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ATTACHMENT 4

A Statistical Analysis of the Flow-Through of Reductions in Switched Access Charges to Residential Long Distance Rates

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Executive Summary

The Federal Communications Commission (FCC) has mandated annual reductions in interstate access charges over the past ten years or more. These reductions have been contemporaneous with substantial reductions in the rates paid by long distance customers. Between 1992 and 1997, long distance rates fell by 24 percent and by twice the amount of access reductions, according to FCC Chairman William Kennard.[1] The issue of whether this reduction in long distance rates has been "enough," however, has become a major focus of attention in the regulatory community. The Regional Bell Operating Companies (RBOCs) and other local exchange carriers (LECs) claim that the long distance interexchange carriers (IXCs) failed to fully "pass through" access reductions. The long distance carriers claim to have fully passed through access reductions, and to have even exceeded a full pass through over certain periods of time.

This report examines the issue of pass through over the time period January 1997 through July 1998. During this time, the FCC substantially restructured and reduced interstate access charges, and, as a result, the debate about pass through has become even more intense. Our analysis utilizes a publicly available database of residential long distance customer

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[1] W. 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].

bills compiled by PNR and Associates, Inc. The database consists of approximately 2000 bills each month provided to PNR in response to surveys mailed to a cross section of consumers. We analyze the entire database of MCI (now MCI WorldCom) customers.

Pricing of long distance service is often complex. A myriad of tariffs and promotional plans are offered, and the nature of these offerings changes frequently. For example, in 1997 MCI introduced 5¢ Sunday calling. Other long distance carriers offer competing discount plans. These plans often have provisions more complex than simple uniform pricing. Under these conditions, pass through must refer to "average" prices, rather than to one or a few specific tariffs. Pass through is a property of seller costs and revenues arising from competition, not a property of a particular tariff. If competition is "working," and other costs of the industry are stable, then the average price received by the long distance carriers should roughly track large changes in average access charges. Indeed, this is precisely the test proposed by the LECs. As stated by Roy Neel, President and CEO of USTA, "reductions [in access charges] have not been accompanied by a reduction in long distance rates, so the IXCs are indeed making a substantial, new profit." If the average price paid per unit tracks average cost of production, then no new profits will be earned when access charges fall. The statistical analysis in this report demonstrates conclusively that the average revenue per minute of MCI exhibits complete pass through of access charge reduction to consumers.

Over the 18-month period evaluated by our study, there are three distinct access periods: Period I is from January-97 through June-97; Period II is from July-97 through December-97; and Period III is from January-98 through June-98. Changes in access charges occurred between each of these three periods (July-97 and January-98), allowing a number of tests of the pass through hypothesis. Access charge estimates provided by NERA, and our own estimates, which vary somewhat from NERA's, are provided in Table I below.[2]

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[2] Paul S. Brandon and William E. Taylor (NERA), *AT&T, MCI, and Sprint Failed to Pass-through the 1998 Interstate Access Charge Reductions to Consumers* (prepared for the United States Telephone Association (USTA)).

Table I.

Access Charge Periods

Period	*Dates*	*NERA*	*Hill/Beard*
I	Jan-97 through June-97	0.0686	0.0673
II	July-97 through Dec-97	0.0600	0.0586
III	Jan-98 through June-98	0.0555	0.0568
Reductions in Access Charges between Periods			
I to II		0.0086	0.0087
II to III		0.0045	0.0018
I to III		0.0131	0.0105

See Appendix B for details on calculations.

A graphical depiction of the monthly ARPM calculations, based on the PNR data, is provided in Figure I.[3] Figure I illustrates two important points. First, the trend in ARPM is clearly down over the 18-month period. Second, when compared to the access reductions provided in Table I, the mean values of ARPM (for each period) clearly indicate that the reductions in ARPM exceed the estimated reductions in access charges in Table I.

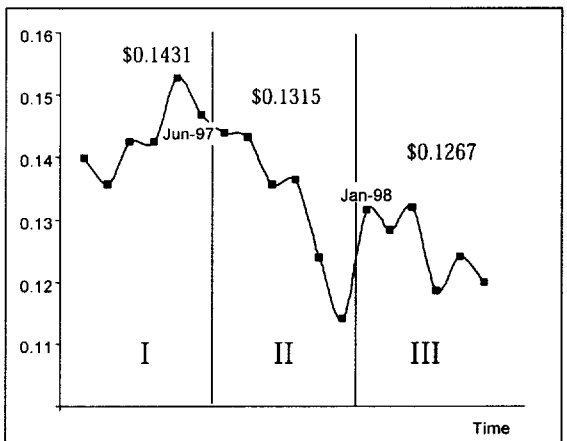

Figure I. ARPM

In addition to comparing the changes in ARPM to estimated access charge reductions, we have also performed statistical tests to confirm our conclusion that pass through occurred. Statistical testing is essential to the

[3] Monthly ARPMs for all samples are provided in Appendix C.

economic analysis of data such as this. Without it, no confidence can be attached to the conclusions reached using the data. The NERA study contains no statistical tests.

We utilize a bootstrap analysis of the PNR data to evaluate whether MCI residential customer average revenue per minute has fallen in amounts equal to reductions in average switched access charges. The bootstrap methodology is termed a "resampling procedure," and is widely accepted by statisticians. Use of this technique is required by data limitations.

Our bootstrap analysis provides strong statistical evidence that MCI's ARPM has fallen over time in a manner consistent either with 100% pass through of access charge reductions, or else has fallen by more than the reductions in access charges depending on the time period studied. Table II provides a summary of our findings for the broadest sample from the PNR data. Over the 18 month period (between Periods I and III), ARPM fell by more than the reduction in access charges, a statistically significant result. Within sub-periods of the 18 months, either full pass through or greater than full pass through occurred.

Table II.

Statistical Tests of ARPM and Access Charge Reductions

Period	*ARPM Reduction*	*Bootstrap 90%Confidence Interval*	*Estimated Access Reduction*	*NERA Access Reduction*	*Flow-through Assessment*
I - II	0.0200	$0.014 < \delta < 0.026$	0.0087	0.0086	> 100%
II - III	0.0012	$-0.004 < \delta < 0.006$	0.0018	0.0045	100%
I - III	0.0211	$0.015 < \delta < 0.027$	0.0105	0.0131	> 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 "more than" 100% pass-through.

Our findings contradict those of NERA. The NERA study finds that not only did MCI fail to pass through access reductions, but that MCI's average prices rose during this period of access reform, a conclusion that is completely at variance with our findings. In fact, the NERA study's finding appears to be at variance with standard economic theory.

A careful look at the path of MCI's ARPM over this 18 month period reveals the source of NERA's peculiar findings. Figure II below reproduces the graph in Figure I, but highlights the particular time periods selected by

NERA to compare ARPM (shaded areas). The NERA analysis uses only data from the periods indicated. As is apparent from this figure, NERA's conclusion of increasing ARPM is a product of the selection of periods over which they compare rates. Indeed, our statistical analyses demonstrate that NERA's conclusions can be supported only by selecting that particular two-month pair to calculate ARPM for 1997.

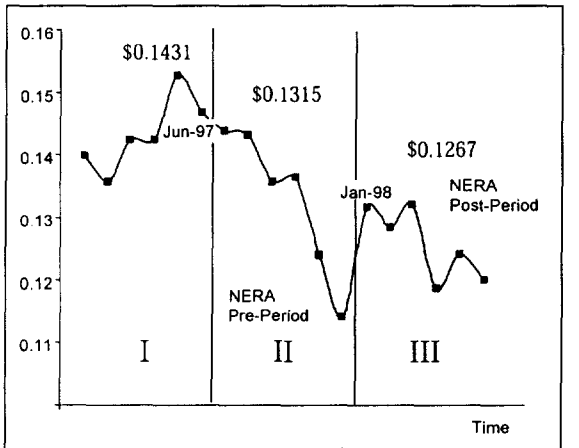

Figure II. ARPM

For many reasons, the changes in long distance prices are not expected to track access reductions precisely on a month-to-month basis. Indeed, it appears probable that the long distance carriers reduced rates *in advance* of scheduled access charge reductions. The lesson is that one must approach the analysis of pass through with caution and care. We believe that our findings provide the strongest evidence to date that pass through occurs in the long distance marketplace.

The debate over pass through will undoubtedly continue. Nevertheless, we urge policymakers to look at broad structural trends and long term pricing behavior in the long distance market. There is no model of competition that conforms to the expectations of contemporaneous and precise mirroring of access charge changes in long distance rates. However, a careful analysis, such as is offered here, shows that pass through does, in fact, occur.

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1.0 Introduction

Current regulatory procedures in the U.S. require that interexchange carriers (IXCs) pay local exchange companies (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.[4] These access charges constitute a substantial portion (in some cases around 40%) of IXC revenues, and generate a multibillion dollar flow from long distance customers to local service providers.[5]

Access charges have long been a serious issue of regulatory debate in the United States. This debate has pitted the IXCs, whose customers pay these charges through the price of long distance services, against the LECs who receive these payments. Unsurprisingly, the IXCs have long supported reductions in access charges, while the LECs traditionally have opposed such efforts. Considerable disagreement regarding the proper methodology for determining access charges is evident, and a number of prominent economists have contributed to this debate.

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* This study was conducted at the request of MCI Worldcom, Inc..

[4] These arrangements have their origins in the period of the 'break up' of the Bell System in the early to mid 1980s.

[5] See J. Lande and K. Rangos *Telecommunications Industry Revenue: TRS Fund Worksheet Data* (November 1997), p. 12.

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.[6] Summarized in a crude form, the LECs, who are recipients of access charge income flows, often argue that reductions in switched access charges will not be passed on to customers, particularly residential customers, in the form of lower prices due to a claimed lack of competition in the long distance industry. Further, it is simultaneously argued that allowing entry by the Bell Operating Companies (BOCs) into the in-region, interLATA toll market will increase long distance competition and eliminate the problem. In contrast, the IXCs argue that access charge reductions lead directly to reductions in prices and to other benefits to consumers, and that the competitive nature of the long distance industry assures this outcome. Although the FCC has occasionally stated that pass-through of access charge reductions has occurred, it is clear that this issue remains a contentious one.[7]

This report examines the extent to which a major long distance service provider, now MCI WorldCom (MCIW), passed through FCC-ordered reductions in interstate switched access charges that went into effect in July-97 and January-98. At the request of MCIW, we have undertaken a careful analysis of changes in average prices paid for direct dialed, interstate calls by MCI customers over the time period January-97 through June-98. Our analysis utilizes a publicly available database of long distance customer bills compiled by PNR and Associates, Incorporated (the *Market Share Monitor*). PNR's *Market Share Monitor* is the same database examined by Paul S. Brandon and William E. Taylor in the NERA-conducted study on this same topic, *AT&T, MCI, and Sprint Failed to Pass-through the 1998 Interstate Access Charge Reductions to Consumers*, prepared for the United States Telephone Association (USTA), a lobbying organization representing local exchange carriers. In addition to our statistical assessment of MCI's flow-through of access charge changes, we evaluate the analysis of flow-through offered by Brandon and Taylor.

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[6] Similar discussions of the efficacy of intrastate access charge reductions have occurred in many states.

[7] For example, see W. Kennard, *A New Federal Communications Commission for the 21st Century*, (March 17, 1999) and J. Lande and K. Rangos, *Telecommunications Industry Revenue: TRS Fund Worksheet Data* (November 1997), p. 12.

The findings of our statistical analysis of relevant MCI residential customer calls can be summarized as follows. Our statistical analysis of all MCI customer calls in the PNR sample for the eighteen-month period January-97 through July-98 unambiguously shows that MCI passed through all access charge reductions during this time period. In fact, statistical tests reveal that MCI reduced prices by more than the access charge reductions in some cases.

These findings contradict the findings of Brandon and Taylor. Brandon and Taylor's analysis, however, was based solely on a comparison of calls occurring in November-97 through December-97, and calls occurring in various periods in early 1998 (the relevant period varying by company). The extended analysis offered here illustrates the source of Brandon and Taylor's findings, and shows that these findings are incorrect and misleading, driven primarily by the inappropriate selection of very narrow time periods for analysis.

2.0 What is Flow-through?

Generally, the "flow-through debate" concerns the effect of a change in seller costs (access charges) on the prices paid by customers, or on some index of those prices. Ordinarily, any change in the marginal costs of producing goods will lead to a change of some sort in the corresponding observed prices paid by consumers for those goods.[8] The pass-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 changes should 'fully reflect' (in some sense) any changes in the incremental costs of providing goods.

In the common parlance of the industry, the failure to flow through access charge reductions would manifest itself in higher profits for IXCs, other things equal. When faced with an access charge reduction, IXCs can, in principle, increase their profits at the expense of consumers and local phone companies by failing to reduce rates sufficiently, holding rates constant, or actually raising rates. Complete flow-through implies that

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[8] See J. Tirole, *The Theory of Industrial Organization* (1988), p. 67, for an analysis of the relationship between price and cost changes for a firm with market power.

profits (or profits per unit) should not increase over time when costs fall. Of course, the more competitive is the industry, the closer to zero will be the economic profits of the firms.

This description of flow-through suggests a straightforward manner by which to measure its presence or absence. Profit is total revenue minus total cost. If the output of the firm is minutes of long distance usage, then average revenue per minute (ARPM) is total revenue divided by total minutes, and average cost per minute is total cost divided by total minutes (ACPM). If the per-minute costs are reduced and flow-through occurs, then ARPM may fall in accordance with the new level of ACPM. Access charges do not solely determine ACPM, but if other elements of cost do not change, then the change in ARPM will equal the change in average access charges per minute. Thus, *flow-through occurs, assuming other costs constant, if the change in ARPM equals the change in average access charges per minute.* This ensures that no "substantial new profits" accrue to the long distance industry.

This definition of flow-through is required if flow-through is to be used as a rough proxy for the degree of competition in the long distance industry. In competitive markets, economic profits tend to zero, but there is no general rule that says all prices charged by a multiproduct firm will exactly reflect a change in unit cost, whatever the degree of competition. Even the multiproduct competitive analysis of MacDonald and Slivinski (1987), in which every good is sold at its marginal cost, will not produce 100 percent pass-through unless the industry exhibits long run constant returns to scale so that all quantity changes are accommodated primarily through entry. With scale and scope economies, the multiproduct competitive analysis of the contestibility-based 'weak invisible hand' theorem of Baumol, Bailey and Willig (1977) does not produce 100 percent pass-through because optimal prices are marked up in the Ramsey manner (by inverse elasticities), and the various demand elasticities will change differently as prices change. Thus, economic theory implies that no simple pass-through relationship for a given tariff (among many) will exist.[9]

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[9] Measuring flow-through in terms of tariffed price changes is even more problematic in the single product case. Since a monopolist changes its price by an amount equal to, less than, or more than a change in marginal cost, depending on the assumptions about the curvature of demand and shape of the marginal cost function (among other factors),

Defining flow-through in terms of ARPM is also consistent with the definition frequently adopted by the local exchange carriers. For example, Roy Neel, President and CEO of USTA, states:

> The ILECs were ordered to lower the per-minute interstate access charges to IXCs and they have done so. These reductions have not been accompanied by a reduction in long distance rates, so the IXCs are indeed making a substantial, new profit (Letter from Roy Neel to William E. Kennard, February 11, 1998).

Mr. Neel correctly notes that "flow-through" is a determinant of changes in sellers' profits.

Our test of flow-through, as just defined, is conducted as follows. ARPM is estimated using bills of MCI customers in the PNR sample over the time period January-97 through June-98. The changes in ARPM over this time period are compared to estimates of access charge reductions. Both fixed and usage sensitive components are present in interstate switched access charges during our sample period; moreover, access charges often vary by region and by other factors. Thus, as in the case of revenues, we must obtain an estimate of average changes in access charges to compare to changes in ARPM. In order to avoid debate over the magnitude of access charge reductions, we compare the changes in ARPM to the changes in Brandon and Taylor's access charge estimates. We also provide our own estimates of access charge reductions. In addition, our analysis is flexible enough to allow a comparison of any estimate of access reductions to the changes in the ARPMs calculated from the PNR data.

2.1 Complexities in Measuring Flow-Through

Our statistical analysis presumes that measuring flow through on a period-to-period basis has merit. In fact, there are good reasons to believe that such an analysis is inappropriate.

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distinguishing between monopoly and competitive behavior is not a straightforward task. See J. I. Bulow and P. Pfleiderer. (1983). A note on the effect of cost changes on prices, *Journal of Political Economy*, 91: 182-85.

2.1.1 Timing of Rate Reductions

The first reason to question a strict period-to-period analysis arises from the ongoing nature of seller-buyer relationships 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 pass-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. Similarly, even if such anticipation did not occur, competition, which 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.

2.1.2 The Structure of Access Charges

A second complexity arises from the somewhat radical change in the structure, and not simply the level, of access charges in January-98. 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.[10] Unfortunately, the IXCs did not have reliable information on secondary lines and were forced to estimate the number of lines and average these charges across all customers.[11] Additionally, some IXCs (including MCIW) do not bill customers that do not make long distance calls in any given month. 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

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[10] The charge for the primary line is nearly equivalent to the NECA assessment in 1997. The NECA assessment, however, did not vary by primary or secondary lines. See Appendix B.

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

basis.[12] Prior to January-98, 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.

2.1.3 Changes in Other Costs

A third complication is that access charges are not, of course, the sole determinant of per minute costs (ACPM) for MCIW or any other IXC. The comparison of changes in ARPM to changes 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 increase costs over the sample period. Likewise, changes in output levels, and the potential scale effects from these changes, can complicate the interpretation of the results. While some telecommunications functions involve "lumpy" capital equipment that may give rise to scale economies, it is unwarranted to use this observation to conclude that long distance residential service itself is therefore subject to increasing returns to scale. In particular, the marketing functions of MCIW and other IXCs are very costly, and the recruitment and retention of customers may result in long distance service exhibiting any pattern of returns.

3.0 Calculating ARPM

It is clear from the above discussion that correctly evaluating pass-through in a valid economic framework is not easy. Competition, if it induces pass-through, presumably does so by requiring that, after costs fall, prices fall in such a manner that no new rents accrue over time to the sellers as a result of the cost reduction. Competition presumably causes prices to fall, on net, so that the cost reduction benefits consumers and not producers, at least in the long run. Since producer profits are the difference between revenues and costs, in the absence of important scale effects and other changes, revenues per unit, on average, should exhibit the required decline

[12] See Appendix B for estimates of the USF charges.

under competition. This is the primary means by which pass-through has been empirically tested, and this approach is used by Brandon and Taylor.

3.1 Definition of ARPM

An important conceptual issue arises when average revenues per minute (ARPM) are used as a price index to evaluate pass-through. If competition implies 100 percent pass-through for some set of services, then ARPM must be calculated for the IXC 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 dial residential calling) under either different tariffs or a nonlinear tariff. Customer A pays $10 for 100 minutes worth of calls, while B pays $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 average prices, while such averaging has the opposite effect in the contrary circumstance.

Pass through clearly applies to the IXC's ARPM, not that of individual buyers. Pass through is a consequence of competition among sellers and, as discussed above, refers to the revenues and costs of the sellers, not the buyers. When ARPM is calculated correctly, and is that of the IXC, then multiplying ARPM by minutes will yield seller proceeds from the sale of those minutes. Presumably, an identical logic applies to access charges. Competition, which is the source of pass through, implies only that changes in seller revenues are equivalent to changes in seller costs. The calculation of ARPM for a *seller* from a sample of buyers must be approached with caution, and certainly avoid the fallacious, per-customer calculation described above. This issue becomes even more critical when sample data weighting is used, as will be seen below.

3.2 Calculating ARPM from the PNR Sample

ARPM, calculated correctly, appears to be the best price index for evaluating pass-through claims. ARPM reflects actual prices received by the IXC (i.e., IXC revenues), and imposes an averaging of any fixed monthly charges based on the actual observed minutes of use. ARPM should reflect the total revenues paid by the consumers to the IXC, including surcharges, discounts, fees for per-paid minutes, and so forth.[13]

Conceptually, ARPM for a *given* set of *n* customers for a *given* time interval *t* is

$$ARPM_t = \frac{\text{Total Revenue}_t}{\text{Total Minutes}_t} \tag{1}$$

where **Total Revenue** is the sum of all relevant expenditures by the *n* consumers, and **Total Minutes** is the sum of all long distance minutes "consumed" by the *n* customers. 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 charge (PICC).

The actual calculation of ARPM for MCI, using the PNR data, is

$$ARPM_t = \frac{\sum_{i=1}^{n}(TSC_t + \lambda SUR_t + \phi PICC_t)}{\sum_{i=1}^{n} Q_t} \tag{2}$$

where the sums are taken over the *n* customers in period *t*, and

TSC_t = time sensitive charges for target calls in *t*

Q_t = minutes of use for target calls in *t*

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[13] Sales taxes that are merely collected by IXCs at the order of state and federal governments are not included.

SUR_t = surcharges to bills in t

$PICC_t$ = charges to recover the FCC-imposed PICC in t

λ = surcharge cost sharing factor, given as the ratio of target minutes of use to total minutes of use in t

ϕ = PICC cost sharing factor, given as the ratio of target minutes of use to target plus international minutes of use (intrastate excluded) in t.

Equation (2) gives ARPM to the carrier as per minute revenues arising from time sensitive charges, time insensitive charges, and the PICC. We restrict target calls to direct dialed, interstate, interLATA calls by residential domestic customers of MCI. 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.[14] Total surcharges are prorated into target (domestic, interstate, interLATA direct dialed) calls using a sharing proportion determined by the ratio of target minutes to total minutes of use. The PICC is pro rated to ARPM for target calls using the entire volume of interstate and international minutes.[15]

3.3 Data

The PNR *Market Share Monitor* data set is a widely used, commercially provided data set based on a voluntary participation survey methodology. PNR and Associates receives and processes 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

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[14] MCIW did not assess USF fees on its residential customers during the first two quarters of 1998.

[15] Several minor variations in the formula given by (2) were also tried, without producing any significant alterations in the findings. For example, one might plausibly question whether international call minutes should be omitted or included in calculating the contribution of PICC to ARPM from target calls. This idea and others like it have a negligible impact on ARPM calculations.

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 compiled on a monthly basis. The durations, distances, origins, destinations, and costs of calls are recorded. The data is presented in Microsoft Access databases, which we imported into SAS® for our computations.[16]

3.4 Sample Selection

Our analysis of the PNR data set is limited as follows. We analyze only bills of MCI customers for the billing date periods January-97 through June-98.[17] Our interest is in residential customers' usage of direct dialed, interLATA, domestic, interstate calls.[18] We do not analyze international or operator-assisted calls, nor calls by consumers who do not receive any services from MCI.

For our analysis, three samples are used. In Sample 1, revenue and usage data for all MCI residential customers' direct dialed, interLATA, domestic, U.S. interstate calls from the PNR data are employed. Some customers are recorded as having negative bills. While such a circumstance may reflect special refunds, we omit them from our analysis.[19] We make no other adjustments to the data.

In an attempt to improve the data by eliminating some observed peculiarities, Sample 1 is modified in the following ways to produce Sample

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[16] SAS Institute Inc., Cary, NC, USA.

[17] MCI customers were selected by: LD_BILCO = 002 (where 002 is PNR's code for MCI).

[18] These calls are selected from the data using the following constraints: CD_CNTRY = Is Null (cell is empty for domestic calls); CD_LLTYP = 0004 (code for interstate/interLATA calls); CD_CTYPA = 0000 (code for direct dialed calls).

[19] Negative bills may reflect a "true up" from billing errors or fraudulent calls in previous periods. The PNR data is not a panel data set, so we cannot account for such occurrences.

2.[20] Some customers appear to have per minute usage charges, for what are recorded as direct dial, interstate, interLATA calls, that exceed the maximum tariff possible during the sample period (i.e., the basic rate schedule). For example, the data includes calls rated at over $2 per minute, well above the maximum basic tariff rate. Monthly charges do not explain these few anomalies because such charges are not usage sensitive. One possibility is that these high charges may result from 900 services recorded as direct dial, interstate, interLATA calls. Thus, in Sample 2, we omit calls with usage charges exceeding MCI's highest tariff rate for presubscribed residential customers.[21]

Lest this restriction to the data raise questions, we note two points. First, we will present analyses that use all sample observations, credible or not. Our conclusions will not change. Second, our goal is not to identify ARPM *per se*, but rather to evaluate changes in ARPM over time.

Sample 3 is constructed by weighting Sample 2 by the weights included in the PNR data. Brandon and Taylor refer to these weights with the statement, 'The database also contains customer weights, which we use to make the sample representative of U.S. households.' (Brandon and Taylor, p. 7, n. 10) Unfortunately, 'representativeness' is not defined here and, in any event, the source of these weights must be examined to justify their use. While Brandon and Taylor argue that the application of the PNR weights causes the weighted sample to be "representative of U.S. households" (p. 7, note 10), the relevant issue for pass-through analysis is whether or not the resulting weighted sample is representative of MCI's (or AT&T's, or Sprint's) customer base. It is unlikely that weights created to make the sample more representative of U.S. households will accomplish this more relevant task. Given that our conclusions are only slightly affected by the use of the PNR weights, the issue of whether or not the weights effectively make the sample more representative of MCI's customer base is not addressed in this report. We do evaluate, in Appendix A, the generic

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[20] The material provided by PNR and Associates describes a three step error checking process.

[21] 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).

problem with the weighting scheme used by PNR and conclude that the weights should be used with great circumspection.

Table 1.

Samples

Sample	*Descriptions*	*Sample Size (Bills)*
1	All MCI Customers with non-negative bills.	3,338
2	All MCI Customers with non-negative bills and all calls rated at less than $0.30 per minute.	3,138
3	All MCI Customers with bills greater than zero and all calls rated at less than $0.30 per minute. Customer revenues and minutes are weighted as described in equation (3).	3,138

Although use of the PNR sample weights must be carefully scrutinized, if these weights are used, then they must be used correctly. In particular, one may not calculate ARPM per customer, and then weight those values. Rather, ARPM using weighting is generally given by:

$$ARPM = \frac{\sum (w_i \cdot R_i)}{\sum (w_i \cdot Q_i)} \tag{3}$$

where R_i is all revenues due from customer i, Q_i are the appropriate minutes of target services for customer i, and w_i is the weight for customer i.

4.0 Results of Calculations

There are 3 distinct access periods in our 18-month sample. The three periods are defined as follows: (a) **Period I** spans January-97 through June-97; (b) **Period II** spans July-97 through December-97; and (c) **Period III** spans January-98 through June-98.[22] Access charges changed between each of the three periods and estimates of these changes are provided in Table 2. Access charge estimates provided by Brandon and Taylor (NERA) are listed

[22] Sample sizes for the three periods (I, II, III) for Sample 1 are 732, 1,037, and 1,569, respectively. For samples 2 and 3, the sample sizes are 663, 973, and 1,502, respectively.

in the Table as well as our own estimates (based on the methodology of Brandon and Taylor). Brandon and Taylor do not provide an estimate of access charges for Period I, but we attempt to estimate one using their methodology. The details of our access charge calculations are provided in Appendix B.

Table 2.

Access Charge Periods

Period	*Dates*	*NERA*	*Hill-Beard*
I	Jan-97 through June-97	0.0686	0.0673
II	July-97 through Dec-97	0.0600	0.0586
III	Jan-98 through June-98	0.0555	0.0568
Reductions in Access Charges between Periods			
I to II		0.0086	0.0087
II to III		0.0045	0.0018
I to III		0.0131	0.0105

See Appendix B for details on calculations.

As shown in Table 2, our access charge estimates differ slightly from those of Brandon and Taylor. Differences in the changes in access charges are more profound. While the reductions in access charges between periods I and II are nearly identical (0.0086, 0.0087), the reductions between periods II and III are much different (0.0045, 0.0018). As a consequence, the difference between periods I and III is also quite different (0.0131, 0.0105). Given that we compare the estimated reductions in access charges to both measures of access charge reductions, we leave it to the reader to determine which access charge estimates are more valid.[23] The fact that flow through is measured by comparing reductions in ARPM to reductions in average access charges, the differences between the two estimates of access charges (and the changes between periods) illustrate some major difficulties in assessing flow-through. When publicly available data is used, both ARPM and access charges are estimated and subject to estimation error. We are unable to make any claim as to the accuracy of our access charges estimates, or those of Brandon and Taylor, as compared to the actual access payments of MCIW or any other IXC.

[23] Note that the FCC has confidential data from MCI, AT&T, and Sprint from which it can assess the reliability of these estimates.

A graphical depiction of our monthly ARPM calculations for MCI (based on equation 2) using Sample 2 is provided in Figure 1. The three access periods, as well as the mean ARPM for each of these periods, are indicated in the figure.

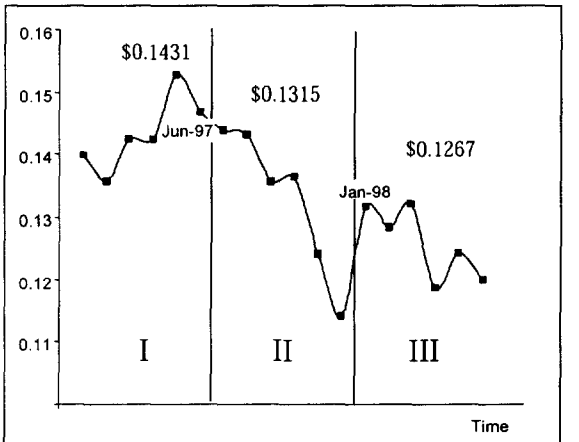

Figure 1. ARPM

Figure 1 illustrates three important points. First, the trend in ARPM is clearly down over the 18-month period. Second, when compared to the access reductions provided in Table 2, the mean values clearly indicate that the reductions in ARPM exceed the reductions using either estimate of access charge reductions. For example, ARPM fell by $0.0116 between periods I and II, exceeding the estimated reductions in access charges of $0.0086 and $0.0087. Likewise, between periods II and III, ARPM fell by $0.0048, exceeding both the $0.0045 and $0.0018 estimated reductions in access charges. Over the entire sample period (I to III), the estimated access charge reductions of $0.0131 and $0.0105 are exceeded by ARPM reductions of $0.0164. The ARPM estimates for all three samples are provided in Table 3.

Table 3.

ARPM and Access Charge Estimates

Period	NERA Access Estimates	Hill-Beard Access Estimates	ARPM: Sample 1	ARPM: Sample 2	ARPM: Sample 3
Estimates					
I	0.0686	0.0673	0.1513	0.1431	0.1433
II	0.0600	0.0586	0.1340	0.1315	0.1298
III	0.0555	0.0568	0.1308	0.1267	0.1254
Differences					
I to II	0.0086	0.0087	0.0173	0.0117	0.0136
II to III	0.0045	0.0018	0.0033	0.0048	0.0044
I to III	0.0131	0.0105	0.0205	0.0164	0.0180

Using Table 3, one could simply compare the changes in ARPM to the estimated access charge reductions, as did Brandon and Taylor, and informally conclude that flow-through did occur. However, the ARPMs in the table are estimated from a sample of MCI customer bills. Therefore, in order to reach a valid conclusion about flow-through, we need to perform a statistical test on the differences in ARPM and whether or not those differences are equal to, less than, or greater than the access charge reductions.

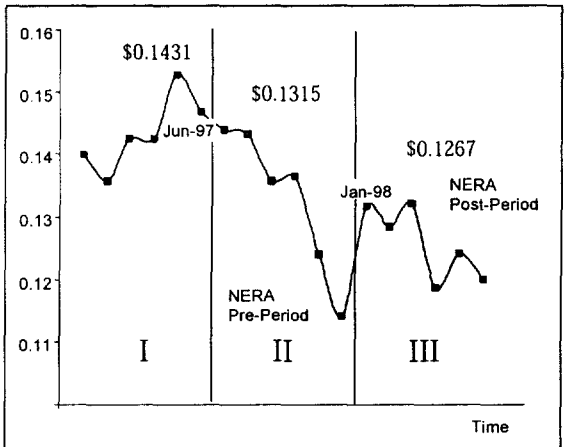

Figure 2. ARPM

The third point illustrated by the figure relates to the analysis of Brandon and Taylor. Specifically, in Figure 2, we illustrate the sample periods chosen by Brandon and Taylor in their analysis of flow-through.

Figure 2 clearly shows that Brandon and Taylor's conclusion that ARPM rose after the access reduction is based on the peculiar selection of months in Period II (November-97 and December-97). We show later that only the particular time periods selected by Brandon and Taylor allowed them to reach their conclusions. In any event, one should use data from all relevant time periods to reach valid conclusions.[24]

5.0 Statistical Formulations for ARPM Comparisons

The simple comparison of ARPMs above can be a form of evidence that access charge reductions did or did not flow through to the consumer. Such evidence was the only evidence provided by Brandon and Taylor. However, a comparison of numerical values is not a statistical test. Without a test we cannot determine if the differences in these ARPMs are statistically significant. Statistical tests allow us to attribute a degree of confidence in our assessment of flow through.

As an example of a statistical test, suppose two large microeconomic principles classes are taught the same material. In one class the instructor uses traditional chalkboard lectures, while in the second the instructor uses multimedia presentations. The classes are given a midterm exam, and we wish to determine if the students taught using multimedia presentations have a higher mean test score. The formula we would use to carry out the test is

$$t = (\bar{x} - \bar{y}) \Big/ \sqrt{\frac{S_x^2}{N_x} + \frac{S_y^2}{N_y}} \tag{4}$$

where $\bar{x}$ and S_x^2 are the sample mean and sample variance from the class of N_x students taught using multimedia, and $\bar{y}$ and S_y^2 are the sample mean and variance from the class of N_y students taught using chalkboard lectures. If the class sizes are large, and if multimedia teaching leads to higher test scores, the values of the t-statistic tends to be large. If the value of t is greater than 1.645, the critical value from the standard normal distribution, then we reject the 'null' hypothesis that there is no difference in the

[24] In particular, the timing of price changes is complex. See Section 2.1.1.

performance in the two classes and conclude that the multimedia class has a higher average score. This test is subject to a Type I error (rejecting the null hypothesis that the means are the same when in fact they are) of 5 percent. If we wanted to test whether the use of multimedia increased the mean test score by 3 percentage points, we would simply subtract 0.03 from the numerator of the t-statistic and proceed in the same way.

5.1 Statistically Testing for Changes in ARPM

The test based on the formula in equation (4) is described in every introductory statistics text. The validity of the test is based on the assumption that large samples of students are randomly selected from two different populations. We would like to perform the same test using our data, comparing the ARPM in one period to that in another period. Unfortunately this is not possible. The ARPM is computed for each period by summing relevant charges on all sampled bills and dividing by the sum of long distance call minutes on the same sample of bills. For each period we have only *one* estimate of ARPM and, as a consequence, no estimate of the standard deviation. Consequently we can not use formula (4). On the face of it, since we have only one observation on each period, it does not seem possible to carry out any statistical test of whether ARPM has declined or not.

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 data at hand.[25] The procedure is called a resampling 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 those interested, Efron (1982) and Sprent (1993) provide a detailed explanation of the bootstrap technique.[26]

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[25] Efron, B., The Jackknife, the Bootstrap, and Other Resampling Plans. Philadelphia: Society for Industrial and Applied Mathematics, 1982.

[26] Id., Sprent, P., Applied Nonparametric Statistical Methods, 2nd ed. London: Chapman and Hall, 1993

To illustrate the bootstrap procedure, suppose that in the month of January the PNR data consisted of 100 MCI bills. We could draw one bootstrap sample from these data by randomly selecting 100 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 could compute ARPM. Now we repeat this process many times. Producing 5,000 bootstrap samples of size 100, by resampling with replacement, yields an empirical distribution of ARPM.

From the empirical distribution derived from the bootstrap technique, we obtain an estimate of the standard deviation of ARPM, and thus its variance.[27] This empirical distribution may be used to make statistical inferences about the changes in ARPM. We can repeat this experiment for any month, or set of months, and use the results to compute a statistic like the t-statistic in equation (4). Our t-statistic for the bootstrap technique is

$$t^{*} = (ARPM_1 - ARPM_2) \Big/ \sqrt{\frac{S_1^2}{N_{boot}} + \frac{S_2^2}{N_{boot}}} \tag{5}$$

where $ARPM_1$ and $ARPM_2$ are the ARPM values for the two periods we are comparing, computed from the original data. In the denominator, N_{boot} is the number of bootstrap samples we created in order to obtain estimates of the variances of $ARPM_1$ and $ARPM_2$, S_1^2 and S_2^2, respectively, as we hypothetically described above. If we wanted to test the hypothesis that $ARPM_1$ is greater than $ARPM_2$ by some specific amount, say ΔARPM = \$0.01, we can adjust the formula in (5) by subtracting this value from the numerator.

5.2 The Test Procedure

Having constructed the value of the test statistic in equation (5), we now must obtain a 'critical value' for the test statistic. The critical value allows us to accept or reject the hypothesis that a reduction in ARPM is of some

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[27] The bootstrap technique is not used to produce the ARPMs in Figures 1 and 2. These ARPMs come from the data.

specified magnitude.[28] This notion of a "rejection region," while technical, is intuitively straightforward.

Suppose one had a coin and wished to discover if the coin were "fair," i.e., if the probability of obtaining a head or a tail were equal to 50 percent. One could conduct an experiment by flipping the coin, say 1,000 times, and recording the results. If the coin were fair, one could calculate the probabilities of the various possible outcomes. Even if the coin were fair, there would be a small chance of obtaining a very unusual result, such as 1,000 straight heads. However, since the alternative belief that the coin is not fair seems more plausible in this case, one wishes to specify a set of results that would cause the abandonment of the hypothesis that the coin is fair. These results are in the so-called "rejection region," and their probabilities are fixed in advance.

If we are testing the null hypotheses H_0: $ARPM_1 - ARPM_2 = \delta$ versus the alternative hypothesis H_A: $ARPM_1 - ARPM_2 > \delta$, we must define a rejection region for t^* such that the probability (α) of a Type I error is some known value such as $\alpha = 0.05$. Once again we can use the bootstrap to find such a value, following the suggestions of Horowitz (1998).[29] The basic idea is that for each of the bootstrap samples we constructed initially, we will carry out another bootstrap experiment in which we compute t^*. An empirical distribution of t^* is constructed, and the 95th percentile of that distribution is used as the $\alpha = 0.05$ critical value for a one-tailed test. The critical values are recomputed for every test. Thus, we are able to provide an answer to the question of whether there is any statistically significant evidence from which we can conclude that long distance carriers have or have not passed through the access charge reductions. We conduct our bootstrap analysis using all three of our samples.

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[28] We cannot appeal to the standard normal distribution for the significance tests.

[29] J. Horowitz, "Bootstrap Methods in Econometrics: theory and Numerical Performance," in *Advances in Economics and Econometrics: Theory and Applications*, Seventh World Congress, Vol. III, eds. D. Kreps and K. Wallis, Cambridge: Cambridge University Press, 1997 (pp. 188-222).

6.0 Statistical Results

The results of our statistical analyses for the three samples (Samples 1, 2, and 3) are summarized in Table 4. The reductions in ARPM are compared to our estimates of the access charges reductions as well as to those estimates provided by Brandon and Taylor (see Table 2).

Note that bills with billing dates of July-97 and January-98, are omitted from all the samples because these bills contain calls made in the previous calendar month, prior to the change in access charges.[30] Because the PNR data set is not a "panel" (i.e., a set that follows the same individuals through time), we cannot reconstruct all the calls made by a consumer in a *calendar month* from *billing* records, as the billing dates do not coincide with the ends of the months. The effect on the differences among ARPMs across periods of excluding these two months can be assessed by comparing the estimates of the reduction in ARPM in Table 3 to those in Table 4.

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[30] These transition months are included in Figures 2 and 3, as well as Table 3. This difference in samples explains the difference in the ARPM estimates. Excluding these two months, the sample sizes for the three periods (I, II, III) for Sample 1 are 732, 901, and 1,396, respectively. For samples 2 and 3, the sample sizes are 663, 849, and 1,335, respectively.

Table 4.

Statistical Tests of ARPM and Access Charge Reductions

Period	*ARPM Reduction*	*Bootstrap 90%Confidence Interval*	*Hill-Beard Access Reduction*	*NERA Access Reduction*	*Flow-through Assessment*
Sample 1					
I - II	0.0200	$0.014 < \delta < 0.026$	0.0087	0.0086	> 100%
II - III	0.0012	$-0.004 < \delta < 0.006$	0.0018	0.0045	100%
I - III	0.0211	$0.015 < \delta < 0.027$	0.0105	0.0131	> 100%
Sample 2					
I - II	0.0156	$0.010 < \delta < 0.022$	0.0087	0.0086	> 100%
II - III	0.0036	$-0.001 < \delta < 0.008$	0.0018	0.0045	100%
I - III	0.0192	$0.014 < \delta < 0.024$	0.0105	0.0131	> 100%
Sample 3					
I - II	0.0137	$0.008 < \delta < 0.020$	0.0087	0.0086	100%
II - III	0.0039	$-0.001 < \delta < 0.009$	0.0018	0.0045	100%
I - III	0.0176	$0.012 < \delta < 0.023$	0.0105	0.0131	≥ 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 "more than" 100% pass-through.

Table 4 provides unambiguous statistical evidence that MCI's ARPM has fallen over time in a manner consistent either with 100 percent pass-through of (estimated) access charge reductions, or with a reduction greater than what access cost changes would suggest. Among *all* periods and with *all* samples, ARPM fell by as much or more than the access charge reductions. Consider the changes in ARPM and access charges between period I and II. Both Sample 1 and 2 data suggest that the observed reduction in ARPM between periods I and II (0.0200 and 0.0156) exceeds the estimated reduction in access charges (0.0087 or 0.0086) by an amount sufficient to allow us to conclude that prices fell by more than this cost reduction. Likewise, ARPM reductions for all three samples meet or exceed the access reductions between periods I and III, and we cannot reject 100 percent flow-through of the access reductions between periods II and III.

In every case, *we find results statistically consistent with 100 percent pass-through or better for either estimate of access charge reductions.* The range of the confidence intervals in Table 4 also show that, unless one believes access charges fell by unrealistically large amounts, pass-through is a consistent

finding. We conclude, with 90 percent certainty, that MCI customers enjoyed reductions in costs per minute equal to, or exceeding, access charge reductions.

The information provided in Table 4 allows one to test flow through against other estimates of access charge reductions. In fact, the confidence intervals for ARPM reductions (δ) may be used to evaluate *any* conjectured reduction in access charges. For example, if estimated access charges were reduced by one cent per minute ($\delta = 0.01$) between periods I and II, we can use Table 4 to test whether the observed reduction in ARPM is consistent with the flow through of this reduction. Using Sample 1, for example, \$0.01 lies below the confidence interval ($0.014 < \delta < 0.026$). Only values of δ within this interval lead to the conclusions that observed ARPM changes may be equal to δ. Since δ is less than the minimum value of the confidence interval (0.014), we must conclude that ARPM fell by more than the hypothesized \$0.01 drop in access charges per minute. Alternatively, a hypothetical reduction of \$0.02 lies within the confidence interval, so we would conclude that the reduction in ARPM is consistent with 100 percent flow-through of this hypothetical access reduction.

Table 5 presents the results of the bootstrap analysis for the null hypothesis that the ARPMs are equal across periods. This table is largely self-explanatory, but it should be emphasized that the bootstrap analysis shows that ARPM has significantly fallen between periods I and II, and I and III. Comparing periods II and III, one finds that while ARPM did fall, the reduction was below that required to conclude there was a statistically significant effect.

Table 5 establishes several useful results. First, ARPM is falling in a manner consistent with casual expectations formed by inspection of Figure 2. Regardless of the sample used, one never finds ARPM rising, as claimed in the analyses of Brandon and Taylor. Second, we observe strongly statistically significant drops in ARPM between Period I and all later periods, regardless of the sample used to make the comparisons. However, we find weaker results comparing Periods II and III. At least three factors may contribute to this result. First, the change in access charges was quite small between these periods (either 0.0045 or 0.0018). The size of the decline is not sufficiently large to produce statistical significance in the bootstrap analysis.

Table 5.

Statistical Tests of ARPM Reductions

ARPM ESTIMATES					
	Period I	*Period II*	*Period III*		
Sample 1	0.1513	0.1313	0.1301		
Sample 2	0.1431	0.1295	0.1256		
Sample 3	0.1433	0.1277	0.1241		
HYPOTHESIS TESTS (Null = No change in ARPM)					
	t-stat	t(0.025)	t(0.05)	t(0.95)	t(0.975)
Sample 1					
I to II	104.37	-40.03	-31.29	30.73	39.29
I to III	112.13	-40.68	-35.05	34.23	40.37
II to III	6.79	-37.90	-30.43	33.28	40.47
Sample 2					
I to II	75.49	-41.11	-36.60	31.41	36.20
I to III	109.64	-39.85	-36.71	35.76	43.89
II to III	24.54	-42.29	-32.85	34.68	42.85
Sample 3					
I to II	94.73	-39.57	-36.46	30.87	35.72
I to III	126.76	-37.72	-33.95	34.15	39.73
II to III	23.94	-43.66	-30.71	31.9	40.46

Second, the access charge reductions between periods II and III were the results of a dramatic change (PICC and USF) in the way access charges are levied upon, and recovered by, the IXCs. The large differences in the estimates of access charge reductions presented in this study may indicate the presence of considerable uncertainty regarding the exact size of such reductions even among the IXCs. Third, the precipitous drop in ARPM in the final months of 1997 may reflect the timing issue discussed earlier. Since MCI knew that the access reduction and restructuring was coming, it may have reduced rates prior to the reduction in an effort to acquire customers from their rivals.

On balance, our analysis establishes that the ARPM calculated for MCI customers from the PNR data sets has declined over the period January-97 through June-98, in a fashion suggesting that reductions in switched access charges have benefited customers directly, and on an at least one-for-one basis, via price reductions.

7.0 Critique of Brandon and Taylor

Brandon and Taylor, on behalf of NERA, produced a study titled, *AT&T, MCI, and Sprint Failed to Pass-through the 1998 Interstate Access Charge*

Reductions to Consumers, which purports to establish that the three largest IXCs have failed to pass through the January-98 reduction in switched access charges to residential customers. In fact, Brandon and Taylor's analysis suggests that ARPM actually increased despite this (rather small) access cost reduction. This conclusion is so completely at variance with our findings, and with economic theory, that it is important to attempt to fathom the source of this disagreement. We do so in this section. However, the reader is urged to note that the report of Brandon and Taylor contains insufficient documentation to allow us to replicate their calculations.[31] Our comments will therefore necessarily be of a somewhat general character.

First, we note that a finding of increasing prices (ARPM) contemporaneous with reduced costs is anomalous: even a monopoly changes price in the same direction as changes in incremental costs. Thus, to observe a price increase in the face of a cost decrease, one must have structural or conduct changes, such as cartel formation, presumably unrelated to the reduction in access charges. Yet, if one accepts such an explanation, then analyses comparing price changes to cost changes will not be satisfactory in any case.

Second, Brandon and Taylor did not conduct statistical tests to determine if their purported increase in ARPM was significant. Brandon and Taylor merely inferred this by comparing averages. Brandon and Taylor also use different time periods for different IXCs. AT&T bills in 1997 have billing dates from December-97 to January 1-98. For MCI, on the other hand, they used November-97 to January-98. While Brandon and Taylor attribute this difference to a desire for adequate sample sizes (p. 5), they provide no statistical analyses, so the role of sample size is obscure.

Third, and most importantly, it appears that the primary sources of the differences between the Brandon and Taylor results and those given here may arise from the selective sample periods used by Brandon and Taylor. It is important to note that differences between the present study and that of Brandon and Taylor cannot be attributed to the weighting or filtering of data since we use weighted, unweighted, filtered and unfiltered data. Nor

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[31] For example, Brandon and Taylors use of "seasonal corrections" is undocumented (p. 6).

can the differences be attributed to disputes over the sizes of access charge reductions because we use Brandon and Taylor's figures and others.

The tremendous significance of the time periods used by Brandon and Taylor is revealed graphically in Figure 2. The pre-1998 bills used by Brandon and Taylor come from a period of extremely low ARPM, according to the PNR data. Whether or not these low ARPMs are the result of the data collection process, or are consistent with reality, we do not know. In order to evaluate whether the comparison periods selected by Brandon and Taylor are atypical *even given* the character of the PNR data, we performed the following calculations.

We test for the significance of the difference in ARPMs via the bootstrap between every consecutive pair of months in 1997 and in 1998. Table 6 presents these results for Sample 2 and Table 7 for Sample 3. Positive values in the tables indicate ARPM was lower in the 1998 month-pairs than in the 1997 month-pairs. Differences between month-pairs that are *not* statistically significant are noted with an asterisk (*).

Table 6.

ARPM Comparisons for Two-Month Groups Using Sample 2 Data

1997 Month Pairs	1998 Month Pairs				
	2 & 3	3 & 4	4 & 5	5 & 6	6 & 7
1 & 2	0.011[a]	0.014	0.018	0.016	0.017
2 & 3	0.011	0.018	0.018	0.016	0.018
3 & 4	0.015	0.018	0.021	0.020	0.021
4 & 5	0.02	0.023	0.026	0.025	0.026
5 & 6	0.021	0.025	0.028	0.026	0.028
6 & 7	0.017	0.019	0.023	0.022	0.023
7 & 8	0.015	0.018	0.022	0.021	0.022
8 & 9	0.012	0.015	0.019	0.017	0.019
9 & 10	0.006*	0.009	0.013	0.012	0.013
10 & 11	-0.002*	0.001*	0.004*	0.006*	0.004*
11 & 12	**-0.010**	**-0.007**	-0.003*	-0.005*	-0.004*

[a] Numbers in cells measure ARPM differences between the two, two month periods.
* Statistically insignificant at the 0.05 level

Looking to Table 6 first, when we compare any pair of consecutive months in the period January-97 to October-97, versus any pair of months in 1998, excluding the transition month January-98, we find that the

reduction in ARPM is positive and statistically significant. If October-November 1997 is compared to February-March 1998, the sampled ARPM rises, but not by a statistically significant amount. If October-November 1997 is compared to other two-month periods in 1998, the ARPM reduction is positive, but not statistically different from zero. If November-December 1997 is compared to February-March 1998 or March-April 1998, the sample ARPM rises, by a statistically significant amount. If November-December 1997 is compared to two-month periods in 1998, the ARPM rises, but by an amount not statistically different from zero.

Table 7.

ARPM Comparisons for Two-Month Groups Using Sample 3 Data

1997 Month Pairs	1998 Month Pairs				
	2 & 3	3 & 4	4 & 5	5 & 6	6 & 7
1 & 2	0.007[a]	0.001	0.014	0.014	0.014
2 & 3	0.009	0.013	0.017	0.016	0.016
3 & 4	0.013	0.017	0.021	0.020	0.02
4 & 5	0.017	0.022	0.026	0.025	0.024
5 & 6	0.020	0.024	0.028	0.027	0.026
6 & 7	0.016	0.020	0.024	0.023	0.022
7 & 8	0.014	0.018	0.022	0.021	0.021
8 & 9	0.010	0.014	0.018	0.017	0.017
9 & 10	0.006*	0.011	0.015	0.014	0.018
10 & 11	0.001*	0.004*	0.008	0.007*	0.007*
11 & 12	**-0.010**	-0.006*	-0.002*	-0.003*	-0.004*

[a] Numbers in cells measure ARPM differences between the two, two month periods.
* Statistically insignificant at the 0.05 level

This set of comparisons clearly shows that Brandon and Taylor's finding is an anomaly. If we compare the ARPM for *any* month pairs from January to October 1997 to any month pairs in 1998, we find that the ARPM was less in 1998 and, in all but one case, less by a statistically significant amount. Only if the 1997 month-pair includes either (or both) of the two months (November and December 1997) used by Brandon and Taylor to measure ARPM before the access reduction does this result change. In November and December of 1997 the ARPM of the customers in the sample is at its lowest level. Comparing these two months to 1998 gives a misleading picture of what is actually happening over all. Table 7, using weighted data, produces

very similar results. Again we see that the dates selected by Brandon and Taylor are quite 'special.'

8.0 Conclusion

We have evaluated changes in ARPM for residential customers of MCI appearing in the PNR data set during the period January-97 through July-98. Using bootstrap (resampling) techniques, we have evaluated whether observed changes in ARPM are consistent with various estimates of changes in interstate, interLATA switched access charges. Our goal was to determine if reductions in ARPM provide statistically significant evidence of the "pass through" or "flow through" of access cost reductions. Additionally, we used our analyses to evaluate the findings of Brandon and Taylor, and to critique their methodology.

Our conclusions are as follows:

1. Statistical analysis indicates that MCI (now MCI WorldCom) either flowed through access charge reductions, or reduced prices by amounts greater than access charge reductions, in every case examined.

2. Our finding of complete flow through is consistent across all period comparisons, and all data sets.

3. The study by Brandon and Taylor offers no statistical evidence on pass through. Further, their results are misleading, and arise solely from the unusual character of the specific months they chose to study.

Despite our findings, the debate over flow through will likely continue. We hope, however, that this study will "raise the bar" on what is an acceptable analysis of flow through. Any claims of flow through, or lack thereof, should be subject to rigorous statistical testing, and estimation procedures appropriate to the problem should be clearly set forth.

APPENDIX A

It is our understanding from PNR that the weights supplied with the PNR data evaluated in this study, and used by Brandon and Taylor, were calculated using the proposal of Deming and Stephen (1980). This technique uses so-called "iterative proportional fitting," which seeks to calculate weights for observations that produce sample joint frequencies as similar as possible to known population marginal frequencies. This approach is able to treat only categorical classifications, and further does not imply that functions of the data calculated from a weighted sample will equal the values of those functions calculated on the population. For continuous variables, arbitrary categories must be defined to utilize any technique based on cell frequency replications. Most critically, only a finite number of such categories is used in calculating the weights, so there is no general implication that the weighted sample is, in fact, "representative" of U.S. households for any other variables, or for functions of any variables. A simple example will illustrate this point.

Suppose a population is composed of a large number of observations (elements) on ordered pairs (X, Y), where X equals either 0 or 1, and Y equals either 0 or 1. Let f_{ij} equal the probability that a random member of the population exhibits the pair ($X = i$, $Y = j$), so that f_{10}, for example, is the population frequency of the pair (1, 0). Let S be a sample, possibly non-random, and let g_{ij} be the corresponding sample frequencies for the pairs ($X = i$, $Y = j$). We have $\sum_i \sum_j f_{ij} = 1$ and $\sum_i \sum_j g_{ij} = 1$. However, suppose the sample is not 'representative' in the sense that $f_{ij} \neq g_{ij}$.

Weights can be used to cause a single sample frequency to equal the corresponding population frequency, but this cannot ordinarily be done for two frequencies with less than two weights. To see this, note that the true average value of X is $E(X) = f_{10} + f_{11}$, and the sample expectation is $E^S(X) = g_{10} + g_{11}$. A weight W_X, assigned to observations exhibiting $X = 1$, can cause $E(X) = E^S(X)$ in the weighted sample if $W_X = (f_{01} + f_{11})/(g_{01} + g_{11})$. However, in order for the sample expectation of Y, $E^S(Y)$, to equal the population value $f_{01} + f_{11}$, we need to apply a weight W_Y to those observations exhibiting $Y = 1$ such that we have $g_{01} + W_Y g_{11} = f_{01} + f_{11}$, so that we must have $W_Y = (f_{01} + f_{11} - g_{01})/g_{11}$. Clearly, $W_Y \neq W_X$ in general.

Although somewhat abstract, the argument above is presented to illustrate that the weights supplied with the PNR data set should be used with great circumspection, as the values of the resulting sample statistics (such as ARPM) may not equal their population valuations. Consequently, we present our analysis using both weighted and unweighted data.

APPENDIX B

Table B1.

NERA Estimates of Access Reductions*

Period	Per Minute	USF	NECA[a]	PICC	Total	Change
I	0.0604	-	0.0082	-	0.0686	
II	0.0518	-	0.0082	-	0.0600	(0.0086)
III	0.0404	0.0059	-	0.0093	0.0555	(0.0045)
						(0.0131)

* Figures may not add due to rounding.

[a] Brandon and Taylor did not provide Period I estimates of access charges. Per minute charges are available from FCC documents, but the per minute calculation of NECA costs were estimated by Brandon and Taylor. Since there was no significant change in the NECA charge in 1997, we assume that the per minute NECA estimates are identical in Period I and II. As noted in the text, any access charge reduction can be assumed and compared against our estimated reductions in APRM.

Table B2.

Estimates of Access Reductions*

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

* 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.

Table B3.

Total Lines and Minutes from the PNR Data

(All Customers in Database)

	I	II	III
Total Lines	9,152	12,716	...
Primary	...	...	17,024
Second	...	...	1,057
Third	...	...	78
Total Costs (NECA/PICC)[a]	4,915	6,541	10,044
Total Minutes[b]	716,946	961,999	1,348,381
Costs Per Minute	0.0069	0.0068	0.0074

[a] Per line charges are provided in Table B2.
[b] Total Minutes include interstate and international minutes. About 6 percent of minutes were not coded as interstate, intrastate, or international. These minutes were allocated to each type call based on their respective percentage of total minutes.

APPENDIX C

Table C1.

Monthly ARPM Estimates from the PNR Data

	ARPM		
Month	Sample 1	Sample 2	Sample 3
Jan-97	$ 0.1435	$ 0.1399	$ 0.1550
Feb-97	$ 0.1370	$ 0.1356	$ 0.1451
Mar-97	$ 0.1416	$ 0.1424	$ 0.1447
Apr-97	$ 0.1433	$ 0.1425	$ 0.1582
May-97	$ 0.1524	$ 0.1527	$ 0.1572
Jun-97	$ 0.1459	$ 0.1469	$ 0.1524
Jul-97	$ 0.1431	$ 0.1439	$ 0.1514
Aug-97	$ 0.1429	$ 0.1431	$ 0.1460
Sep-97	$ 0.1365	$ 0.1356	$ 0.1407
Oct-97	$ 0.1320	$ 0.1365	$ 0.1347
Nov-97	$ 0.1199	$ 0.1240	$ 0.1207
Dec-97	$ 0.1148	$ 0.1142	$ 0.1211
Jan-98	$ 0.1294	$ 0.1317	$ 0.1308
Feb-98	$ 0.1258	$ 0.1283	$ 0.1304
Mar-98	$ 0.1313	$ 0.1321	$ 0.1386
Apr-98	$ 0.1177	$ 0.1187	$ 0.1221
May-98	$ 0.1240	$ 0.1241	$ 0.1352
Jun-98	$ 0.1205	$ 0.1199	$ 0.1276