APPENDIX B

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Appendix C

Total Factor Productivity and the LEC "X" Under Interstate Price Cap Regulation

1. Introduction

This appendix examines whether the differential in growth rates between LEC Total Factor Productivity (TFP) and overall U.S. TFP, as calculated in Attachment 6 to USTA's Comments by Christensen, Schoech and Meitzen (hereafter, Christensen), is an appropriate surrogate for the "X" factor in the Commission's LEC price cap plan – as USTA and numerous other LECs have alleged.[1]

We find that this TFP differential is not equivalent to, and actually understates significantly the "X" in the Commission's LEC price cap plan – contrary to the intimations in USTA's Comments (p. 81) and in its Attachment 5 prepared by NERA (p. 16) (hereafter, NERA). This is both because the proffered productivity offset value of 1.7% is not consistent with the explicit theoretical relation between TFP differential and a productivity offset that Christensen and NERA themselves present; and because even if Christensen and NERA had properly calculated an actual productivity offset from Christensen's TFP differential analysis, that offset simply would not measure the productivity intended to be measured by "X" in the Commission's LEC price cap plan.

In particular, this appendix will show the following:

1. USTA's statement that TFP differentials imply a productivity offset of 1.7% is inconsistent with Christensen and NERA's own theoretical analyses because:

[1] *See, e.g.*, USTA (pp. 79-84), Bell Atlantic (p. 15), BellSouth (p. 34), GTE (p. 73), Lincoln (p. 9), NYNEX (pp. 36-38), Pacific Companies (p. 31), SWBT (p. 33).

- The productivity offset must incorporate the differential between LEC and U.S. input price growth - and accounting for this differential *raises* the offset to at least 5.2%.
- Without an adjustment to TFP for the supernormal levels of LEC profit achieved at the end of the 1984-92 time frame of Christensen's study, the theoretical link between these TFP analyses and a productivity offset is severed.

2. But even more basically, even if the above adjustments are made, Christensen's TFP analysis simply does not generate a productivity offset that is at all consistent with how "X" is used in the Commission's LEC price cap plan. This is because:
   - Christensen's analysis computes a TFP for the entire aggregate of LEC services rather than for just the interstate access services regulated by the Commission's price cap plan. Indeed, Christensen himself suggests that interstate access services have experienced productivity growth above the overall LEC average.
   - Christensen's TFP analysis measures LEC prices and outputs differently from how they are measured by the price cap indices and basket structure of the Commission's plan.
   - Christensen's TFP calculations measure capital consumption differently from the depreciation methodology prescribed by the Commission for ratemaking purposes.

Thus, for all of these reasons, the TFP analyses presented by Christensen and NERA are simply not valid indicators of the level of "X" that the LECs have, or could have, achieved under price caps. In fact, a close reading of both the Christensen and NERA Attachments reveals that neither of these studies state unequivocally that their calculated TFP differentials equate to the Commission's LEC price cap "X."

In Section 2, TFP differential is examined using NERA's equations to determine how it relates to a productivity offset. In Section 3, we show that the TFP differential of 1.7% calculated by Christensen does not conform to Christensen's or

NERA's own requirements for a productivity offset, and actually understates substantially such an offset. Next, in Section 4, we examine the role of "X" in the Commission's price cap formulas, and show that even when corrected for the above errors, TFP differentials based on Christensen's methodology still do not generate productivity offsets that meet the requirements for "X" in the Commission's LEC price cap plan. Concluding remarks are in Section 5.

2. What does TFP differential represent?

TFP is a measure of the physical efficiency of the firm. Thus, TFP growth is the difference between the percentage growth rate of a firm's physical outputs and the percentage growth rate of that firm's physical inputs. Because a LEC produces many joint, physically noncomensurate outputs (*e.g.*, lines, minutes, and telephone directories), and uses many joint, physically different inputs (*e.g.*, hours of labor, miles of fiber optic cable, and billing computers), measures of TFP, especially for multi-output, multi-input firms such as LECs, require elaborate aggregation schemes.

Christensen (pp. 1-11) aggregates LECs' noncomensurable physical output (or input) quantities by summing the dollar value of output (input) 1 with the dollar value of output (input) 2, *etc*. Although using dollar-value summation finesses aggregation problems, it introduces a second difficulty. Because the dollar value of outputs and inputs reflects both their physical quantities as well as the prices charged for these outputs and inputs, the effects of changes in output and input prices must be removed. Christensen does this by dividing the output and input value indices by indices of output and input prices to derive output and input quantity indices. TFP growth is then calculated as the difference between the percentage growth rate of a firm's output quantity index and the percentage growth rate of its input quantity index.

An examination of NERA's mathematical derivation of the relation between TFP, and LEC and U.S. input and output prices, will highlight the inconsistency

(discussed in Section 3, below) between Christensen's TFP differential calculations and their use as a surrogate for the Commission's "X" productivity offset.

Begin with NERA's equation (1), which is equivalent to Christensen's equation (A5):

$$dp^L = dw^L - dTFP^L \pm dZ^L, \tag{1}$$

where the $d(\cdot)$ operator indicates annual percentage change, the superscript L denotes LEC, and:

p^L is the collection of revenue-weighted LEC output prices,

w^L is the collection of cost-weighted LEC input prices,

TFP^L is LEC TFP, and

Z^L is the collection of cost-weighted LEC exogenous cost changes.

NERA's equation (2) provides the analogous relation for the overall U.S. economy:

$$dp^N = dw^N - dTFP^N \pm dZ^N. \tag{2}$$

where the superscript N denotes the national U.S. economy.

If equation (2) is subtracted from equation (1), the result is:

$$dp^L - dp^N = \left(dw^L - dw^N\right) - \left(dTFP^L - dTFP^N\right) \pm \left(dZ^L - dZ^N\right),$$

and rearranging terms gives:

$$dp^L = dp^N - \left[\left(dTFP^L - dTFP^N\right) - \left(dw^L - dw^N\right)\right] \pm \left(dZ^L - dZ^N\right). \tag{3}$$

The terms in this equation may be interpreted as follows:

dp^L is a measure of growth in LEC output prices that are subject to price caps,

dp^N is a measure of growth in economy-wide output prices, *e.g.*, GNP-PI,

$\left(dTFP^L - dTFP^N\right) - \left(dw^L - dw^N\right)$ is an expression that we shall call Ω, and $\left(dZ^L - dZ^N\right)$ is an expression for the difference between LEC-experienced exogenous cost changes and those experienced by the economy as a whole.[2]

3. Christensen's calculated TFP differential is not a productivity offset

3.1 Differential in input price growth has been omitted

According to NERA (pp. 8-9), the expression denoted Ω above is "a productivity offset, X, which now represents a productivity growth differential between the annual TFP growth of the regulated industry and the U.S. economy, adjusted for differences, if any, between the rate of growth of input prices for the regulated industry and for the U.S. as a whole."[3] While NERA's complete expression for Ω includes an adjustment for the difference in LEC and U.S. input price growth rates, NERA (p. 9, footnote 9) suggests that it is appropriate in this instance to express the productivity offset Ω as merely:

$$\Omega = dTFP^L - dTFP^N,$$

because, NERA claims, the term $(dw^L - dw^N)$ contained in Ω may be assumed to equal zero.[4] To support this assertion, NERA proffers results from a different Christensen TFP study of the entire Bell System from 1947 to 1979 that it claims finds no significant difference in the growth of LEC and U.S. input prices over this period.[5]

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[2] Christensen (p. 7, footnote 7) and NERA (pp. 25-28) both agree that it is appropriate to neglect the contribution of this Z term in their following analyses. Thus a shorthand interpretation of equation (3) would be: $dp^L = dp^N - \Omega$.

[3] The reason TFP differential must be adjusted for differences in the rate of growth of LEC and U.S. input prices is because "X" is an offset of output prices against GNP-PI, while TFP is an offset of output prices against actual input prices.

[4] NERA takes pains to repeat this assumption about ignoring the potential contribution of $(dw^L - dw^N)$, and thereby emphasizes its importance, in its footnote 10 and in its Section II.B.

[5] In addition to this Christensen study, NERA also cites two Bureau of Labor Statistics studies, one from 1951 to 1987, and another from 1984 to 1990. Based on these studies, NERA states that, "there was no statistically significant difference between industry and U.S. input price growth." (NERA, p. 16). But

It is extraordinarily curious that NERA did not report the difference in the growth of LEC input prices versus overall U.S. input prices (*i.e.*, the value of the $dw^L - dw^N$ term) that is implicit in the actual TFP differential analysis presented by Christensen in USTA's Attachment 6.[6] We compute it now.

Christensen's 1984-92 data underlying Attachment 6, that were provided in USTA's supplemental submission, show that the LECs experienced a compound annual growth rate of 1.1% in total input prices (dw^L).[7] Growth in overall U.S. input prices (dw^N) can also be computed using Christensen's 1984-92 data and NERA's equation (2) (equation 2 in this Appendix), neglecting the dZ^N terms:

$$dp^N = dw^N - dTFP^N.$$

Rearranging terms gives:

$$dw^N = dp^N + dTFP^N.$$

Because dp^N is GNP-PI growth, which USTA reports to be 3.7% annually from 1984 to 1992;[8] and because Christensen (p. ii) states that U.S. TFP growth ($dTFP^N$) over this period was 0.9%; it is easy to solve for dw^N:

$$dw^N = 3.7\% + 0.9\% = 4.6\%.$$

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note that the "industry" in the above studies was the total U.S. telecommunications industry, and not just LEC, or LEC interstate access, services.

[6] In earlier filings before this Commission, Christensen himself has also noted the need to adjust TFP differential for differences between LEC and U.S. input price growth. *See* Christensen attachment to AT&T Comments filed on October 19, 1987, in CC Dkt. No. 87-313 (Appendix F, p. 10). Indeed, in Christensen's current attachment to USTA's Comments, Christensen never states that an unadjusted TFP differential equates to the productivity offset in the Commission's LEC price cap plan. Rather, Christensen states that, "[t]he productivity offset in the price cap formula is *related* to the differential in productivity growth between LECs and the U.S. economy" (p. ii, and repeated on p. 12) (emphasis added).

[7] *See* Christensen Study Data, Table 1 - attached to "Response of the United States Telephone Association to Ad Hoc's Motion to Compel and Motion for Extension of Time," June 2, 1994, (hereafter, Christensen Study Data).

[8] *See* Attachment 11 to USTA's Comments.

Thus, the actual difference in the growth of LEC input prices versus overall U.S. input prices implicit in Christensen's Attachment 6 TFP analysis is:

$$\left(dw^L - dw^N\right) = 1.1\% - 4.6\% = -3.5\%.$$

Recomputing NERA's proposed productivity offset Ω, without ignoring the -3.5% annual growth in LEC input prices relative to overall U.S. input prices, now yields:

$$\left(dTFP^L - dTFP^N\right) - \left(dw^L - dw^N\right) = 1.7\% - (-3.5\%) = 5.2\%.$$

Hence, Christensen's and NERA's own TFP differential analysis actually implies a LEC productivity offset of 5.2%.

3.2 A correction for LEC profit growth has been omitted

Appendix 1 to Christensen's Attachment 6 demonstrates how the TFP growth of a firm, as derived from differences in the growth of its physical outputs and inputs, may be used to describe differences in the growth of that firm's input and output prices – using a mathematical concept known as duality theory. But as Christensen (p. 28) and NERA (p. 5) note, mathematical duality holds only if the firm's profits are constrained to normal levels over the entire time period of the study.[9] While rate-of-return regulation may have enforced such a normal profit constraint on LEC pricing from 1984-90, that constraint was removed with the advent of price cap regulation in 1991. Indeed, not only was competition not present in LEC markets over the 1991-92 period to restrict profits, but given the large decline in the LECs' cost of capital over this period, it is highly likely that the LECs have earned supernormal profits during this

[9] As Christensen states on page 28 of his Attachment 6, Appendix 1, "[i]n market equilibrium, as competitive forces constrain firms to earn only a normal profit, the rate of change in revenue equals the rate of change in cost." *See also* Douglas W. Caves, Laurits R. Christensen and Joseph A. Swanson, "Productivity in U.S. Railroads, 1951-1974," *The Bell Journal of Economics*, Vol. 11 (Spring 1980), pp. 166-181; *or* Michael Denny, Melvyn Fuss and Leonard Waverman, "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries," in T. G. Cowing and R. E. Stevenson, *Productivity Measurement in Regulated Industries*, Academic Press, 1981, pp. 179-218.

period.[10] If this has occurred, then the theoretical link between Christensen's measurement of TFP growth derived from output and input quantity indices, and measures of output and input price growths (*i.e.*, the link expressed in Christensen's equation A5 and in NERA's equation 1), is invalid.

4. Even corrected, productivity offsets computed from TFP differentials do not equate to the Commission's LEC price cap "X"

4.1 What "X" represents in the Commission's price cap plan

The Commission's "X" is intended to act as a "productivity offset" between growth in overall U.S. prices (as measured by GNP-PI) and required LEC price performance – as specified by the Commission's price cap formulas. In particular, "X" is the productivity offset for a price cap structure that:

- controls only LEC interstate access and interexchange rates,
- measures the level of Common Line prices by combining End User Common Line prices with Carrier Common Line prices, which are then adjusted for demand growth using the Commission's "Balanced 50/50" mechanism,
- measures Traffic Sensitive prices on an aggregate per-minute basis,
- measures Trunking/Special Access and Interexchange prices on a revenue-weighted basis, and
- was designed to dovetail with the Commission's previous rate-of-return prices that were based on a particular system of regulatory accounting and depreciation.

[10] *See, e.g.*, AT&T (pp. 30-33 and Appendix D), MCI (pp. 23, 29, and Appendix A), GSA (pp. 4-7), Ad Hoc (pp. 22-23).

Hence, if Christensen's calculations of TFP differential do not mirror these requirements, there is no valid relation between the Commission's "X" and a productivity offset calculated from these TFP differentials.[11]

4.2 Christensen does not compute the TFP of LEC services subject to the Commission's price cap regulation

Christensen's study segregates LEC outputs into seven categories: local, interstate end user access, interstate switched access, interstate special access, intrastate access, long distance, and miscellaneous.[12] Thus, dp^L in Christensen's analysis is the aggregate price change for the amalgam of this entire collection of LEC services - and not just the price change for interstate access services that are subject to the Commission's jurisdiction. In fact, interstate access services account for only about 23% of the dollar value of LEC services included in Christensen's TFP calculations.[13] Because the LEC service universe used in Christensen's analysis does not correspond to the set of services governed by interstate price caps, its TFP cannot be used to infer any particular value for the Commission's LEC "X." In fact, the aggregation of intrastate services with interstate access services has likely masked a higher than average rate of TFP growth for interstate access services. As Christensen himself notes, "growth in high markup services contributes more to TFP growth than growth in low markup services."[14] Thus, because interstate access is assuredly a high markup service, it has likely contributed disproportionately to the LEC total-company average TFP growth that Christensen measures.

4.3 Christensen's TFP analysis measures LEC prices and outputs differently from Commission's price cap rules

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[11] Because the productivity study included in Appendix B to AT&T's Comments uses Commission-specified measurements of LEC prices and outputs - as reported by the LECs in their ARMIS and TRP filings - it suffers from none of these potential defects.
[12] Christensen, p. iii.
[13] Christensen Study Data, Table 4.
[14] Christensen, p. 14.

For Christensen's TFP differential to have any applicability for "X," it must measure interstate access prices and outputs in the same fashion as do the Commission's price cap rules. For interstate Common Line (representing close to one half of LEC interstate revenues), this is clearly not the case. Christensen's revenue-based weighting of End User Common Line and Carrier Common Line does not accord with the Commission's Balanced 50/50 formula for adjusting for demand growth and computing Common Line prices under price caps from 1991 to 1992 - or the manner in which the Commission determined these Common Line prices under rate-of-return regulation from 1984 to 1990.[15]

Thus, because Christensen's TFP calculations do not measure the same outputs and prices (in scope or in level) as are measured by the Commission's price cap rules, they cannot be used to generate a productivity offset that equates to the price cap plan's "X."

4.4 Christensen's TFP analysis does not measure capital inputs in conformity with the Commission's rules

Christensen's TFP analysis does not measure LEC capital inputs in the same fashion as does the Commission for ratemaking purposes. In particular, the Commission measures capital consumption based on the straight-line application of particular depreciation rates to a LEC's gross stock of plant in service valued at actual historical cost. Christensen, however, applies "economic" depreciation rates to the net stock of LEC capital valued at a measure for replacement cost.[16] That Christensen's figures for LEC capital consumption are likely to differ greatly from the Commission's figures is manifest when one simply notes that Christensen's capital consumption is

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[15] Under rate-of-return regulation, the Commission set End User Common Line prices based on a particular cost formula, and determined Carrier Common Line prices as a residual adjusted fully for expected demand growth.

[16] Christensen, pp. 5-8. Christensen's figures for the replacement cost of LEC net capital stocks are based on "benchmarks" for the replacement cost of these net capital stocks that were estimated by the LECs back in 1984.

spread over time in a curvilinear accelerated fashion, while the Commission's spread is straight-line; and that in 1984 the Regional Bell Operating Companies reported holding net capital stocks of $189 billion on a replacement cost basis - as compared with just $114 billion on a historical cost basis.[17] Thus, there is no way to comport the capital consumption assumptions used in Christensen's analysis with the Commission's depreciation and ratemaking methodologies that underlie LEC interstate rates.

In all events, LEC price cap performance review should not be used as a backdoor method of reconsidering the Commission's depreciation orders in CC Dockets Nos. 92-296 and 93-452 by possibly negating their effect through the selection of a price cap "X" based on an alternative capital accounting methodology.

5. Conclusions

The TFP differential as calculated by Christensen is severely inconsistent with the explicit theoretical underpinnings of a link between TFP differential and a productivity offset - and in fact, substantially understates the offset. Furthermore, any corrected offset that could be calculated from TFP differential simply does not measure the productivity intended to be measured by "X" in the Commission's LEC price cap plan. Therefore, the calculations of TFP differential by Christensen are of no use in identifying the appropriate "X" for the Commission's LEC price cap plan.

[17] RBOC 1984 Annual Reports.

CERTIFICATE OF SERVICE

I, Ann Marie Abrahamson, do hereby certify that on this 29th day of June, 1994, a copy of the foregoing "AT&T Reply Comments" was mailed by U.S. first class mail, postage prepaid, to the parties listed on the attached Service List.

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