(\frac{1-m}{1+m}\right)a$, such a deviation does not increase LEC $i$'s profit. Raising $r_i$ while lowering $\widehat{r}_i$ below $\widehat{r}^*$ will induce the IXC to interconnect exclusively with LEC $i$. The resulting profit of LEC $i$ will be less than the expression in the middle line of (14) and hence is unprofitable. Raising $r_i$ while keeping $\widehat{r}_i = \widehat{r}^*$ will induce the LEC to pick one of the LECs at random and interconnect exclusively with that LEC. The resulting expected profit of LEC $i$ is half of the expression in the middle line of (14), and hence is unprofitable as well. Hence, it never pays LEC $i$ to change $r_i$. But if $r_i$ is constant, then raising $\widehat{r}_i$ above $\widehat{r}^*$ does not affect the equilibrium, while lowering $\widehat{r}_i$ below $\widehat{r}^*$ will induce the IXC to interconnect exclusively with LEC $i$, so LEC $i$'s profit will be given once again by the expression in the middle line of (14). □

Comparing Propositions 1 and 4 reveals that the LECs benefit when they have all the bargaining power vis-a-vis the IXC in the sense that they end up receiving higher interconnection fees from the IXC: when the IXC has all the bargaining power, the interconnection fees are at most $\left(\frac{1-m}{1+m}\right)a$, while if the two LECs have the bargaining power, the interconnection fees are at least $\left(\frac{1-m}{1+m}\right)a$. Moreover, Proposition 4 shows that when the LECs have all the bargaining power, the IXC will efficiently interconnect directly with both LECs implying that the potential ex post inefficiency identified in Corollary 1 is completely eliminated.

Proposition 4 has several interesting implications. First, the interconnection fees depend only on the reciprocal access fee, $a$, the cost of transmission, $c$, and the ratio of outbound to inbound traffic, $m$, but are independent of the shares of the two LECs in the long-distance traffic, $\gamma$ and $1-\gamma$, and the costs of call termination, $c_t$, and call origination, $c_o$. The fact that the interconnection fees are independent of the LECs' costs of originating and terminating long-distance calls is akin to the "off-net-cost pricing principle" of Laffont et al. (2003). According to this principle, internet backbones set their retail price as if their connections were entirely off-net. Here the relevant prices are not retail prices but rather interconnection fees that the IXC pays; nonetheless, these fees are set as if all traffic was transited to the rival LEC (i.e., on the basis of the off-net costs, $c + \left(\frac{1-m}{1+m}\right)a$).

Second, the equilibrium payoff of each LEC $i$ is given by the top line of (14) with $\left(\frac{1-m}{1+m}\right)a \leqslant r_i^* \leqslant \left(\frac{1-m}{1+m}\right)a + c$. Hence, as in the case where the IXC makes offers, the LECs can strategically use $a$ as a way to boost their profits at the IXC's expense. However, unlike in the case where the IXC makes offers, here there is no conflict of interest between the two LECs: both wish to raise $|a|$ as much as possible. [14]

[14] Again, if the demand for long-distance calls is price elastic, the two LECs will wish to raise $a$ only up to a certain point.

**Corollary 5.** (*The LECs' preferences over the reciprocal access fee when they make offers to the IXC*) *If the two LECs can simultaneously make offers to the IXC, then they will both prefer to raise* $|a|$ *as much as possible.*

Third, and again unlike the case where the IXC makes offers, now the two LECs mutually prefer to commit not to transit calls to and from one another. Absent transit, each LEC becomes a monopolist with respect to calls that originate and terminate at its own network and can charge the IXC appropriate interconnection fees. [15] Transit introduces competition between the two LECs and hence weakens their bargaining power vis-a-vis the IXC. By contrast, when the IXC makes offers, transit boosts the LECs bargaining power vis-a-vis the IXC since it allows them, when $m \neq 1$, to get a revenue of at least $\left(\frac{1-m}{1+m}\right)a$ on transited calls. Note, however, that so long as transit can be done on a unilateral basis (i.e., it does not require the mutual consent of both LECs), then there does not exist an equilibrium in which both LECs refuse to transit calls to one another. To see why, suppose otherwise and suppose that the monopoly price of LEC $i$ is equal to or below the monopoly price of LEC $j$. Then, LEC $i$ would offer the IXC an exclusive interconnection at a price which is slightly below the monopoly price of LEC $j$. The IXC will accept the offer (this arrangement lowers the IXC's cost of sending and receiving long-distance calls to and from LEC $j$), thus upsetting the putative equilibrium. Consequently,

**Corollary 6.** (*Voluntary transit*) *Transit makes both LECs worse off relative to the case where they can refuse to transit long-distance calls. However, absent a binding agreement that prohibits transit, the LECs will be unable to commit not to transit calls to and from one another.*

Finally, Proposition 4 implies that if the LECs are required to interconnect with each other at no charge ($a = 0$) or if the long-distance calling pattern is balanced ($m = 1$), then the equilibrium will be such that $r^* = \hat{r}^* \in [0, c]$. Consequently, both LECs will at best recover their cost of transmission, $c$, but not their costs of call termination, $c_t$, or call origination, $c_o$. This result is striking since it implies that the ability to transit calls via a competing LEC at no charge (when $m = 0$ the access charges cancel out so the situation is similar to that under $a = 0$) induces both LECs to interconnect with the IXC at below-cost rates, even though the LEC–IXC interconnection is not regulated and the LECs have all of the bargaining power vis-a-vis the IXC. [16]

[15] Carter and Wright (1999) argue that if the LECs compete with one another and use two-part tariffs, they will use their profits from long-distance access charges as a way to subsidize their respective retail fixed line charges in an attempt to increase their respective market shares and thereby boost their profits from long-distance access charges. This would lead to an escalation of the long-distance access fees (which in their model are set by the LECs) until the long-distance market will vanish.

[16] It should be stressed however that the LECs need not lose money on long-distance calls as they may be able to recover the remaining cost of call origination and termination from their own customers. Indeed, this is one of the main justifications for mandating "bill and keep" regimes.

## 6. Conclusion

While a variety of network industries around the world continue to open up to competition, with an accompanying hope for reducing regulatory intervention, the terms under which networks grant access to their customer base is still, for the most part, under strict regulation. This access regulation reflects the concern of regulators that despite competition between networks, access to their customer-base remains a bottleneck monopoly. In this paper, we explored the role that competitive transit can play in this context. We showed that there is a wide set of cases in which competitive transit could justify complete deregulation of access to a network's customer base.

Our analysis applies to the case of two-way access problems involving interconnected LECs and IXCs as well as to one-way access problems that arise when an ISP seeks access to a LEC or cable carrier's customer base, or an electricity generator or retailer seeks access to a utility's infrastructure. A closely related issue is the termination charges that cellular carriers charge other carriers (wireline or cellular) for calling their subscribers. This issue has been the subject of an ongoing public and regulatory debate in many countries. The general feeling is that, absent access price regulation, cellular carriers will set excessively high termination charges since these charges are not borne by their own subscribers, and hence are not subject to competitive pressures. Our results suggest that competitive transit could alleviate this problem as well: if the cellular carrier is interconnected with another network (wireline or cellular), the caller's network could access the cellular carrier's subscribers via this other network. Unlike in our model, however, the cellular carrier pays access fees to other networks for calls that originate in its network, whereas in our model, the LECs always receive access fees from the IXC irrespective of whether the calls have originated or were terminated in their own networks. It would therefore be interesting to examine in future research how competitive transit affects the multilateral access fees in such an environment.

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