The Flow Through of Cost Changes in Competitive Telecommunications: Theory and Evidence

T. Randolph Beard
Department of Economics
Auburn University
Auburn, Alabama
rbeard@business.auburn.edu

George S. Ford
Z-Tel Communications
601 Harbour Island Blvd.
Tampa, Florida
gford@z-tel.com

R. Carter Hill
Department of Economics
Louisiana State University
Baton Rouge, Louisiana
eohill@lsu.edu

Richard Saba
Department of Economics
Auburn University
Auburn, Alabama
rsaba@business.auburn.edu

Abstract: *Flow through* refers to the effect of a change in incremental production costs on the prices of goods or services, and is a topic of great interest to regulators and others. This article provides a framework for both analyzing flow through, and for evaluating whether or not flow through, properly defined, occurs in the long distance telecommunications industry. We focus on the effects of changes in switches access charges on domestic long distance prices for the largest long distance carriers in the late 1990s. Utilizing a double bootstrap technique uniquely suited to this problem, we find flow through occurred over the sample period. The technique illustrated here may find useful applications in other regulated sectors.

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T. Randolph Beard, Department of Economics, Auburn University, Auburn, Alabama, rbeard@business.auburn.edu

George S. Ford, Z-Tel Communications, 601 Harbour Island Blvd., Tampa, Florida, gford@z-tel.com.

R. Carter Hill, Department of Economics, Louisiana State University, Baton Rouge, Louisiana, eohill@lsu.edu

Richard Saba, Department of Economics, Auburn University, Auburn, Alabama, rsaba@business.auburn.edu

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I. Introduction

Current regulatory procedures in the U.S. require that interexchange carriers (IXCs) pay local exchange carriers (LECs) regulated fees for access to the LECs' local telecommunications networks. Production of a typical residential long distance call requires both originating and terminating access services, for which IXCs pay access charges. These access charges constitute a substantial portion (around 30 to 40%) of IXC revenues, and generate a multibillion-dollar flow from long distance customers to local service providers.[1]

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[1] See, e.g., Speech by the Federal Communications Commission's Chairman William Kennard, *A New Federal Communications Commission for the 21st Century* (March 17, 1999) [Average revenue per minute declined from $0.135 to $0.102; access charges declined from $0.058 to $0.042J;

Not surprisingly, access charges have long been a serious issue of regulatory debate, pitting the IXCs, whose customers pay these charges through the price of long distance services, against the LECs who receive these payments. The IXCs have long supported reductions in access charges, while the LECs traditionally have opposed such reductions.[2] Considerable disagreement regarding the proper methodology for setting access charges is evident, and a number of prominent economists have contributed to this debate.[3]

Among the most contentious aspects of the "politics of access" is the issue of so-called "flow through" (or "pass through") of FCC mandated reductions in interstate, switched access charges.[4] Summarized in crude form, the LECs, who

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Lande and K. Rangos *Telecommunications Industry Revenue: TRS Fund Workshee; Data* (November 1997), p. 12; *Trends in Telephone Service*, Federal Communications Commission, Tables 1.2 and 13.5 (July 1998).

[2] Access is 10 percent of ILEC total revenues, and by all accounts the demand elasticity for long distance service is inelastic (implying the input, access, is inelastic as well). *See* ARMIS Form 43-03 (Rows 5082 and 530, 1998 data) and Lester Taylor, *Telecommunications Demand in Theory and Practice*, Dordrecht: Kluwer Academic Publishers, 1994.

[3] *See*, e.g., *Sixth Report and Order*, CC Docket No. 96-262 (May 31, 2000).

[4] There is a similar debate regarding the flow-through of reductions in intrastate access charges, and this debate occurs primarily before the state regulatory commissions.

are recipients of access charges, argue that reductions will not be passed on to long distance customers, particular residential customers, in the form of lower prices due to a claimed lack of competition in the long distance industry. Thus, such reductions are a windfall benefit of the IXCs alone, providing no benefit to consumers. Further, it is simultaneously argued that allowing entry by the Bell Operating Companies (BOCs) into the in-region, interLATA long distance market will increase long distance competition and eliminate this "flow through" problem. In contrast, the IXCs argue that access charge reductions lead directly to reductions in prices and to other benefits for consumers, and that the competitive nature of the long distance industry assures this outcome. Although the FCC has occasionally stated that flow through of access charge reductions has occurred, it is clear that this issue remains a contentious and important one.[5]

Despite the highly politicized character of the flow through debate, the issue of the effects of (incremental) cost changes on prices, and the role of competition in this linkage, is likely to remain an important topic regardless of the ultimate fate of the telecommunications industry. Besides containing a complex

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[5] See, e.g., FCC Chairman William Kennard, *A New Federal Communications Commission for the 21st Century* (March 17, 1999) [Average revenue per minute declined from $0.135 to $0.102; access charges declined from $0.058 to $0.042]; J. Lande and K. Rangos, *Telecommunications Industry Revenue: TRS Fund Worksheet Data* (November 1997), p. 12.

theoretical problem, the flow through issue is widely relevant to policy discussions in newly- or partially-deregulated industries such as electric power and natural gas service, as evidenced by recent difficulties in California and other markets. Even unregulated industries are subjected to the flow through debate, such as the effect on retail gasoline prices of changes in the price of crude oil.[6]

Much of the difficulty connected to the flow-through debate arises from two sources: a) the proper definition of "flow through" and b) the econometric difficulties attendant on correctly evaluating whether flow through, appropriately defined, has occurred in any real sample. This article seeks to address these problems by providing credible empirical evidence on the effects of (incremental) cost changes on actual transactions prices.

Initiated by Sumner (1981), and subjected to further refinements by Bulow and Pfleiderer (1983), Sullivan (1985), and Ashenfelter and Sullivan (1987), the analysis of the effects of incremental cost changes on prices has gradually become a relatively important tool for evaluation of market performance and

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[6] See, e.g., "Gas prices: Explainable - or gouging?," *USA Today* (June 15, 2000); *What's Up With Natural Gas Prices*? Montana Public Service Commission (January 2001), available at www.psc.state.mt.us.

competition. Not all researchers are supportive of this trend. Basic criticisms of the approach stem from the "static" nature of most applications, the strong structural assumptions often made regarding the shapes of demand curves and other unobserved market characteristics, and the statistical difficulties arising from testing whether or not price changes are consistent with estimated cost changes. The technique presented in this paper goes some distance in addressing these issues.

We examine the effects of mandated reductions in switched access charges on average per-minute prices for direct-dialed, person-to-person long distance telephone calls provided by AT&T and MCI, the two largest U.S. interexchange carriers, over the period January 1997 through July 1998. To provide a credible test of whether reductions in switched access charges were flowed through to consumers, we calculated the actual average per-minute cost paid by customers using a large, publicly available sample of customer billing records. Our findings show that changes in average prices actually paid by customers of AT&T and MCI during this period are consistent with full flow through of access cost reductions. Our findings are supportive of claims that the U.S. residential interexchange market is effectively competitive, at least as can be deciphered from the response of prices to cost changes.

Unlike previous studies on flow through in the long distance industry, we begin our analysis by contemplating theoretically the relationship between cost and price changes. Consequently, as for reasons explained in this paper, the calculations used to determine effective prices are theoretically correct. Further, we perform statistical tests for the presence or absence of cost flow through utilizing a non-parametric statistical procedure (i.e., the double bootstrap) that also is consistent with the theoretical requirements, and represents an improvement over previous econometric practice regarding the issue of flow through.

The paper is organized as follows. Section II presents a theoretical background on the flow through of cost changes, and examines some of the literature on this topic. Section 3 describes the statistical methodology and data used, while Section 4 presents statistical results. A conclusion follows.

II. What is Flow Through?

Generally, the "flow through debate" concerns the effect of a change in seller costs on the prices paid by customers, or on some index of those prices. Ordinarily, any change in the marginal costs of producing goods leads to a change (of some sort) in the corresponding observed prices paid by consumers for those goods.[7] The flow through terminology suggests that final goods' prices (or an appropriate index thereof) should change in such a manner that any cost savings benefit buyers and not sellers, or else that price change should "fully reflect" (in some sense) any changes in the incremental costs of providing goods. Since the textbook model of single product, perfect competition holds that a change in marginal cost is matched by an identical change in price, some analysts contend that the competitiveness of a market can be assessed by evaluating the presence or absence of this condition.

To illustrate the somewhat curious nature of flow through in a more realistic and practical setting, consider the following theoretical template. Imagine an industry composed of i firms, each firm selling a set of k similar services, where R_{ik} is the revenue firm i earns from selling service k. Let q_{ik} be firm i's quantity sold of service k. With simple uniform pricing, $R_{ik} = p_{ik}{}^{x}q_{ik}$, and the revenues of firm i are just $R_i = \sum_k R_{ik}$. Suppose further that each service is produced at incremental cost $c_{ik} = c + e_{ik}$, where c is the uniform price of an input needed on a one-for-one basis to produce any service k, and e_{ik} is some (presumably firm- and

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7 See, e.g., Jean Tirole, *The Theory of Industrial Organization*, MIT Press: Cambridge (1995), p. 67.

service-specific) per unit cost for other necessary inputs. For simplicity, assume constant incremental costs for all firms and all services.

Initially, suppose that the cost c is equal to some value c_1, and firm i produces and sells quantities (q_{i1}, q_{i2}, … q_{ik}) with uniform prices $p_i = (p_{i1}, p_{i2}, \ldots p_{ik})$. Denote firm i's profits as $\pi_i(p_i, c_i)$. The set of all prices p presumably reflects some unspecified industry equilibrium configuration. Industry profits are

$$\pi = \sum_i \pi_i(p_i, c).$$

Now, consider a change in the cost of the "universal" input, where c changes from c_1 to c_2 and $c_2 < c_1$. As a consequence, industry equilibrium prices and quantities presumably all change to reflect the new, lower cost of production. It is apparent that there are at least three senses in which one could say the cost of production has been "flowed through" to consumers. These cases are:

1) Industry prices adjust so that, on net, industry profits are unchanged;

2) Each firm individually adjusts its prices so that each firm continues to earn a profit equal to that earned at c_1;

3) Each firm adjusts its prices so that the prices that result with cost c_2, denoted p_{i2}, satisfy the condition $(p_{i1} - p_{i2}) = (c_1 - c_2)\lambda$, where p_{i1} is the vector of firm i's prices when $c = c_1$ and λ is a $k \times 1$ vector of ones.

We may denote these three cases as (1) industry flow through; (2) firm flow through; and (3) price flow through. We note that case (2) implies case (1), but not the converse, and that (3) is generally inconsistent with both (1) and (2).

The analyst's ability to detect the occurrence of flow through will clearly differ substantially between these cases. Definitions (1) and (2) are based on profit consequences of the cost change, and, consequently, are likely to be difficult to evaluate. However, case (2) seems particularly appealing in the sense that any price changes that satisfy (2) will cause all benefits of the cost savings to be obtained by consumers, so that one could say the (benefits of the) cost reduction was truly "flowed through" to buyers. Note, however, that there will ordinarily be many sets of prices that satisfy case (2), and these various sets will not necessarily produce identical welfare for buyers.

Case (3) differs substantially from the others, as it ignores profits (which can be difficult to measure) and instead requires that, for each firm, each service's price should change by an amount equal to the change in the common per-unit costs. Such changes need not be consistent with equilibrium, of course. Further, such changes will usually result in a change in seller profits. To illustrate, let k = 1 so that firm i's profits are just $\pi_i = (p_i - c - e_i)q_i$. For a change Δp_i and common input cost change Δc, the change in i's profits are $\Delta\pi_i = (\Delta p_i - \Delta c)q_i + (p_i - c - e_i)\,\Delta q_i$. Flow through in the price sense (case 3) implies that $\Delta p_i = \Delta c$, so that $\Delta\pi_i = (p_i - c -$

e_i) Δq_i. Thus, $\Delta\pi_i = 0$ in general only if Δq_i, or ($p_i - c - e_i$), equals zero. If $\Delta q_i > 0$, profits rise when costs fall with flow through in sense (3), and profits fall when costs rise, so long as the margin ($p - c - e$) is positive.

The role of market competition in enforcing flow through is rather problematic. Flow through as in case (3) does occur in certain textbook cases of perfect competition, although the practical usefulness of such models is suspect. Case (2) seems more realistic, but satisfaction of the "equal profits" or "no windfall" condition does not by itself imply intense competition. Just because profits are equal does not mean they are low or normal: intense competition presumably implies *zero* economic profits, not merely a situation of no windfalls. On the other hand, flow through of the Case (3) sort can be observed in pure monopoly, as shown by Bulow and Pfliederer (1983). Thus, caution should be applied in asserting that the presence of flow through implies competition, or in claiming that the absence of flow through (in some sense) implies a lack thereof.

From the public policy perspective in U.S. long distance telecommunications, however, these theoretical niceties seem irrelevant: flow through, as the FCC and many commentators have used the term, refers to Case (3). This circumstance is quite understandable, as the public-at-large is more likely to focus on prices, which are easily seen, than on underlying financials that are largely opaque even to professional financial analysts. Further, flow through as envisioned in Case (3) does guarantee that a presumably large portion of the benefits of common input cost reductions will, in fact, accrue to customers. Further, as shown above, Case (3) flow through does imply no windfalls when quantities do not change. However, cost reductions, which lead to lower prices in virtually all conceivable models of product market competition, generally result in higher quantities, although it must be recognized that, since all prices are reduced, the sales of an individual firm may not increase if cross price effects are suitably unfavorable.

Thus, flow through as described in Case (3) is a legitimate policy issue, and it is this definition of flow through we evaluate in this paper. An additional complication arises that obviates our ability to simply test for it. Specifically, in the U.S. long distance industry, interexchange carriers offer a large number of tariffs and rate plans that include fixed charges, various quantity-dependent or time-sensitive discounts, free minutes of usage, and so on. There is no set of uniform prices to evaluate, and it is clearly inappropriate to merely arbitrarily select a single tariff for evaluation. While one might use a "flagship" tariff for this purpose, such a course may neglect the effects of cost changes on customers using older, and possibly inferior, calling plans. The existence of fixed monthly charges should also be taken into account, as should discounts. Thus, it is necessary to calculate "average" per minute prices paid by consumers, these averages being as inclusively defined as feasible. In this case, to obtain "average revenue per minute" ("ARPM"), all relevant charges paid by customers are summed and then divided by the number of units of service (minutes) that generated those revenues. Once computed, changes in these ARPMs may be evaluated to determine whether such changes are consistent with known changes in the common inputs costs (in our case, switched access charges).

An additional difficulty with evaluating Case (3) flow through using ARPM (or any other similar index of price) is that there is only one value for this figure in any customer sample. Thus, it is not possible to test for the statistical significance of any change in ARPM in the conventional manner (using a simple means-difference test). Non-parametric statistics, however, are ideally suited to surmount this difficulty. Not only can flow through be evaluated in a statistically rigorous manner, but the non-parametric approach has the added advantage of freeing the resulting analysis from stringent assumptions on the nature of the underlying probability model. We therefore take this approach, which is described more fully in the next section.

III. The Statistical Methodology

An analysis of flow through typically requires price and cost data from different time periods during which costs and prices change. For our analysis, we employ price and cost data from three time periods surrounding two major cost events. These two cost events involve regulatory-mandated incremental cost reductions, so the data is ideally suited to evaluate the effect of cost reductions on prices.

Data used to compute ARPM comes from a database collected by a private telecommunications research firm. The *Market Share Monitor* data set, collected by PNR and Associates, Inc., is a widely used, commercially provided data set based on a voluntary participation survey methodology.[8] For Market Share Monitor, PNR and Associates, Inc., received and processed approximately 2,000 bills each month from members of Market Facts, Inc.'s Consumer Mail Panel. In 1997, about 31,000 surveys per month were mailed to the Consumer Mail Panel with a response rate of about 66 percent. About 10 percent of respondents participated in PNR's bill harvesting project. From these responses, several data sets detailing calling patterns, consumer spending on services, discount plan participation, and so on, are complied on a monthly basis. The durations, distances, origins, destinations, and costs of calls are recorded. The data was provided as a Microsoft Access database, which we imported into SAS for our computations.

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8 The task of collecting and managing this data is now handled by TNS Telecoms (www.tnstelecoms.com).

In order to determine if flow through in the Case (3) sense has occurred, it is necessary to obtain estimates of the relevant switched access charges paid over the sample period. Two access charge "events" (reductions) occurred during the sample period January-1997 to June-1998, the first in June-1997, and the second in January-1998. These two events make for three time periods for comparison:

Period I (January-1997 through June-1997);

Period II (July-1997 through December-1997); and

Period III (January-1998 through June-1998).

For the second event (January-1998), significant changes in the structure of access charges occurred, when the primary interexchange carrier charge ("PICC") and Universal Service Fund ("USF") charges were imposed. The PICC is an interstate access charge, and consists of a per-line charge that varies by primary and secondary lines. When this charge was introduced, the IXCs, including AT&T and MCI, did not have data on which lines were "primary" or "secondary", so they estimated these values and averaged across all subscribers.[9] Further, customers who make zero long distance calls were sometimes not billed

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[9] See MCI Telecommunications Corporation, Emergency Petition for Prescription, CC Docket No. 97-250, CCB/CPD No. 98-12 (Feb. 24,1998).

by MCI, so that these charges were again averaged across billed customers only. Prior to January-1998, these latter charges were not explicit, but were embedded in switched access charges.

Switched access charges were computed using publicly-available data provided by the FCC and the *Market Share Monitor*.[10] Calculated access charges for the three periods are provided in Table 2. The reasonableness of our estimates was evaluated using confidential access charge data made available by MCI and estimates by the economic consulting firm National Economic Research Associates ("NERA").[11] While our estimated access charge reductions overstate the reductions computed by MCI, the estimates are reasonably close (see Table 2). First period access charge reductions are similar to those estimated by NERA, but NERA's estimates in the second period are substantially larger than those we compute. NERA's estimates are substantially larger than those provided by MCI, so we base on analyses in later sections on our own estimates of access charge reductions. Overall, if anything, our own estimates, based on

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10 The details of the calculations are provided in Table 2.

11 Paul Brandon and William Taylor (1989). This study was paid for by the trade organization for the Bell Operating Companies, the United States Telephone Association ("USTA").

publicly- and commercially-available data, make for a stricter test of flow through than would the estimated reductions of a major IXC.

1. CALCULATION OF APRM

An important conceptual issue arises when average revenue per minute (ARPM) is used as a price index to evaluate flow through. If competition implies 100 percent flow through for some set of services, then ARPM must be calculated for those services, and not for various customers individually. Consider the following very simple example. An IXC has two customers, A and B. Both buy the same service (e.g., interLATA, direct-dialed residential calling) under either different tariffs or a non-linear tariff. Customer A pays $10 for 100 minutes of calling, while B pays $4.20 for 400 minutes. The average revenues per minute for A and B are $0.10 and $0.05, respectively. Merely averaging these two ARPMs produces a figure of $0.075 per minute. Yet, this is not the IXC's ARPM. The total revenue of the IXC is $30, earned from selling 500 minutes of service, for a true ARPM of $0.06 per minute. Averaging ARPMs calculated for individual consumers overstates ARPM for the carrier when smaller users pay higher than average prices, while such averaging has the opposite effect in the contrary circumstance. Thus, flow through applies only to a firm's customers collectively, and must be analyzed in that light.

Conceptually, ARPM for a given set of *n* customers for a given time period *p* (A_p) is

$$A_p = R_p / Q_p \tag{1}$$

where R_p is the sum of all relevant expenditures by the *n* customers in *p*, and Q_p is the sum of all long distance minutes "consumed" by the *n* customers in *p*. As mentioned above, long distance charges are not all based on minutes of conversation, but also may include monthly charges for particular calling plans and, beginning in 1998, monthly charges for the primary interexchange carrier charges (PICC).

The formula for ARPM for AT&T and MCI is

$$A_p = \frac{\sum_1^n U_p + \gamma S + \phi P}{\sum_1^n Q_p} \tag{2}$$

where the sums are taken over the *n* customers in period *p*, *U* is usage sensitive charges (i.e., price per minute multiplied by minutes of use), *S* is any surcharges or flat fees paid by the customer, *P* is the primary interexchange carrier charge, and Q_p is target minutes of used defined as direct-dialed, interstate, interLATA calls by residential customers of MCI and AT&T. Surcharges include the long distance service charge ("plan price"), other long distance charges, the amount of non-itemized calls on the bill, charges for holiday usage, charges for promotions, and the universal service fund charge. Neither all surcharges (*S*) nor the PICC are properly allocated in total to direct-dialed, interLATA, interstate minutes of use, so an allocation of these charges to the target minutes of use is required. The parameter γ is the surcharge cost sharing factor, given as the ratio of target minutes of use to total minutes of use, and ϕ is the PICC cost sharing factor, given as the ratio of target minutes of use to target plus international minutes of use. The PICC is an interstate charge, so intrastate minutes are excluded from the denominator of the allocation factor ϕ.

Our analysis of the data set is limited as follows. We analyze only bills of MCI and AT&T customers for the billing date periods January-97 through June-98. Our interest is in residential customers' usage of direct-dialed, interLATA, domestic, interstate calls. We do not analyze international or operator-assisted calls. Two samples are used. In the "unfiltered sample," revenue and usage data for *all* MCI and AT&T residential customers' direct-dialed, interLATA, domestic, interstate calls from the dataset are employed. Some customers are recorded as having negative bills. While such a circumstance may reflect special refunds, we omit them from our analysis. We make no other adjustments to the data.

In an attempt to improve the data by eliminating some observed anomalies, we develop some filters and create a "filtered sample." Some customers appear to have per minute usage charges, for what are recorded as direct-dialed, interstate, interLATA calls, that exceed the MCI's and AT&T highest residential tariffed rates.[12] This suggests a miscoding of some calls, and we delete these observations from the filtered sample. In addition, the filtered sample utilizes observational specific weights (intended to make the sample more representative of U.S. households) that are provided in the data set, even though the relevant issue for flow-through analysis is whether or not the resulting weighted sample is representative of MCI or AT&T's customer bases. It is unlikely that weights created to make the sample more representative of U.S. households will accomplish this more relevant task. In any event, the use of the weights does not alter the basic conclusions, nor does the deletion of inaccurately high per-minute charges.

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[12] The highest tariff rate for MCI residential, domestic, direct-dialed, interstate, interLATA service was $0.2899 in July 1997. Therefore, we restrict the data to customers whose bills contain only usage charges less than $0.30 per minute (not including fixed monthly charges).

2. Additional Complications

Although we argue that ARPM provides the best feasible measure of flow through in the case at hand, there exist a set of complications of a practical nature that should be considered. These complications include: (1) the timing of cost reductions and price changes; (2) changes in the structure of federally regulated switched access charges; and (3) changes in other costs. We discuss each in turn.

Timing of Cost Reductions

The first reason to question a strict period-to-period analysis arises from the ongoing nature of the seller-buyer relationship in long distance telecommunications. In particular, IXC customers understand that their relationship with their long distance service provider may last for months or years. Likewise, long distance carriers recognize that customer relationships are often long term. Given this, one must ask if flow-through would happen exactly contemporaneously with the relevant access cost reduction. Since customers sign up for service over a nontrivial time period, and access reductions are known in advance, IXCs may reduce prices before access charge reductions take place in order to attract new buyers and retain existing customers. Similarly, even if such anticipation did not occur, competition , which presumably forces prices down to "break even" levels in long run equilibrium, may require time to achieve its results. Thus, one must act with caution in evaluating and interpreting price changes through time.

Structure of Costs

A second complexity arises form the somewhat radical change in the structure, and not simply the level, of access charges in January 1988. Specifically, the primary interexchange carrier charge (PICC) and Universal Service Fund (USF) charges were implemented at that time. The PICC is a per-line charge that varies by primary and secondary lines. Unfortunately, the IXCs did not have reliable information on secondary lines and thus estimated the number of such lines and averaged these charges across all customers. Thus, all PICC charges incurred from zero-bill customers and multi-line customers were (initially) recovered on an averaged basis from all billed customers. USF charges paid by IXCs are levied and collected on a percent-of-revenue basis. Prior to January 1988, these charges were embedded in the access charges and not explicitly levied as an ad valorem tax. These dramatic changes in the structure of access charges, in conjunction with the lack of reliable data on secondary lines, complicates a strict period-to-period assessment of flow through.

Other Costs

A third complication is that access charges are not, of course, the sole determinant of ARPM for any IXC. The comparison of changes in ARPM to change in access charges (on a per minute basis) assumes that other sources of costs do not change. This is clearly a strong assumption. For example, our analyses, and those of many other contributors to this debate, use nominal financial values for revenues and costs. Even today, however, inflation occurs, if only at a modest rate, and this phenomenon will presumably tend to increase costs over the sample period. Problems related to inflation, technological change, or any other determinant of costs should be *de minimus* given the relatively short time period (18 months) for which we base our analyses.

3. Non-Parametric Statistical Test of Means Differences

The relevant values of ARPM for a flow through analysis refer to revenues *of the seller*. However, a direct calculation of ARPM for any seller for any time period yields only a single observation. Should one wish to compare A_t to A_{t+1} for some service provider, conventional parametric tests for the statistical significance of any differences between them are unavailable. As a consequence, the evaluation of flow-through would be reduced to a pair-wise comparison of two random variables with unknown variances, a seemingly impossible task.

The phrase "pulling oneself up by one's bootstraps" is a description of such an impossible task. Bradley Efron gave the name "bootstrapping" to a procedure that allows us to make statistical inferences using only the data at hand. The procedure is called a re-sampling technique, because in it we draw many samples, called "bootstrap samples," by sampling with replacement from the original collection of data. Using each of these we compute the statistic of interest, which in our case is ARPM. These bootstrap values reveal to us the empirical "probability distribution" for the statistic in which we are interested.

For example, the March 1997 the PNR data consists of 105 bills for MCI (for the filtered data). We draw one bootstrap sample from these data by randomly selecting 105 bills, with replacement, from the original data, in such a way that each bill has an equal chance of being selected each draw. Using this bootstrap sample we compute ARPM, and we repeat this process many times. Producing 5000 bootstrap samples as just described yields the bell-shaped empirical distribution of ARPM in Figure 1. The value of ARPM in March 1997 is 0.1416533. The average value of ARPM in the 5000 bootstrap samples is 0.1419691, with a sample standard deviation of $s = 0.005198$ and a sample variance of $s^2 = 0.00002702$.

From this empirical distribution generated using the bootstrap, we have an estimate of the standard deviation and variance of ARPM. Repeating this experiment for any month, or any set of months, it is possible to compute a test statistic like the textbook means-difference *t*-statistic. This process proceeds as follows. In a given month, or set of months, we may randomly draw a sample of individuals' long distance calls, in particular their duration and cost to the consumer. Let the total duration of calls for individual j, $j = 1, 2, \ldots n$, in period t be q_t, and let the total expenditures, defined consistently with Eq. (2), be r_t. For the period we measure ARPM (A_t) as

$$A_p = \sum_{j=1}^{n} r_{jp} \Big/ \sum_{j=1}^{n} q_{jp} \,. \qquad (3)$$

This statistic is a random variable, and will change depending upon the sample of individuals we draw and the period in question. Assume that A_p has a true mean value μ_p, and variance σ_p^2. Let Period 1 be the period prior to and Period 2 be the period after the access charge reduction. To test the effect of an access charge reduction of magnitude δ on the mean value of ARPM, we test the simple hypothesis H_0: $\mu_p - \mu_{p+1} = \delta$. The constant δ equals the amount of the access charge reduction, or some other value (of interest). The alternative hypothesis H_A: $\mu_1 - \mu_2 > \delta$ indicates that the change in ARPM is greater than δ. The alternative H_A: $\mu_1 - \mu_2$? δ implies that the change might be greater than or less than δ. If $\delta = 0$, we are hypothesizing that the mean ARPM did not change, despite the access charge reduction. Alternatively, and more optimistically, if δ

is set equal to the access charge reduction, we are hypothesizing that the entire access charge reduction was "passed through" to consumers. So, it seems natural that we base a test of the hypothesis H_0: $\mu_1 - \mu_2 = \delta$ on the value of $(A_1 - A_2) - \delta$, and we do so by constructing a test statistic analogous to the usual *t*-statistic for testing differences in means.

Specifically, the test statistic is

$$t^* = \frac{(A_1 - A_2) - \delta}{\sqrt{\hat{\sigma}_1^2 / nboot + \hat{\sigma}_2^2 / nboot}} \,. \tag{4}$$

In the denominator of (4) are bootstrap estimates of variances of A_p, which we compute as follows. In a given period we have a large sample of individual bills. From each bill (each j) we have total expenditure r_j and total call duration q_j. The bootstrap sample is built by randomly selecting n bills, with replacement, from this data. Let the re-sampled values of total expenditures across n bills be R_j* and total call duration Q_j*. The bootstrap value of ARPM in some period p is

$$A_b = R^* / Q^* \,, \quad b = 1, \ldots, nboot. \tag{5}$$

The number of bootstrap samples we employed was 400 (*nboot* = 400).[13] From these 400 bootstrap values of ARPM we compute the sample mean and sample variance,

$$\overline{A}_b = \sum_{b=1}^{nboot} A_b \Big/ nboot \tag{6}$$

$$\hat{\sigma}^2 = \sum_{b=1}^{nboot} (A_b - \overline{A}_b)^2 \Big/ (nboot - 1)\,. \tag{7}$$

For each period we compute the sample variances in this way, and use them in the denominator of Equation (4).

Having constructed the value of the test statistic in equation (4), we now must obtain a "critical value" for the test statistic. If we are testing the null hypothesis H_0: $\mu_1 - \mu_2 = \delta$ versus the alternative hypothesis H_A: $\mu_1 - \mu_2 > \delta$, then we must define a rejection region for t^* such that the probability of a type I error, rejecting the null hypothesis when it is in fact true, is some known value, such as $\alpha = 0.05$. Once again we can use the bootstrap to find such as value, following

13 While we used 5,000 bootstrap samples when producing Figure 1, experience suggests that a much smaller number can be used for the purpose of estimating the mean and variance of the empirical distribution.

the suggestions of Horowitz (1997). The basic idea is that for each of the 400 bootstrap samples we constructed initially, we will carry out another bootstrap experiment in which we compute t^*. An empirical distribution of t^* is constructed, like Figure 1, and the 95th percentile, t_c, of that distribution used as the $\alpha = .05$ critical value for a one-tailed test. Consequently a 90% interval estimate of a parameter β using an estimate b is $b \pm t_c \times se$, where se is a standard error, in our case the bootstrap standard error. The critical values are recomputed for every test. Thus, we are able to provide an answer the question of whether there is any statistically significant evidence from which we can conclude that long-distance carriers have passed through the access charge reductions, or not.

The bootstrapping procedure we employ, known as the "double bootstrap" (Mooney and Duval, 1993, p.41) is infrequently used in the economics empirical literature for two reasons. First, in most economic applications the estimation procedures have known asymptotic covariance matrices. In such a case the pivotal statistic will use in the denominator the asymptotic standard error, which is recalculated in each resample. Our double bootstrap uses a second resampling so that the bootstrap standard error can be used in place of the asymptotic standard error. As Moody and Duval (1993, p.41) observe, "[t]he double bootstrap is the most general approach to the percentile-*t*, but it will clearly increase the overall computational effort by a factor of the number of "re-resamples" one undertakes to determine 'the bootstrap standard error' in each resample." In our case this is a factor of 400. The large computational burden, and the lack of ready-made software, limits the use of the double bootstrap.

IV. Results

Figure 2 shows sample ARPMs for MCI and AT&T, respectively, on a monthly basis for the entire sample period.[14] We note that ARPM is subject to nontrivial fluctuations month to month, a consequence primarily of the sampling procedure used to collect the data. While trends in ARPM appear generally downwards, the data is subject to sufficient fluctuation to necessitate statistical testing.

Figure 2 masks another complication, loosely related to the issue of the timing of cost-induced price reductions that should be addressed in our analysis. In particular, the dates given in Figure 2 refer to the billing date (i.e., the last day on which changes for a current bill are generated). Thus, a bill with a date of, for example, January 15th, will typically include calls made between December 16th and January 15th. Thus, one could erroneously conclude that a price change did,

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14 Sample sizes for AT&T unfiltered (filtered) in the three periods (I, II, III) for are 3,925 (3,742), 5,689 (4,466), and 6,286 (5,988), respectively. Sample sizes for MCI unfiltered (filtered) in the three periods (I, II, III) for are 662 (634), 849 (805), and 1,335 (1,240), respectively.

or did not, occur in a given period as a result of using data applying to an earlier period. In order to avoid this complication, we do not use data from bills with billing dates in July-97 nor January-98 (the transition months for the three periods), as these bills illustrate the difficulty described above. Bills from January-97 are not excluded because no change in access charges occurred then, or in the previous month.

Table 3 and 4 present the statistical results for evaluation of flow through by AT&T and MCI. Note that the columns labeled "ARPM Reduction" are defined as the earlier period ARPM minus the later period ARPM, so that a negative entry indicates an *increase* in ARPM between the specified periods. The largest such increase is observed for AT&T using the weighted sample between periods II and III.

We turn now to the primary purpose of our analyses -- the evaluation of whether mandated reductions in switched access charges were flowed through to consumers of long distance telephone services. One may evaluate if the observed differences in ARPM across periods are statistically consistent with the stated reductions in access charges (from Table 1) by determining if the desired access reduction lies within the bootstrap 90% confidence intervals.

Inspection of Tables 3 and 4 illustrate several of the complexities of evaluating the flow through of costs into prices. We note first that, should any

90% confidence interval (CI) contain the value zero, then one cannot reject the claim that ARPM did not change between the specified periods. Thus, there is no statistical difference for AT&T's or MCI's ARPMs between periods II and III. In most cases, however, the CI's do not contain zero, so that statistically significant changes in ARPM were seen to have occurred.

Turning to AT&T first (Table 4), we find that ARPM declined sufficiently to be consistent with a 100% flow through of reductions in switched access charges between periods I and II, II and III, and periods I and III in the unfiltered sample. In the filtered sample, the results are somewhat different. AT&T's ARPM reduction exceeds the access charge reduction between Periods I and II, but 100% flow through is rejected between Periods II and III. Over the entire period, Periods I to III, the reduction in AT&T's ARPM is consistent with 1005 flow through. On balance, the evidence suggests that either AT&T flowed-through access charge reductions completely, or else failed to do between Periods II and III with a shortfall of no more than 0.002 cents per minute.

The results for MCI are similar, although noticeably stronger than those for AT&T. In every case, we find 100% flow through or, as commonly, flow through in excess of 100%. For the unfiltered sample, we find that ARPM among sampled customers fell between Periods I and III by more than 0.015 with 95% probability, while the reduction in access costs was 0.0105 per minute. In every case it appears that MCI has reduced average prices sufficiently to provide customers with the benefits of the access cost reductions, and in half the cases reduced average prices by more than access charge reductions.

On balance, our findings suggest that flow through is a fairly general but, perhaps, not universal phenomenon. While MCI appears to flow through access reductions fully (or even more than fully), the situation with AT&T is somewhat cloudier. There is no question, regardless of the sample or access charge figures used, that AT&T reduced prices at least as much as access charges were reduced between period I and II. The transition from period II to III, at least in the weighted sample, appears to be the source of difficulty. The access charge reduction associated with this point is small compared to that implemented earlier, and this circumstance may contribute to our findings.

In summary, the analysis presented here provides strong but qualified evidence that mandated reductions in switched access charges have generally been associated with reductions in prices sufficient to reduce ARPM enough to "flow through" cost savings to customers. MCI appears to have reduced rates more than access charges over the entire sample period. AT&T's ARPMs, while falling in a manner consistent with full or 100% flow through after the first reductions in June-1999, did not fall as required for the smaller reduction made in January-1998. However, taking the relevant periods as a whole, we find 100%

flow through of access charge reductions, as calculated by us, in both unweighted and weighted sample analyses. Using the higher total access reduction given by Brandon and Taylor, however, weighted sample analyses suggest inadequate price reductions, although the discrepancy is quite small.

V. Conclusion

Evaluation of the link between incremental cost changes and price changes is of interest for at least two reasons. First, despite theoretical arguments against the usefulness of the link for evaluating competition, many analysts would undoubtedly find a valid demonstration of a one-to-one linkage to be good, if not sufficient, evidence of effective competition. Second, and more importantly, the existence (or nonexistence) of flow through (primarily in regulated markets) in the third sense defined in this paper will continue to be a contentious issue of some political importance. Regulated bodies that implement cost reductions contrary to the interests of powerful firms might be unwilling to do so unless they believe consumers would enjoy price cuts as a result. Thus, it is important to find a valid approach to the evaluation of this phenomenon.

This article provides that valid approach. Several points should be emphasized. First, flow through is a phenomenon that characterizes firms, not individual customers or individual prices. Given this, any evaluation of flow through must utilize a statistic characterizing a firm's pricing. We use average revenue per minute here as a natural candidate for such a study in the long distance industry. Most importantly, though, for any set of customers, and for any time interval, there is only one value for the ARPM (or any other suitable price index). As a results, no conventional test of the significance of any change in ARPMS is possible. To circumvent this difficulty, we utilized a bootstrap procedure which facilitates valid tests of the flow-through hypothesis.

We applied our method to a large, public sample of customer long distance bills, in an attempt to determine if AT&T and MCI, the two largest U.S. interexchange carriers at the time, flowed through mandated reduction in switched access charges in the late 1990s. We both calculated change in access charges as documented in the appendix, and used estimates of these changed from an alternative source.

Our results provide relatively strong support for flow through of access reductions in the sample period. in the case of MCI, 100% or greater flow through is seen in all cases in all samples. Results for AT&T also indicate flow through, though there the evidence is somewhat more muted. In particular, the small reduction in access charges instituted in December-1997 is not mirrored in prices, although the sample periods taken as a whole, we find either 100% flow through, or else something close to it. These findings are consistent with the hypothesis that the U.S. residential long distance market was effectively competitive during the sample period.

Despite its shortcomings, flow through is likely to remain a topic of considerable public interest for the foreseeable future. Potential applications of the concept in newly deregulated electric and natural gas markets are apparent. We believe the use of the bootstrap to evaluate flow through in these and other cases will be a useful tool, and we urge further research on this topic.

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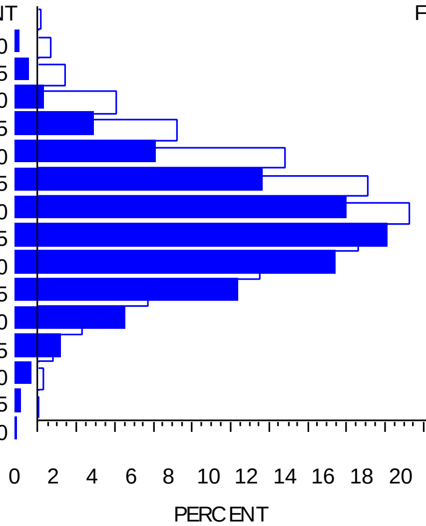
Figure 1. Empirical Distribution of Bootstrap



ARPM MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0.1250	10	10	0.20	0.20
0.1275	32	42	0.64	0.84
0.1300	71	113	1.42	2.26
0.1325	203	316	4.06	6.32
0.1350	360	676	7.20	13.52
0.1375	642	1318	12.84	26.36
0.1400	857	2175	17.14	43.50
0.1425	964	3139	19.28	62.78
0.1450	830	3969	16.60	79.38
0.1475	577	4546	11.54	90.92
0.1500	285	4831	5.70	96.62
0.1525	116	4947	2.32	98.94
0.1550	39	4986	0.78	99.72
0.1575	13	4999	0.26	99.98
0.1600	1	5000	0.02	100.00

Figure 2. Sample Mean ARPMs for AT&T and MCI

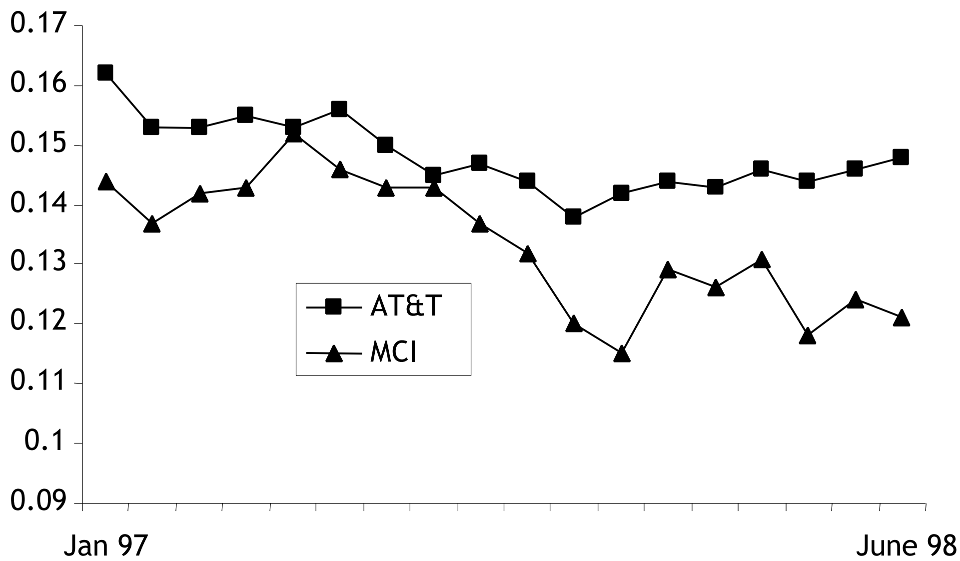


Table 1.

Estimates of Access Reductions*

Period	Per Minute[a]	USF[b]	NECA[c]	PICC[d]	Total	Change	NERA Change[f]
I	0.0604	-	0.0069	-	0.0673		
II	0.0518	-	0.0068	-	0.0586	(0.0087)	(0.0086)
III	0.0404	0.0089	-	0.0074[e]	0.0568	(0.0018)	(0.0045)
						(0.0105)	(0.0131)

* Figures may not add due to rounding.
[a] Trends in Telephone Service (Feb. 1999), Table 1.2.
[b] The tax rate on interstate/international revenue is 5%, which is calculated by recovering an amount equal to 0.72% tax on interstate, interstate, and international revenues and 3.19% tax on interstate and international revenue on interstate/international revenues alone. See DA 97-2623. The total USF payments (5% multiplied by international/international revenues) are divided by total interstate/international minutes. Total interstate/international revenue from the PNR dataset during period III is $238,645. Five percent (5.04%) of these revenues (12,022) are divided by interstate/international minutes (1,348,381) to estimate per minute costs.
[c] In Periods I and II, the per-line NECA assessment was $0.5371 and $0.5144, respectively (Trends in Telephone Service, Table 8.2, February 1998). Per minute estimates are calculated by multiplying the per-line assessment by the total lines (PNR data) in each period, then dividing this figure by total interstate/international minutes. Total lines are estimated from data on subscriber line charges. We assume the following: one line for all customers; two lines if subscriber line charges exceeds $3.50 but is less than or equal to $8.50; three lines otherwise.
[d] The average PICC was $0.49 per-line for primary lines, and $1.50 for secondary lines. Per minute estimates are calculated by multiplying the per-line assessment by the total lines (see above) in each period, then dividing this figure by total interstate/international minutes (Trends in Telephone Service, Table 1.1, February 1999).
[e] The FCC estimates the PICC charges on a per minute basis in the February, 1998, version of Trends in Telephone Service. Their estimate is $0.0088. If we replace our estimate (based on the PNR data) with the FCC's estimate then the access reduction between Periods II and III falls to $0.0005.
[f] Brandon and Taylor (1998).

Table 2. Accuracy of Access Charge Reductions

(Each series normalized to 1.00 in Period I)

Period	MCI Confidential*	Beard, et al.,	Brandon-Taylor
I	1.00	1.00	1.00
II	0.87	0.87	0.87
III	0.85	0.84	0.81

* MCI calculation based on actual billing data. Data provided to authors on a confidential basis, and used here with permission.

Table 3.

Statistical Tests of ARPM and Access Charge Reductions for AT&T

Period	*ARPM Reduction*	*Bootstrap 90% Confidence Interval*	*Estimated Access Reduction*	*Flow-through Assessment*
Sample I				
I – II	0.0112	0.0085 < δ < 0.0137	0.0087	100%
II – III	-0.0020	-0.0074 < δ < 0.0032	0.0018	100%
I – III	0.0092	0.0034 < δ < 0.0141	0.0105	100%
Sample II				
I – II	0.0118	0.0089 < δ < 0.0146	0.0087	> 100%
II – III	-0.0031	-0.0061 < δ < -0.0002	0.0018	< 100%
I – III	0.0087	0.0058 < δ < 0.0113	0.0105	100%

Changes in ARPM may not add due to rounding. Confidence intervals for δ indicate values δ must assume to conclude ΔARPM = δ in a statistical sense. "<" indicates "less than" 100% flow-through.

Table 4.

Statistical Tests of ARPM and Access Charge Reductions for MCI

Period	*ARPM Reduction*	*Bootstrap 90% Confidence Interval*	*Estimated Access Reduction*	*Flow-through Assessment*
Sample I				
I – II	0.0200	0.014 < δ < 0.026	0.0087	> 100%
II – III	0.0012	-0.004 < δ < 0.006	0.0018	100%
I – III	0.0211	0.015 < δ < 0.027	0.0105	> 100%
Sample II				
I – II	0.0137	0.0080 < δ < 0.020	0.0087	100%
II – III	0.0039	-0.001 < δ < 0.009	0.0018	100%
I – III	0.0176	0.0012 < δ < 0.023	0.0105	100%

Changes in ARPM may not add due to rounding. Confidence intervals for δ indicate values δ must assume to conclude ΔARPM = δ in a statistical sense. "<" indicates "less than" 100% pass-through.