Pareto Improving Telephone Tariffs Under Bypass Alternatives

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1. Introduction

Since the breakup of the AT&T network, local telephone companies (LTCs) have faced the problem of how to price service to recover fixed network costs. There are two serious complications which limit the application of early literature on nonuniform tariffs (Spence (1977); Roberts (1979); Mirman and Sibley (MS, 1980); and Goldman, Leland, and Sibley (GLS, 1984)) to this problem. First, customers can use alternative bypass technologies to avoid the local network; these alternatives would appeal to large users and consortia of small users. If large users are not captive, local companies can not excessively price usage to these customers. Second, although small users apparently are more captive, political pressures from consumer advocates and legislators will not permit small-user prices to be increased excessively either. Therefore, local companies must determine how to recover their fixed costs when both ends of the customer spectrum are powerfully resistant to price increases.

In a forthcoming article (Einhorn (1987)), I demonstrate that a profit-maximizing or profit-constrained, welfare-maximizing local telephone company that is faced with possible (large) customer bypass should be permitted to price some high-level customer usage below the associated marginal usage cost;

low-level usage prices still should exceed marginal cost. Under such a tariff, I showed that each customer would still make a positive net revenue contribution toward recovering the company's fixed costs; furthermore, only economic bypass would result. However, the paper placed no limits on what the local company may charge small users. We now add the additional constraint that small-user utility must not fall below a prespecified level; i.e., the level that prevailed under an earlier uniform tariff. In this way, we meet consumerist fears that policies designed to eliminate large customer bypass may cause harm at the small-usage end of the customer spectrum.

The resulting nonuniform tariff that I shall design does not maximize social welfare or utility profits but is Pareto-improving; i.e., each customer can be made better off with a nonuniform price schedule than with a uniform price schedule that prices usage above marginal cost. Willig (1978) has demonstrated this result already and argued that customer usage prices should eventually fall to (but not below) marginal cost. However, he does not derive the shape of the best Pareto-improving schedule nor does he consider the potential for large customer bypass. I shall derive the shape of the best Pareto-improving schedule; when large customer bypass is possible, any Pareto-improving schedule should still eventually price some large customer usage below marginal cost. The only bypass that will result under an ideal Pareto-improving schedule will be economic.

This article is part of the theory of regulation under assymetric information. In this case, we shall assume that customer usage intensities are distributed across a spectrum;

LTCs and regulators form a Bayesian prior (e.g., Baron and Myerson (1981)) regarding the distribution of these intensities but have no idea of the usage intensity of any one customer. Consequently, it is necessary to construct a cost-recovering tariff using only the distribution of expected usage.

This article is organized as follows. Section 2 discusses the basic problem and the notion that marginal cost can sometimes legitimately exceed usage price. In Section 3, I extend a prior analysis of Spence to derive a profit-constrained nonuniform price schedule where no customer's welfare is reduced from a prespecified level. Section 4 derives the basic results of the model; Section 5 considers some additional complexities ignored in Section 3, including large customer bypass. Section 6 concludes the paper.

2. A Simple Problem Illustrated

This section will discuss the cost-recovery problem in telecommunications and an economic solution to that problem. In particular, it will be shown that a profit-maximizing or profit-constrained welfare-maximizing utility facing bypass alternatives for large customers should price some high-level usage below marginal cost.

Bypass Illustrated

Each telephone customer can reach his long-distance carrier through any of his (many) installed circuits, which can feature any mixture of bypass and switched access technologies. Assume that the operating company has fixed costs K, constant switched access line costs Z, and constant marginal usage cost C. Each customer pays an access fee A per line and a varying marginal price P(q) per unit of line usage q; let R(q) represent the usage-sensitive revenue associated with q. Each switched access line faces the same price schedule.

Bypass circuits have higher initial costs (Z^*) but lower usage costs (C^*). Assume that bypass technologies are economically efficient choices for the most heavily-used circuits and that the bypass market is competitive with prices equal to their marginal costs.[1] Bypass circuit i's payments are $Z^* + C^* q_{i*}$; $q_{i*}(C^*)$ is usage on the bypass circuit.

In the remainder of this section, assume that customer usage is own-price inelastic. With utility (bypass) service, circuit i would impose costs of $Z + Cq_i$ ($Z^* + C^* q_i$) (see Figure 1). In Figure 1, economic efficiency would be promoted if circuits that use less (more) than q^* chose switched access (bypass). Ideally, prices A_o and P_o would equal marginal costs Z and C, respectively; circuit bypass would then occur (efficiently) at usage levels q^* and above. But marginal cost pricing would not recover LTC fixed costs. Consequently, $A + R(q_i) > Z + Cq_i$ is needed somewhere at usage levels $q_i < q^*$.

If P were constant and above C, circuit i would profitably bypass if $A + Pq_i > Z^* + C^* q_i$. Assuming that A = Z, bypass would occur if $q_i > q^@ = (Z^* - Z)/(P - C^*) < q^*$; see Figure 1. Bypass by circuits that use between $q^@$ and q^* (above q^*) is uneconomic (economic).

Optimal Pricing

With a nonuniform price schedule, a profit-maximizing or profit-constrained, welfare-maximizing LTC could retain any circuit with $q_i < q^*$. To see this, note that the customer will forego switched service only if $A + R(q_i) > Z^* + C^*q_i$. If bypass occurred, the LTC would make no profit from this circuit; social welfare would be reduced as well since $q_i < q^*$. Consequently, LTC profits and social welfare would both increase if the price schedule were altered so that $Z + Cq_i < A + R(q_i) < Z^* + C^*q_i$ for all $q_i < q^*$. The permissible region for the payment schedule lies between $Z + Cq_i$ and $Z^* + C^*q_i$ in Figure 1.

By contrast, the LTC could not and should not retain any circuit with usage above q^*. To retain the circuit, switched access must be priced at or below $Z^* + C^*q_i < Z + Cq_i$. Consequently, the LTC's costs would exceed its revenues. Furthermore, bypass costs are below the LTC's. Therefore, switched access is both inefficient and nonprofitable to the LTC.

Under a correctly implemented price schedule, bypass would result if and only if it were economic. At $q_i = q^*$, $A + R(q^*) = Z + Cq^*$. Because demand for usage is price-inelastic, efficient choice requires that $A + R(q_i) \gtrless Z^* + C^*q_i$ when $Z + Cq_i \gtrless Z^* + C^*q_i$.

Under any second-best efficient price schedule (so that first-best marginal cost pricing is excluded), $P(q) < C$ at some point $q < q^*$.[2] As the next section will confirm, this does <u>not</u> mean that any circuit will necessarily be subsidized in total; the net revenues that a circuit generates prior to reaching the subsidy range will be sufficient to cover the maximum subsidy.[3]

Pareto-Improving Pricing

We now can present a Pareto-improving tariff that can make some customers better off without harming anyone. Suppose that the initial line and usage charges are A_o and P_o. Assuming that line charges are not sufficiently high to recover fixed costs alone, $P_o > C$. If this tariff were implemented alone, uneconomic bypass would result at $q^@ = (Z - A_o)/(C - P_o)$. Presumably, net revenues recovered from usage prior to $q^@$ would be sufficient to cover fixed costs. To stop uneconomic bypass and secure additional revenues, the local company could add a second block running through q^*, as shown in Figure 1. As illustrated above, usage price in the second block P_1 must be below marginal cost C.

By retaining lines that use above $q^@$, the LTC keeps circuits that it would otherwise lose and enjoys some positive contribution from each retained switched access line. By choosing LTC service instead of bypass once the second block is offered, large customers indicate, by revealed preference, that they have been made better off. The net contribution from large-circuit retentions can be used to reduce the usage price of small-block customers below P_o; therefore, small customers can benefit as well. The tariff then manages to recover local company fixed costs while improving everyone's utility beyond their original levels at A_o, P_o.

3. A Mathematical Model: Pareto-Improving Nonuniform Tariffs

Spence derives a nonuniform price schedule that maximizes social welfare subject to the constraint that LTC profits are non-negative. We shall now extend his analysis to require that no customer's utility be lowered from an initial level that resulted under previous line and usage charges. Demand for usage is price-elastic; each customer has at most one circuit, which can be switched access or bypass. Section 5 relaxes this latter assumption.

Variables, Definitions, and Assumptions

Demand-for-usage intensities vary among customers. Assuming that demand curves do not cross (see Faulhaber and Panzar (1977); Spence; MS; GLS), each customer can be indexed by an ordinal parameter $i \in [0, 1]$, which is continuously distributed with cumulative distribution function $F(i)$ and density $f(i) = dF(i)/di$. Let a designate the infimum and d the supremum of intensities i of LTC customers; $(a, d) \in [0, 1]$. This section assumes that both a and d are fixed; Section 5 will make both variables-of-choice.

Assume that intensity 0 is such that customer usage $q_0 = 0$ at $P \geq 0$.[4] Represent optimal usage by customer i on a switched access circuit as q_i; willingness to pay for service and net welfare then depends upon intensity i and usage q. The net welfare of consumer i on switched access circuits can be written:

$$3.1) \quad W_i(q) = W(i,q,P(q)) = U_i(q) - R(q) - A$$

where:

$U_i(q) = U(i,q)$ = consumer i's willingness to pay for q.

$R(q_i)$ = usage-sensitive revenue paid for usage q_i

A = access fee per customer line

We assume that $dU_i(q)/dq > 0$, $d^2U_i(q)/dq^2 < 0$, and $d^2U(i,q)/didq > 0$. For individual i to maximize utility, $dU_i(q)/dq \big|_{q=qi} = dR(q)/dq \big|_{q=qi} = P_i$.

The remainder of this section employs three assumptions:

Assumption 1: All customers $i \in (a, d)$ are switched access customers.

Assumption 2: The price schedule is continuous over (a, d) and differentiable except at a finite number of points.

Assumption 3: The price schedule is single-crossing. (A price schedule P(q) is <u>single-crossing</u> at q_i if, for any i such that $P(q_i) \leq dU_i(q)/dq \big|_{q=qi}$, $P(q_j) \leq dU_i(q)/dq \big|_{q=qj}$ for $q_j \leq q_i$ (GLS).

As a result of Assumption 1 and Assumption 2, we may integrate over customer intensities between endpoints a and d; a proof of Assumption 1's validity is available upon request. Assumption 2 disallows gaps and jumps (see Burtless and Hausman (1978), GLS) in the price-schedule; Section 4 relaxes this assumption. Assumption 3 ensures that second-order conditions for a utility maximum are always met; it is equivalent to assuming that customer usage increases with customer intensity at all prices P_i. The single-crossing assumption also insures that customer i's demand curve intersects the price schedule from above at q_i; it must either be assumed to hold (Spence, MS) or be imposed as a constraint (Mirrlees (1976); Roberts; GLS).

First-Order Maximizing Conditions

Turning to the formal optimization problem, we define aggregate consumer welfare W:

$$3.2)\quad W = \int_a^d W_i(q_i)\,dF(i).$$

Utility profits are defined:

$$3.3)\quad X = \int_a^d [A + R(q_i) - Z - Cq_i]\,dF(i) - K.$$

In a Pareto-improving tariff, no customer can be made worse off than he was initially; i.e., $W_i(q_i) > W_{io}(q_{io})$ where the o subscript indicates initial levels of welfare and usage that prevailed originally under customer and usage charges A_o and P_o. If $W_i = W_{io}$, we shall term the customer <u>original-indifferent</u>. We shall then term this constraint the original-indifference constraint.

The objective function can be expressed as follows:

$$3.4)\quad L = (1 - g)W + gX + \int_a^d h_i(W_i - W_{io})\,di$$

If g = 1 (1/2), (3.4) is a straightforward profit- (welfare-) maximizing problem. A profit-constrained welfare-maximizing problem must weight X more heavily than W; consequently, $1/2 < g < 1$ for a profit-constrained welfare-maximizing problem. (For more explanation, see Schmalensee (1981), MS.) The last RHS term in (3.4) is the Kuhn-Tucker term needed to ensure that $W_i(q_i) \geq W_{io}(q_{io})$ for all customers i. The multiplier h_i must be nonnegative for all i. If $h_i > 0$, customer i is original-indifferent.

A trivial extension of a derivation by Spence (1977) shows that (see Einhorn):

3.5a) $$g(dU_i(q)/dq\Big|_{q=qi} - C)f(i) + (1 - 2g + h_i)(\partial^2U(i,q)/\partial i\partial q)[F(d) - F(i)] = 0$$

3.5b) $$X \geq 0;\ g \geq 0;\ gX = 0$$

3.5c) $$W_i(q_i) \geq W_{io}(q_{io});\ h_i \geq 0;\ h_i[W_i(q_i) - W_{io}(q_{io})] = 0.$$

For all i, $dU_i(q)/dq\Big|_{q=qi} = dR(q)/dq\Big|_{q=qi} = P(q_i)$. Equation (3.5a) can then be reexpressed:

3.5a') $$P_i = P(q_i) = C + (2g - 1 - h_i)t(i)(\partial^2U(i,q)/\partial i\partial q\Big|_{q=qi})/g$$

where:

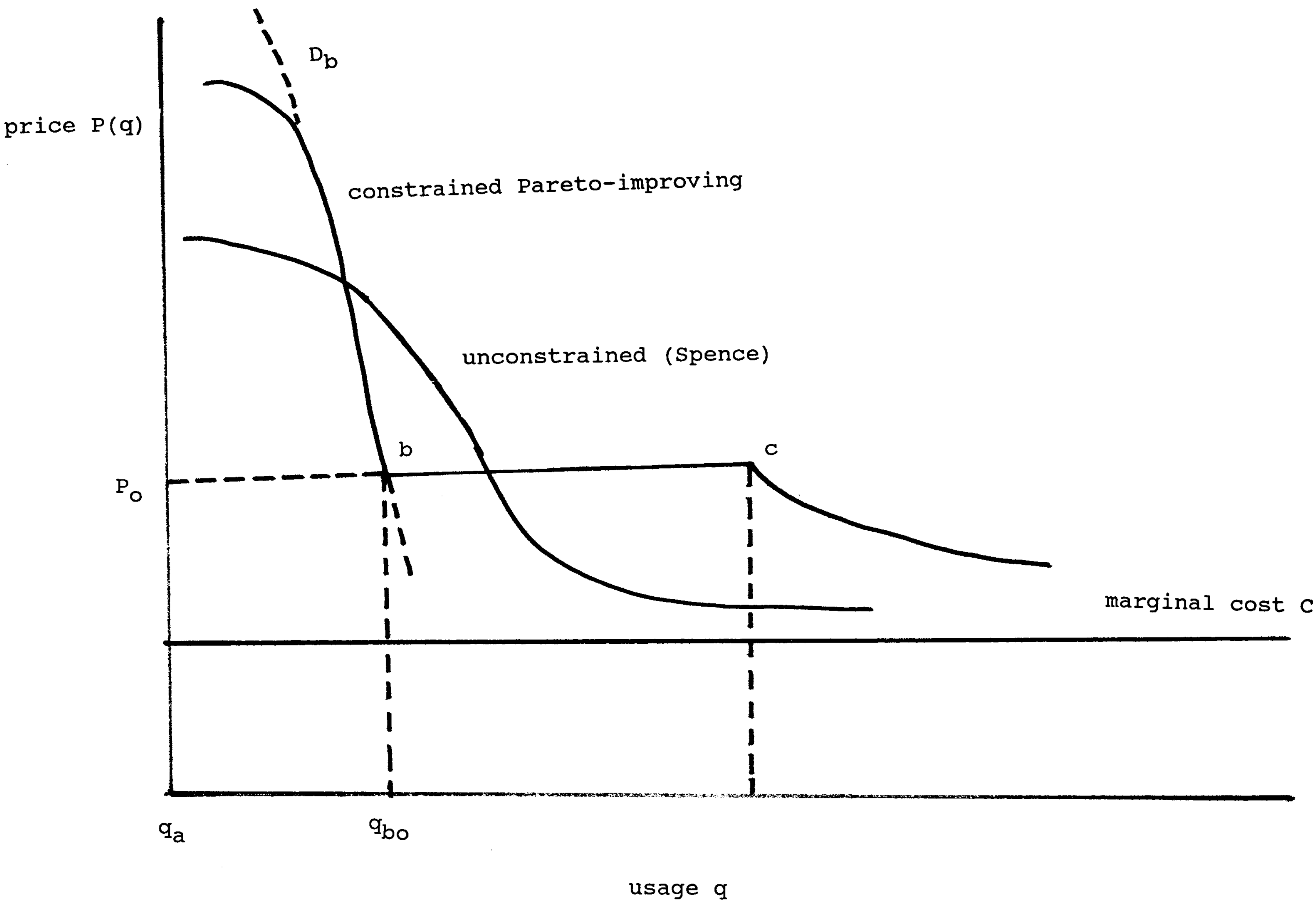
$$t(i) = [F(d) - F(i)]/f(i) \geq 0.$$

4. An Optimal Nonuniform Price Schedule

Spence derives the shape of the optimal nonuniform price schedule when the original-indifference constraint is not binding (i.e., $h_i = 0$ in (3.5a')); see Figure 2. The schedule need not be monotonically increasing; P(q) must be greater than or equal to C and eventually P(q) must fall to C. We now consider the implications of adding the Pareto-improving constraint to an optimal nonuniform price schedule.

Theorem 1: Let [b, c] represent the first band of customers who are original-indifferent. Suppose that $P(q_i) > P_o$ for some $i \in (b, c]$. Then for some $j \in (b, i)$, $P(q_j) < P_o$.[5]

Figure 2: Unconstrained and Pareto-Improving Nonuniform Price Schedules



either A_o, P_o or A_1, P_1), we may require that each customer be better off under the nonuniform price schedule than under either of the two original alternatives. Because consumer demand curves do not cross one another, only one customer can be indifferent between A_o, P_o and A_1, P_1. Therefore, at most only one customer can be indifferent between the two original price schedules and the nonuniform alternative. Let [b, c] ([b', c']) represent the spectrum over which customers are indifferent between A_o, P_o (A_1, P_1) and the nonuniform price schedule; from the above remarks, $c \leq b'$ is necessary.[8]

A Pareto-improving price schedule therefore would have two plateaus. If c = b', we would jump from one plateau to the second by moving down the demand curve of customer c = b'. If b' > c, there would be an interval of unconstrained customers between the two plateaus; usage price P(q) would be fixed over the plateau; (see Figures 4a and 4b.) Adding additional original-indifference constraints to the problem is now a trivial extension.

5. Important Extensions

This section introduces three important extensions to the model of Section 3. First, both endpoints a and d may be variables of choice (d may be variable if large customers can bypass the LTC.) Second, each customer can have more than one switched access line. Third, regulators might not have information regarding F(i) and may need to impose an even more constrained Pareto-improving schedule than derived above.

Figure 4a: Two Original-Indifference Constraints

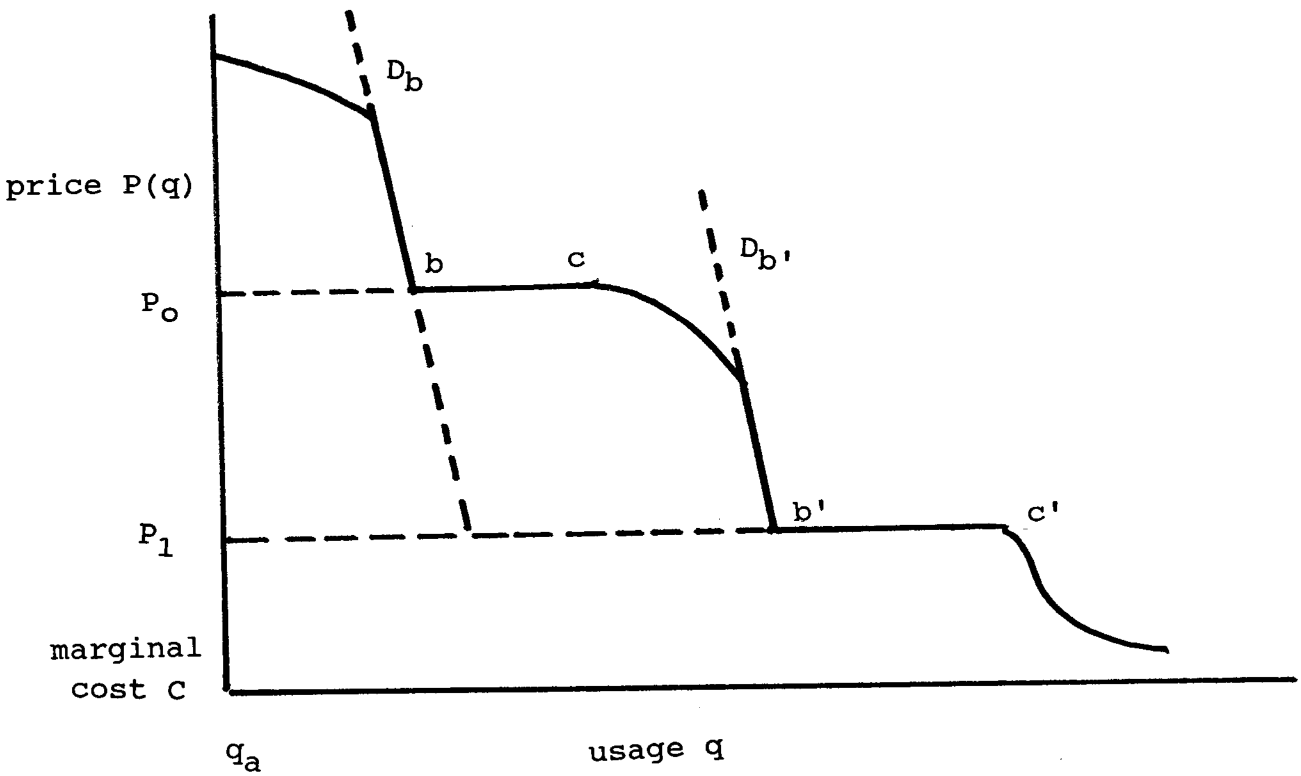
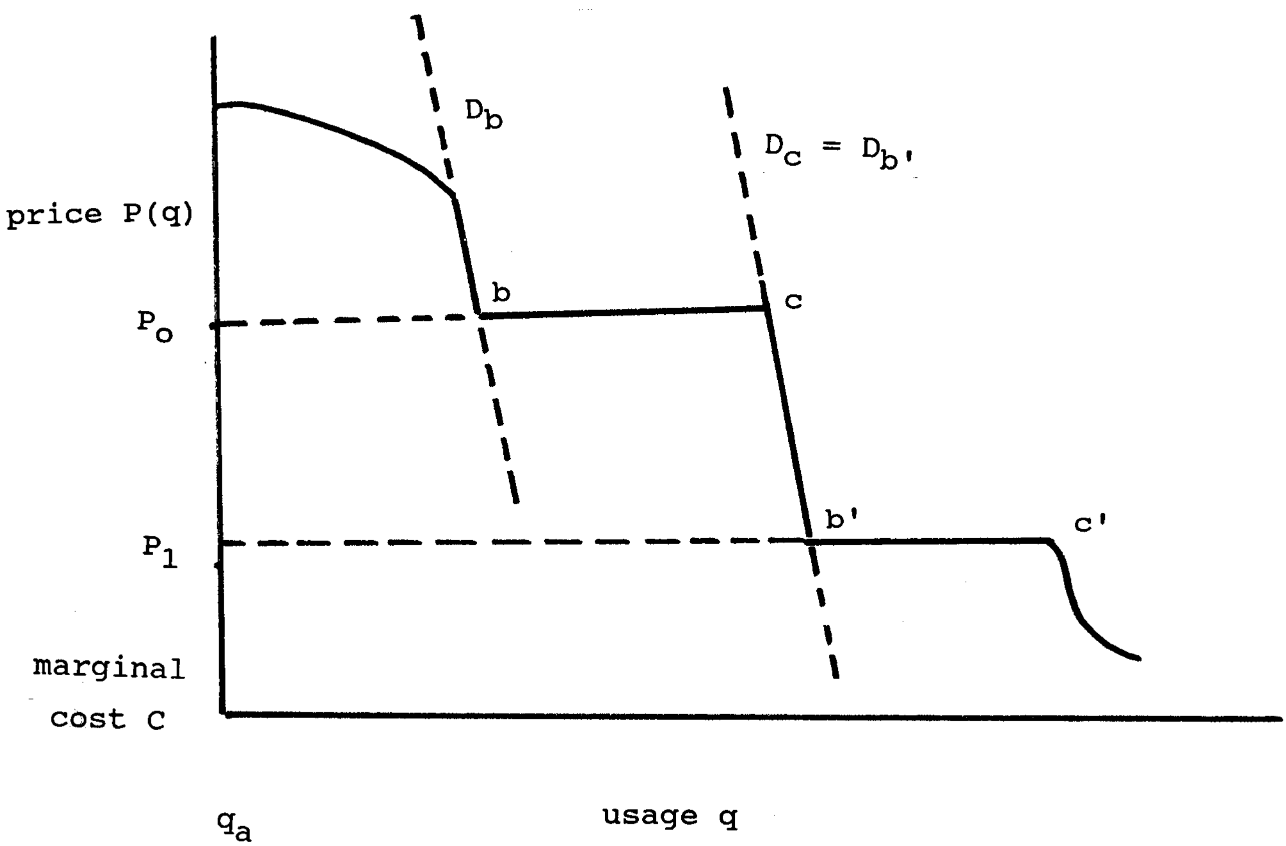


Figure 4b: Two Original-Indifference Constraints



Bypass Alternatives

Assuming that bypass vendors constitute a competitive market, access and usage prices will be driven to costs Z^* and C^*. Usage of customer i is then $q_{i*} = q_i(C^*)$. Under bypass, the welfare of customer i would be:

$$5.1)\quad W_{i*}(q_{i*}) = W(i, q_{i*}, C^*) = U_i(q_{i*}) - C^*q_{i*} - Z^*$$

Prospective customers may then choose between bypass, LTC service (see eq. 3.1), and no service at all. We assume that bypass technologies can be economic at a sufficiently high level of usage; i.e., $C^* < C$ and $Z^* > Z$. Therefore, $P_o > C > C^*$.

Potential consumers can be divided into two groups. If utility services were unavailable, small consumers would rather forego service altogether rather than bypass; i.e., $0 > W_{i*}(q_{i*})$. By contrast, large consumers would rather bypass; i.e., $W_{i*}(q_{i*}) > 0$.

We now let endpoint intensities vary; we choose a and d to maximize social welfare subject to binding profit- and original-indifference constraints.

Assumption 4: a is a small customer and d is a large one.

Given the definitions of infimal and supremal intensities and Assumptions 3-4, a consumer with $i < a$ ($i > d$) would prefer having no service at all (bypass) even if switched access were available. That is, $W_i(q_i) < 0$ for $i < a$; $W_i(q_i) < W_{i*}(q_{i*})$ for $i > d$. If customer intensities are continuously distributed, customers a and d would be indifferent between utility service and their next best alternative.

The relevant welfare-maximand is then:

5.2) $$W = \int_a^d W_i(q_i)dF(i) + \int_d^1 W_{i*}(q_{i*})dF(i).$$

Utility profits are defined as before:

3.3) $$X = \int_a^d [A + R(q_i) - Z - Cq_i]dF(i) - K.$$

We must add two Kuhn-Tucker conditions to (3.3) to require that each customer prefer or be indifferent to LTC service (versus his next best alternative). The objective function can be expressed as follows:

5.3) $$L = (1 - g)W + gX + \int_a^d h_i(W_i - W_{io})di + \int_a^d k_i(W_i - 0)di + \int_a^d m_i(W_i - W_{i*})di$$

The k_i terms are Kuhn-Tucker constraints that require each customer to prefer or be indifferent between utility service and no service at all; i.e., $W_i(q_i) \geq 0$. The m_i terms are Kuhn-Tucker constraints that require each customer to prefer or be indifferent between LTC service and bypass; i.e, $W_i(q_i) \geq W_{i*}(q_{i*})$.

It is possible to derive formal optimizing conditions as in Section 3 (see Einhorn). However, a less formal discussion makes the basic points. We may conceive of the two next-best alternatives (i.e., no service at all and bypass service) as being two additional original-indifference constraints with $A = 0$, $P = 0$ and $A = Z^*$, $P = C^*$. As discussed in the previous section, a nonuniform price schedule with several original-indifference constraints must jump from plateau to plateau with gaps of strong preference possibly in between; that is, there can be constrained sections where customers on any plateau are small-, large- , or otherwise original-indifferent.

We now shall characterize the small- and the large-indifference plateaus. We first differentiate (5.3) with respect to a and d:

5.4a) $$(g - h_a - 1)W_a(q_a)f(a) - g(A + R(q_a) - Z - Cq_a)$$
$$= -g(A + R(q_a) - Z - Cq_a) \leq 0;$$
$$a \geq 0; \quad ag[A + R(q_a) - Z - Cq_a] = 0$$

5.4b) $$(1 + k_d - g)[W_d(q_d) - W_{d*}(q_{d*})] + g(A + R(q_d) - Z - Cq_d)$$
$$= g(A + R(q_d) - Z - Cq_d) \geq 0;$$
$$d \leq 1; \quad (d - 1)g[A + R(q_d) - Z - Cq_d] = 0$$

The first equalities in (5.4a) and (5.4b) result from the fact that $W_a(q_a) = 0$ and $W_e(q_e) = W_{e*}(q_{e*})$ when $a > 0$ and $e < 1$.

From (5.4a), $A + R(q_a) = Z + Cq_a$; i.e., revenues from customer a must just cover his associated costs. Because customer a is indifferent, $W_a(q_a) = U_a(q_a) - R(q_a) - A = 0$; therefore, $U_a(q_a) = Z + Cq_a$. This means that customer a should obtain LTC service if the resulting social benefit $U_a(q_a)$ equals the associated social cost $Z + Cq_a$. If customer a is the infimal intensity of the customer spectrum, no customer $i > a$ can be small-indifferent.[9] Consequently, for small q_i, $P(q_i)$ is either at an unconstrained level somewhere above marginal cost C (as in (3.5a')) or it falls to usage price P_o.

From (5.4b), $A + R(q_d) = Z + Cq_d$; i.e., revenues from customer d are just sufficient to cover its costs. Since the marginal usage cost of bypass $c^* < c$, the utility must extend its c^* plateau until it breaks even on usage q_d of the largest customer. Above q_d, it is necesssary to dissuade large customers from staying with switched access; this can be done by raising the marginal usage price (for usage beyond q_d) above c^* (see Einhorn). Einhorn demonstrates that bypass will occur if and only if it is economic. Figure 5 illustrates an Pareto-improving optimal nonuniform price schedule with large customer exit.

Multiline Customers

To this point, we have assumed that each customer has one access line. However, the model can be easily generalized to allow for multiline customers. Einhorn shows that results from an optimal nonuniform schedule for switched access line usage (with large customer bypass) can be extended to a multiline model if we assume that each bypass circuit has a flat-rate line (usage) cost of z^* (c^*), each switched access line has a usage-sensitive price schedule $P(q)$, $P(q)$ is the same for each switched access line, and $dP(q)/dq \leq 0$ for usage q on each switched access line.

Because of the last assumption, marginal usage price on any switched access line monotonically decreases as more calls are routed over the line; a profit-maximizing customer should always concentrate usage by routing calls over his available lines in an unchanged order. Assuming that circuit demand curves for different customers do not cross, all installed switched access lines can be unambiguously designated by an ordinal demand intensity parameter i with i continuously distributed with

Let q_{bo} represent the usage level of customer b if the marginal price of usage is P_o (i.e., point E in Figure 3). At this point, we prove Lemma 2.1, which will be useful for proving Theorem 2.

Lemma 2.1: $R(q_{bo}) = A_o + P_o q_{bo}$.[6]

Theorem 2 establishes that the price schedule has a plateau at P_o over the interval (b, c]:

Theorem 2: $P(q_i)$ cannot be less than P_o for $i \in (b, c]$.[7]

We can combine Theorem 1 and Theorem 2 to state a major corollary:

Corollary 2.1: $P_i = P_o$ for all customers $i \in (b, c]$.

From the proof of Lemma 2.1, P(q) and D_b must coincide from points B to E (Figure 3); it follows from Corollary 2.1 that $P_i = P_o$ from q_{bo} (point E) to q_c.

We have established the general form of a Pareto-improving price schedule (see Figure 2). Unlike Spence's nonuniform price schedule, the new schedule reaches a plateau (b, c] along which $P(q) = P_o$. For usage charges prior to the plateau, $A + R(q_{bo}) = A_o + Pq_{bo}$. If the original-indifference constraint were binding, g would be higher under a Pareto-improving schedule than under an unconstrained schedule; customers i who are not original-indifferent ($i \in [b, c]$) would consequently face higher prices under a Pareto-improving schedule.

If more than one original-indifference constraint existed (i.e., each customer must be better off than he would be under cumulative distribution function F(i) and density f(i) = dF(i)/di. Results from Section 3 emerge unchanged, owing to the fact that intensity of line usage is now ordinally ranked in an unambiguous fashion as was intensity of customer usage before.

To ensure Pareto-improvement in a multiline model, we add the requirement that net willingness-to-pay for usage on any switched access line i $[W_i(q_i) - R(q_i) - A]$ must not be less than willingness-to-pay for usage on the same line under the original tariff $[W_i(q_{io}) - P_o q_{io} - A_o]$; while this requirement is not necessary for Pareto-improvement for any multiline customer, it is sufficient. It guarantees that the results established above for single-line customers can be extended to multiline customers as well. Given this requirement and the assumptions stated above, the results of the single line model (integrated over customer intensities i) can be extended <u>mutatis mutandis</u> to a multiline model as well. For each switched access line, P(q) declines (possibly through one or more plateaus). Eventually, $P(q) = C^* < C$. At a prespecified level of usage q_d, $A + R(q_d) = Z + Cq_d$; bypass will occur above this point. Einhorn provides more details.

<u>More Limited Information</u>

To this point, we have assumed that regulators and the LTC have a Bayesian prior regarding F(i) (although no knowledge regarding a particular customer's usage intensity i); however, even this much information might not be available. Information on F(i) would be needed to enforce Lemma 2.1, which can allow

$P(q_i) > P_o$ for $q_i < q_{bo}$, and is needed to design the best Pareto-improving price schedule of Section 4.

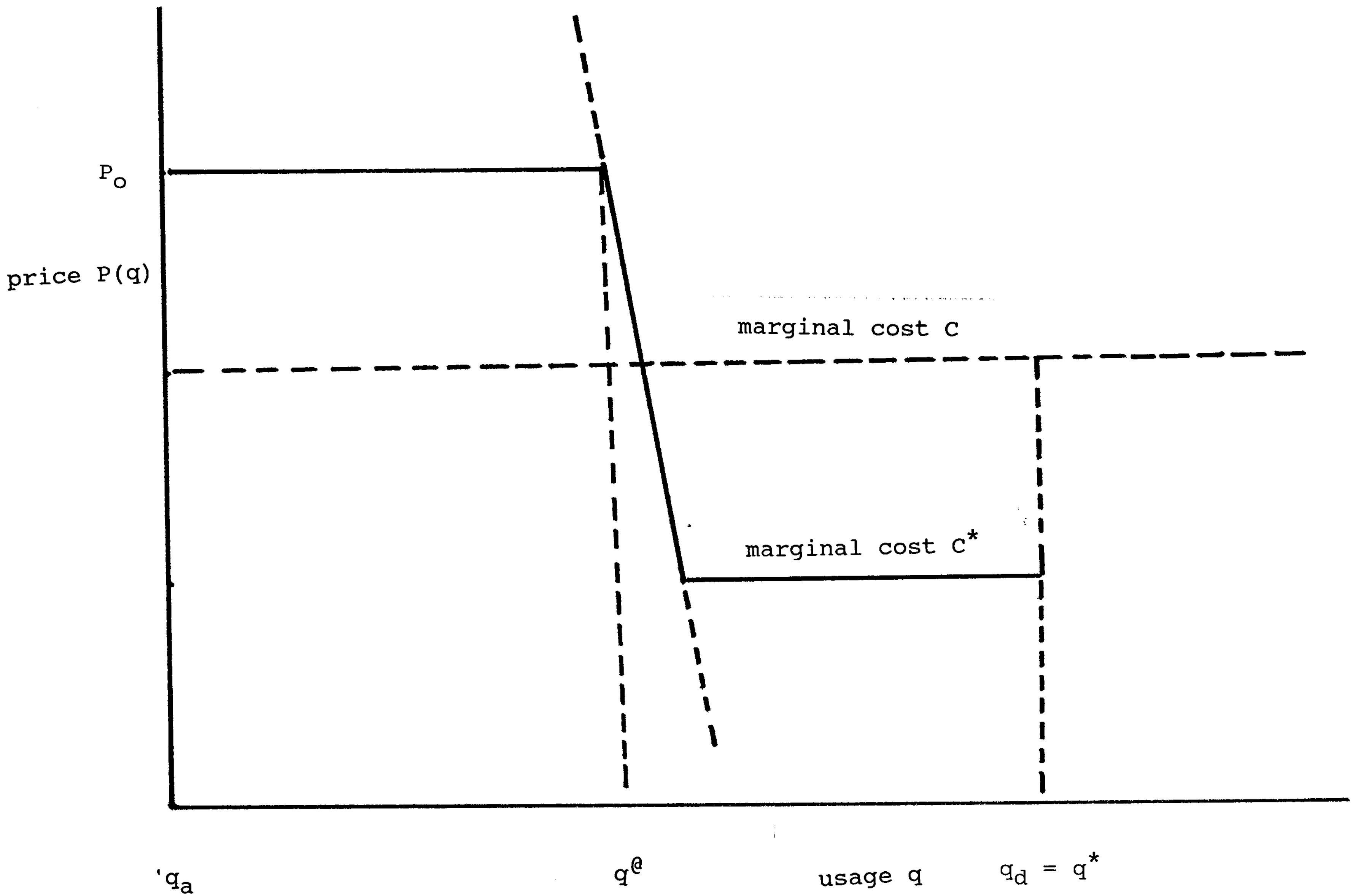
Without this information, Pareto-improvement can still be guaranteed by requiring that $A \leq A_o$ and $P(q) \leq P_o$ for all q_i. This would require replacing the original-indifference constraint $W_i \geq W_{io}$ with $A \leq A_o$ and $P(q) \leq P_o$. Under these conditions, P(q) must not exceed P_o; as before, a plateau (b, c] can exist where $P(q) = P_o$. However, endpoint conditions on supremal intensity d still hold (eq. (5.4b)); usage price must eventually fall to C^*. As before, at supremal usage q_d, $A + R(q_d) = Z + Cq_d$.

Figure 6 illustrates an alternative Pareto-improving nonuniform price schedule with large customer bypass. Assuming that no information on F(i) is available, the LTC may nonetheless improve upon the original prices A_o, P_o by identifying the likely point $q^@$ and customer size where uneconomic bypass would occur (assuming that P_o exceeds C); at this point, the utility may add a second block ($P(q) = C^*$) for usage between $q^@$ and q^*. The only information needed to construct the tariff in Figure 6 is P_o, C^*, and some information regarding customer demand responses to determine $q^@$.

6. Conclusion

This paper has demonstrated several important points regarding the prices that LTCs should bill to long-distance users. First, given any set of initial uniform prices A_o, P_o with $P_o > C$, it is possible to make each LTC customer better off by implementing a nonuniform price schedule; this schedule can be designed to make each customer better off than he was originally.

Figure 6: Alternative Pareto-Improving Nonuniform Price Schedule with Large Customer Bypass



Second, when large customer bypass presents a problem, this nonuniform price schedule should have an outer block where usage is priced below marginal usage cost; large customers would nonetheless provide a net revenue contribution because prices in the inner block would exceed marginal usage cost. Third, under any correctly implemented Pareto-improving schedule, bypass will result if and only if it is economic. Fourth, although information regarding F(i) can help in the design of a Pareto-improving price schedule, such information is not necessary to Pareto-improving the uniform tariff A_o, P_o ($P_o > C$); a nonuniform price schedule can be construcuted that unambiguously benefits each customer even without any prior knowledge of F(i).

ENDNOTES

[1]Because bypass technologies display increasing returns at some usage levels, we assume that consortia of users can form to exploit optimally any possible economies of scale; alternatively, users may purchase bypass service from optimally-scaled resellers.

[2]To prove this, note that $A + R(q_i) > Z + Cq_i$ for some $q_i < q^*$ if fixed costs are to be covered; $A + R(q^*) = A + R(q_i) + [R(q^*) - R(q_i)]$ and $Z + Cq^* = Z + Cq_i + C(q^* - q_i)$. Since $A + R(q^*) = Z + Cq^*$ and $A + R(q_i) > Z + Cq_i$ at some $q_i < q^*$, $R(q^*) - R(q_i) < C(q^* - q_i)$ for that q_i. Therefore, $P(q) < C$ somewhere between q_i and q^*.

[3]If customer i were subsidized, then $D(q_i) = A + R(q_i) < Z + Cq_i$. Let (I_1, I_2) designate the interval of subsidized customers; with

no loss of generality, assume that there is only one subsidy interval. For customers i in (I_1, I_2), both LTC profits and total social welfare (but not consumer surplus) can be increased by setting $P(q_i) = C$. If this were done, customers $i > I_2$ would be made worse off, since their inframarginal payments prior to q_{I2} would increase by $G = D(q_{I2}) - D(q_{I1})$. But each customer ($> I_2$) could be restored to his original utility level via a lump sum income grant of G. (If any further subsidy interval results, the process could be repeated.) Therefore, both LTC profits and social welfare may be increased without making any customer outside (I_1, I_2) any worse off; the offsetting gain in producer surplus more than offsets any reduction in consumer surplus in (I_1, I_2).

[4]In making this assumption, we have implicitly excluded the possibility that access fees may be increased without distorting customer subscription in some manner; this possibility would be fortuitous from a welfare-maximizing standpoint, but the optimization problem would be trivial.

[5]Proof by contradiction. Suppose that $P(q_j) \geq P_o$ for all $j \in (b, i)$ and that $P(q_i) > P_o$. Figure 3 displays the relevant demand curves for customers b and i (D_b and D_i), one possible price schedule P(q), and the original usage price P_o. Area ABC (FGC) represents the net consumer surplus that customer b (i) enjoys with utility service; with bypass, customer b (i) would enjoy a net consumer surplus of area ADE (FDH) minus the flat-rate fee z^*. Since b is original-indifferent, area ADE - A_o = area ABC; therefore, A_o = area BCDE. Since i is original-indifferent, area FDH - A_o = area FGC; therefore, A_o = area GCDH. But area GCDH =

area BCDE + area GBEH; unless area GBEH = 0, this equality cannot hold. Area GBEH cannot equal zero if $P(q_j) \geq P_o$ for $j \in (b, i)$. E.O.P.

[6]Proof: From Theorem 1, $P(q_i) \leq P_o$ for some customer $i > b$. Since Assumption 3 implies that P(q) cannot cross D_b twice, P(q) and D_b must coincide from B to E; see Figure 3. At E, consumer b can purchase usage at price P_o, the same as originally. Since consumer b is original-indifferent, inframarginal payments prior to q_{bo} must be the same under the two alternatives; therefore $A + R(q_{bo}) = A_o + P_o q_{bo}$. E.O.P.

[7]Proof by contradiction. Let i represent the first point ($i > b$) where $P(q_i) < P_o$. Because customer i is original-indifferent:

$$4.1) \quad U_i(q_i) - R(q_i) - A = U_i(q_{io}) - P_o q_{io} - A_o.$$

We may express:

$$4.2) \quad R(q_i) = R(q_{bo}) + [R(q_i) - R(q_{bo})]$$
$$= A_o + P_o q_{bo} - A + [R(q_i) - R(q_{bo})],$$

where the second equality follows from Lemma 2.1. Substituting (4.2) into (4.1) and rearranging terms yields:

$$4.3) \quad U_i(q_i) - [R(q_i) - R(q_{bo})] = U_i(q_{io}) - P_o(q_{io} - q_{bo}).$$

Since $P(q_i) < P_o$, $U_i(q_i) > U_i(q_{io})$. Since $P(q) = P_o$ for all q between q_{bo} and q_i, $R(q_i) - R(q_{bo}) \leq P_o(q_{io} - q_{bo})$. But then equality cannot hold in (4.3), which means $P(q) < P_o$ is not possible. Q.E.D.

Note: If $P(q_i) = P_o$, $U_i(q_i) = U_i(q_{io})$ and $R(q_i) - R(q_{bo}) =$

$P_o(q_{io} - q_{bo})$; (4.3) would hold.

[8]If $c > b'$, there would be more than one customer intensity that is indifferent between the three alternatives; if customer demand curves do not cross one another, this makes no sense.

[9]Proof: Since $a = \inf(S)$, $W_a(q_a) = 0$ and $U_a(q_a) = R(q_a)$ for this user; see (3.1a). Since demand curves do not cross, $U_i(q_a) > U_a(q_a)$ and $W_i(q_a) = U_i(q_a) - R(q_a) > 0$ for $i > a$. Since $W_i(q)$ is maximized at $q = q_i$, $W_i(q_i) > W_i(q_a) > 0$.

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