Table 16. Marginal Cost and Revenue Weights in Output Aggregation

U.S. Postal Service

	OUTPUT INDEXES			REVENUE WEIGHTS		MARGINAL COST WEIGHTS		
YEAR	FIRST CLASS MAIL (PIECES INDEX)	ALL OTHER MAIL (PIECES INDEX)	THIRD CLASS MAIL (PIECES INDEX)	(PIECES INDEX)	CHANGE FROM PRIOR YEAR (%)	(PIECES INDEX)	CHANGE FROM PRIOR YEAR (%)	ABSOLUTE ERROR (PERCENT
1965	0.81617	0.84498	0.92790	0.839690		0.844718		
1966	0.83842	0.86191	0.96851	0.862252	2.69	0.870871	3.10	13.22
1967	0.84602	0.87659	1.00093	0.874368	1.41	0.883977	1.50	6.63
1968	0.91442	0.88808	0.98565	0.915302	4.68	0.930666	5.28	11.36
1969	0.98760	0.90241	0.93598	0.955264	4.37	0.965887	3.78	15.37
1970	1.01866	0.86210	0.93667	0.959665	0.46	0.979826	1.44	68.08
1971	1.04495	0.85724	0.94772	0.974069	1.50	0.997688	1.82	17.66
1972	1.02614	0.90593	1.00572	0.990856	1.72	1.007852	1.02	69.17
1973	1.06332	0.94536	1.01043	1.024373	3.38	1.035204	2.71	24.64
1974	1.07989	0.96936	0.99018	1.038904	1.42	1.042236	0.68	108.83
1975	1.06310	0.98459	0.95781	1.029506	-0.90	1.025983	-1.56	41.99
1976	1.06079	1.04724	0.98227	1.046635	1.66	1.039590	1.33	25.46
1977	1.05736	1.10633	1.00495	1.060579	1.33	1.050357	1.04	28.64
1978	1.08393	1.07027	1.07825	1.080205	1.85	1.080895	2.91	36.35
1979	1.09610	1.09185	1.07450	1.092199	1.11	1.090451	0.88	25.59
1980	1.12189	1.15554	1.09161	1.124868	2.99	1.118699	2.59	15.47
1981	1.13128	1.20513	1.08769	1.139794	1.33	1.129871	1.00	32.87
1982	1.12349	1.28073	1.08906	1.145808	0.53	1.133496	0.32	64.44
1983	1.14715	1.30134	1.17232	1.177218	2.74	1.168832	3.12	12.07
AVERAGE CHANGE: REV WTS 1.9036 MC WTS 1.8315								
MEAN ERROR IN OUTPUT GROWTH (ABSOLUTE) 0.6286								

Source: Computed from results reported in Norsworthy and Jang, 1992, ch. 12.

6. The USTA Model Does Not Take Account Of Service Quality.

This criticism of the USTA model is based on the results of an earlier investigation (Norsworthy and MacDonald, 1994), which found evidence suggesting that large LECs trade off efficiency, measured by TFP or gross profitability, against the quality of services provided to telephone customers. The incentive to make this trade off under price cap regulation has been recognized by Laffont and Tirole (1993). However, the trade off found in the investigation excerpted below occurred during the post-divestiture period *before* LEC price cap regulation was initiated by the FCC in 1991. If anything, the incentives are stronger now for the LECs to reduce service quality in exchange for profitability. The notion that competition will regulate service quality applies only when there is *actual* competition. The contemplation of future competition in the LECs' markets does not in itself diminish the incentive to reduce the quality of service.

The consequence of such a trade-off is that service quality declines while the captive customer continues to pay the same price for the service. TFP measured in its conventional manner is unaffected by quality declines. The situation could be remedied – if appropriate ways to measure quality were generally agreed upon – by multiplying each output by an index of its quality before making the TFP computation. Then if the quality of service were to decline, TFP would also decline and the price cap incentive would press the LECs to enhance or maintain service quality. The chief limitation of this approach is that we do not know how to measure service quality in such a way that the index of service quality would match one-for-one changes in the quantity of service. Statistical methods could help us approach the goal of a reasonable quality measure for incorporation into the LEC price cap index.

In the past, the conventional wisdom has been that (a) quality of service is primarily related to the vintage of technology, and (b) rate-of-return regulation so encourages investment in new technology that concern for quality is unnecessary. Rate-of-return regulation does not usually include specific provisions for quality of service; however, quality issues may arise in the course of a rate hearing, and some state jurisdictions impose quality standards.

In principle, the LEC price cap regulation could include provisions that explicitly tie rate incentives to quality targets.[32] For example, long-term railroad and coal supply contracts resemble price cap agreements, in that they include provisions for cost-related price adjustments over the length of the contract, but they also often include a set of quality incentives that directly link prices to service standards.[33] At present, approximately eighteen states include quality of service evaluations in telephone rate case reviews, resulting in rate case penalties (NARUC 1992). Three states have included specific quality of service standards in their incentive regulation plans, using such standards as factors in the allocation of earnings. But as yet there have been no systematic attempts to include quality measures explicitly in price cap formulas. Increasingly, parties to rate determinations recognize that possible quality adjustment should be taken into account.[34]

There are ten quality variables taken from the Automated Reporting Management Information System (ARMIS) that I have examined. All are increasing through

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32 Noam (1990).

33 U.S. Department of Energy (1991); MacDonald (1989).

34 MacDonald, Norsworthy and Fu (1994).

time and average near .90. The reported data cover the period from 1986 to 1990, and the responsiveness of the various LECs has varied over time.

Two of these quality indicators are primarily technical: the proportion of the time that a customer gets a dial tone within three seconds, and the quality of transmission (an inverse function of line noise). Four of these indicators are survey-based measures of the segments of the customer population, in which customers express satisfaction with the service they receive. Three indicators concern whether work orders are performed on-time, for residences, for businesses, and for access. Two indicators concern the rates of call completion for interLATA and intraLATA calls.

These various quality measures were regressed on several sets of variables representing technology, i.e., the distribution of working channels among baseband, analog, digital and fiber types and the proportion of fiber interoffice cable miles. While improved switching and transmission equipment should to improve several dimensions of service quality while reducing telephone company costs, more refined empirical analyses and a larger data set would be required to investigate these relationships more completely.

The results of estimating this model are shown in Table 17. The findings for the relationship between service quality and TFP are strong: the relationship is negative for six out of ten quality measures, and significantly negative for four of them. On the basis of these data, there appears to be a substantial tendency on the part of the LECs studied to subordinate service quality for improved productivity and profitability.

Table 17. Service Quality and TFP, Seven Large LECs

	RSQ	RSQ Adj	Obs	d.f.	TFP Relation to Service
On-time Residential Service Calls	.756	.715	36	30	+ S
Satisfaction of Residential Customers	.454	.366	37	31	- NS
Satisfaction, Large Bus. Customers	.151	.014	37	31	- S
Satisfaction, Small Bus. Customers	.583	.515	37	31	+ NS
InterLATA Connection: % completed	.600	.527	35	29	- S
IntraLATA Connection: % completed	.369	.219	27	21	- NS
On-time Business Service Calls	.634	.574	37	31	+ NS
On-time Access Service Calls	.703	.616	23	17	+ NS
Dial Tone Response Time	.128	-.013	37	31	- S
Transmission Quality	.270	.152	37	31	- S

RSQ: R-Squared
RSQ Adj: RSQ Adjusted degrees of freedom
Obs: Number of Observations
d.f. : degrees of freedom
+ S: significant positive TFP relation to service (1 occurrence)
+ NS: insignificant but positive TFP relation to service (3 occurrences)
- S: significant negative TFP relation to (4 occurrences)
NS: significant positive TFP relation to service (2 occurrences)
Source: Norsworthy and MacDonald, 1994.

II. DESCRIPTION OF THE PERFORMANCE-BASED TFP AND X-FACTOR MODEL.

The FCC, in its Fourth Further Notice of Proposed Rulemaking in Docket No. 94-1, requested comments on the USTA model for calculating total factor productivity, as well as comments on alternative methods. The previously submitted AT&T Direct Model, referred to by the FCC as the "Historical Revenue Method" of calculating the X-Factor, provided a sound

alternative to the USTA method. It showed the rate of return for the price cap LECs implied by particular X-Factors based on the actual historical performance of the LECs during the price cap period from mid-1991 to 1994.

In response to the FCC's indicated preference for a TFP method to measure the X-Factor, I developed with AT&T a TFP model, called the "Performance-Based Model." This model is similar to the predecessor AT&T Direct Model in several respects. Like the AT&T Direct Model, the Performance-Based Model is based on actual performance of the LECs in a post-divestiture period. The AT&T results shown for the Performance-Based Model are based on data for the period 1985-1994, omitting the year 1984, pursuant to the FCC's First Report and Order in CC Docket No. 94-1, released April 7, 1995, para. 208. The new model is similar to the AT&T Direct Model in that it is based on interstate only data. Further, the Performance-Based Model resembles the USTA model in that it directly measures TFP in terms of the prices and quantities of outputs supplied to customers of the LECs, and of inputs purchased by the LECs to provide the outputs. However, we have taken a number of steps in the Performance-Based Model to correct for the many defects in the USTA model, which were previously pointed out. Before elaborating further on various aspects of the Performance-Based Model, it is useful to summarize in the table below some of the principal differences between the Performance-Based Model and the USTA model, as they are discussed in Appendix A.

COMPARISON OF THE PERFORMANCE-BASED MODEL AND THE USTA MODEL	
Performance-Based Model	**USTA Model**
1. All costs are based on actual historical performance of the LEC.	1. Capital costs are assumed and do not reflect actual costs paid by customers.
2. Relies exclusively on publicly available data and fully documented methodology.	2. Uses some proprietary data not publicly available; procedures are not fully described.
3. Directly measures the input price differential.	3. Assumes that input price differential is zero.
4. Directly measures productivity for the LECs' interstate access services.	4. Measures only productivity for all LECs' services, and assumes that productivity measure applies to the LECs' interstate services.
5. Actual utilization of capital at LECs is captured in TFP calculation. Allows for excess or deficient returns to capital input.	5. Utilization of capital assumed to be ideal at all times in TFP calculation. Makes no allowance for excess or deficient returns to capital input.
6. All costs assessed on ratepayers are used in TFP calculation.	6. Capital costs assigned to ratepayers may differ from capital costs used in TFP calculation.
7. Depreciation used in TFP calculation is that authorized by FCC for telecommunications plant and equipment.	7. Depreciation used in TFP calculation differs from FCC authorized rates, and is not based on telecommunications industry.
8. Costs of capital are based on LECs' actual costs, with debt and equity costs separately measured.	8. Costs of capital do not distinquish debt from equity, and are thus distorted by upward bias.
9. Adjustment to capital stock for technological changes in performance of capital goods is included in the TFP calculation.	9. No adjustment to capital stock is made for technological changes in performance of capital goods.

1. The Performance-Based Model Relies Exclusively on Publicly Available Data and Fully Documented Methodology.

In any economic modeling effort, decisions must be made about what to measure and how to measure it. These decisions necessarily exclude alternatives. However, if the model is based on publicly available data and fully revealed procedures, the effects of the choices made in implementing the model can be studied by recalculating or re-estimating the model's results with alternative choices of data and procedures. The Performance-Based Model described here goes further to encourage reproducibility and analysis of the sensitivity of the model: the data are provided and the methods of calculation fully revealed.

This approach differs markedly from that of the USTA model, whose procedures are not fully described (and in some cases appear to be unknown even to the creators of the model), and some of whose data inputs are not disclosed for "proprietary" reasons. The results of the USTA model are therefore not reproducible and auditable, and its sensitivity to alternative choices of methods and data cannot be determined. For these reasons, assessed from a scientific perspective, the USTA model in its present state would seem to be a poor basis for Commission adoption.

In contrast to the USTA model, the Performance-Based Model uses **only publicly available data** to compute TFP and the associated input price differential and X-Factor. The data are documented as to sources, so that the data collection process itself is reproducible and

auditable. In cases where it has been necessary to project or interpolate data to replace missing values, the data are clearly identified and the methods explained. At present, the data used in the calculations are up-to-date to the best of our knowledge.

The methods of calculation for the Performance-Based Model are laid out in spreadsheet form for those interested parties who may wish to examine, question or reproduce them. The spreadsheet itself is publicly available to interested parties. Further, the basis in economic theory for the TFP and related calculations are specified, and those calculations are based wherever possible on peer-reviewed best practice methods. In cases where reasonable alternatives to the currently applied methods can be identified, or where opportunities for refinement have been identified, quantitative analyses of the sensitivity of the results are being carried out or are planned for the immediate future. The spreadsheet approach also readily accomodates the incorporation of the results of econometric modeling, as in the instance of the hedonic adjustment for quality change in the capital input.[35]

In the crucial area of **capital measurement**, for example, the current approach in the Performance-Based Model uses the **net book value** as the measure of the **capital stock**. This treatment reflects the regulatory accounting practices on which current and past reporting of the financial performance of the LECs is based: the **value of investment** and the associated **rate of return** on that investment. Interested parties may use their own versions of capital measurement to appraise the sensitivity of the Performance-Based Model to measurement

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[35] This is discussed and illustrated in Norsworthy and Jang (1992) ch. 2.

alternatives. The same approach is being applied to the alternative depreciation methods. This procedure, in contrast to that of the USTA model, whose data and methodologies are not fully revealed, will enable interested parties to assess the effects of *any* alternative analytic method or data sources. The results of those parties' alternative methods should then also be reproducible by others.

2. The Performance-Based Model Directly Measures and Includes The Input Price Differential.

A major deficiency of the USTA analysis of the X-Factor for price cap regulation is its conclusion that the input price differential should be zero. As pointed out above, USTA's conclusion in this regard was reached by a distortion of statistical reasoning. In the Performance-Based Model, an index of input prices is computed directly, using data reported to the FCC to calculate the labor and capital input price indices. Publicly available price series, and aggregation weights computed from the Bureau of Labor Statistics (BLS) input-output table, are combined to compute a materials price index. These three price indices cover the three categories of input expenditures of the LECs: labor, capital and other purchased input, called materials. These categories include all reported costs of the LECs, and conform to the requirement of the economic theory of production in the short run that all revenues are assigned to costs.

In the Performance-Based Model, the three input price indices for labor, capital and materials are combined into a single input price index using Fisher's Ideal Price Index method, as documented by Diewart (1993).[36] The Tornquist input index used in the calculation

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[36] Diewart (1993) ch. 13, Diewart and Nakamura (1993).

of TFP by USTA implies an input price index. That is, the input price index that is consistent with the input quantity index used by USTA is obtained by dividing the total expenditure on inputs by the input quantity index. This USTA procedure gives unstable results. The input price index obtained in this way is different from that which would be obtained by aggregating the input prices of the LECs directly, using the Tornquist method. In contrast to this instability, the input price index in the Performance-Based Model is the same, whether it is inferred from the quantity index or computed directly. Even if the USTA analysis acknowledged the necessary role of the input price differential, the value implied by its model is ambiguous.

The input price differential for determining the X-Factor is calculated as the difference between the growth of input prices for the U.S. non-farm business economy, and the growth of the input price index of the LECs. The calculations of the input price index and its growth rate are carried out in the spreadsheet for the Performance-Based Model. As noted above, the input price differential for the 1985-1994 period in 2.54 percent, which should be included in the calculation of the X-Factor for the LECs' interstate access services.

3. The Performance-Based Model Directly Measures Productivity for Interstate Access.

The organizing principle for productivity analysis of an enterprise that provides services to a market is that the output measures should reflect the quantities of services that are chosen by the customers and the prices that the customers face when deciding what quantities of services to buy. For implementation in practice, the output measures must reasonably match the available revenue data sources. When these principles are applied to productivity measurement

for the LECs, the output measures available through the ARMIS reports that most accurately capture the customer decisions are minutes of interstate access, supplemented by end user access lines and special access lines; minutes of intrastate toll calls; and the number of local calls. The corresponding revenues from the same source are interstate access revenues, intrastate toll and access revenues combined, and local revenues.

As previously noted in Part I above, the Fisher Ideal Index of interstate access services provided by the LECs have grown more rapidly than local service or intrastate toll service. Table 6, which was previously shown at page 26, supra, sets forth the rates of growth for three categories of telephone service for the post-divestiture period commencing in 1985.

These measures of activity represent the services provided by the LECs better than the categories of deflated revenues in the USTA model. Specifically, the output index used in the USTA model is distorted by the price for special access services, which rises from an index value of 100% in 1984 to over 700% in 1989.[37] This price behavior follows administrative decisions by the Commission, and while the price changes may be historically accurate, they surely do not reflect the marginal cost of special access services to the LECs in each of the years, as required by the economic theory of productivity. Neither can it be argued that these price changes reflect values to the customers in each of the years, as advocated for using revenue weights based on administered prices by Fuss and Waverman.

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[37] Based on worksheets submitted by Christensen Associates in California PUC proceedings. As noted above, the source for this price index is not revealed.

The three categories of service in the Performance-Based Model are priced directly, not from deflated revenues. The basis of interstate access pricing, which is regulated by the FCC, is the Common Line formula. Interstate access services are sold to the Interexchange Carriers (IXCs). Intrastate access and toll services are regulated by state authorities and are sold primarily to end users of telephone services. Minutes of use for interstate and intrastate toll services are traffic-sensitive, as are the charges assessed for these services. Further, the output quantities that result from deflating revenues may understate output because the price indexes may not include discounts-- a major element of competition in long-distance service -- while the revenues do.[38]

As shown in Table 6 above (p. 26), interstate access services have grown at an annual rate of 6.83 percent, while other regulated services (local and intrastate toll) have grown at annual rates of 3.03 percent and 6.78 percent, respectively. When these two categories (local and intrastate) are combined into a single Fisher Ideal Quantity Index based on their revenues, the rate of growth is 4.22 percent per year.

Interstate access services rely to a greater extent on fixed inputs (e.g. switches and transmission equipment) and to a lesser extent on labor and materials inputs, as compared to local service. Consequently, there should be greater economies of scale in the LECs' provision of interstate access than in their provision of other telephone services. In the Performance-Based Model we assumed that inputs grow at the same rates for interstate access as for the LECs' other

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38 The USTA model's worksheets are not documented as to its data sources, and thus it cannot be determined whether discounts are reflected.

regulated telephone services. The implied allocation of costs that results is thus quite conservative. The actual proportion of interstate revenues of all price cap LECs to revenues subject to separation is 25.3 percent, while the corresponding proportion of total operating expense is 23.1 percent. It is important to note, however, that no specific allocation of costs is required by the assumption that inputs grow at the same rates for all categories of service, although the assumption is consistent with the allocation of all costs in proportion to revenues and with the separations allocation noted above. Making this conservative assumption permits the computation of TFP separately for interstate access and other (intrastate and local) services in a way that combines to overall company TFP as it is measured directly.

These results, together with the input price differential (IPD) and associated X-Factors, are shown in Table 7 (which is reproduces from Part I above). As this table shows, for the LECs' interstate access services during the period 1985-1994, the TFP growth rate for the LECs is 4.94 percent, the input price differential is 2.54 percent, and the LECs' X-Factor is 7.33 percent.[39]

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[39] As discussed above (pp. 29-30 supra), we also made a calculation of the effect of differences in interstate revenue growth and interstate expense growth, according to the jurisdictional separations data for the 1991-1994 period. Table 7A, p. 30 supra, shows that, after this adjustment, the LECs' X-Factor for their interstate access services for the 1985-1994 period would increase to 8.24 percent.

Table 7. TFP, Input Price Differential and X-Factor in Interstate and All LEC Regulated Services: Rates of Growth, 1985-1994

	Interstate Access Services	All LEC Regulated Services
Output Growth	6.83%	4.90%
-Input Growth	1.89%	1.89%
=TFP Growth LECs	4.94%	3.01%
+IPD	2.54%	2.54%
- TFP Gr in NFB	0.15%	0.15%
= X-Factor	7.33%	5.40%

Note: TFP Gr in NFB is Total Factor Productivity Growth in Non-Farm Business

Source: Computed in Performance-Based Model

The results shown in Table 7 reflect the rate of growth of aggregate inputs (labor, materials and capital) for the 1985-1994 period, which are aggregated using the Fisher Ideal Quantity Index. The TFP index is the Fisher Productivity Index advocated by Diewart (1993), which is the ratio of the corresponding Fisher Ideal Quantity Indices for outputs and inputs.

In the case of the LECs' interstate access services, the aggregate interstate output index, as described above, is used. The rate of input growth for all LEC regulated services is assigned to interstate access. The input price differential, described in the preceding section, is used with the TFP measures to compute the respective X-Factors for Interstate Access, and for All LEC Regulated Services.

Clearly, it is feasible to calculate separate measures of TFP for interstate access services and other regulated telephone services for the RBOCs, based on conservative assumptions about costs and direct measurement of outputs in the respective sectors, using only publicly available data. If more specific data concerning the LECs' expenditures and prices of materials were reported and were accessible to the public, more refined estimates of the input prices and the input price differential could be achieved, with a resulting refinement in the TFP and X-Factor.

The TFP and X-Factors in Table 7 reflect separate calculations for interstate access and all LEC regulated services. These calculations are consistent with the assertions of certain LECs before state regulatory bodies that *price caps for intrastate services should be based on TFP calculations that exclude interstate services*. Further, the results shown above are consistent with the general approach advocated by Dr. Lee Selwyn, who advocated the separation of interstate from intrastate TFP and X-Factors in his recent testimony before the California Public Utilities Commission.

The period used in Table 7 is 1985-1994. The year 1984 was omitted in

accordance with the Commission's finding that the year 1984 should be excluded for purposes of measuring the X-Factor. (First Report and Order, para. 208.)

4. The Capital Measurement Methods in The Performance-Based Model Are Based on The Actual Performance of The LECs.

The Performance-Based Model applies a generalized approach to measurement of TFP that is consistent with the actual performance of the LECs. It allows for the fact that capital utilization may differ in any period from the ideal that would exist in long-run equilibrium in an industry experiencing no economies of scale or diseconomies of scale. In other words, the Performance-Based Model does not assume that the capital stock is fully adjusted to a cost minimizing equilibrium level. By contrast, the USTA model uses of an out-dated framework that requires these very restrictive assumptions for measuring and analyzing the capital input employed by the LECs. This approach in the out-dated USTA model affects the user cost of capital and requires the assumption of a rate of return to capital that is determined outside the model, rather than determined by the costs and revenues of the LECs. As a result, the rate of return actually realized by the LECs may differ considerably from that which USTA assumes in its capital cost and TFP calculations, and thus the costs reflected in the USTA model do not account for the revenues received by the LECs.

In addition, the Performance-Based Model uses the depreciation charges authorized by the FCC, whereas the USTA model uses higher depreciation rates determined in a study completed well before divestiture and before the widespread adoption of newer technology. The Performance-Based Model acknowledges the effect that the financial structures of the LECs have on their tax liabilities, in contrast to the USTA model which does not distinguish debt and equity, and thus overstates the cost of capital. The USTA model does not adjust the capital stock and the prices of telecommunications equipment for changes in the performance of capital goods, whereas the Performance-Based Model has incorporated hedonic estimates of performance change. The structure of the latter model makes the computed X-Factor much less sensitive to differences in the prices and depreciation of capital than the USTA model.

a. The Performance-Based Model measures capital and related variables based on the actual performance of the LECs.

In its computation of the cost of capital, the USTA model assumes that the capital stock is adjusted to the level that would be achieved in a **competitive industry in the long run**. This assumption entails a number of implications that are unlikely on their face. These implications include the following: the **capital stock is adjusted** to the level that minimizes the total cost of production at all times; capacity utilization of the stock is ideal, with no bottlenecks and **no excess capacity** at any time; the **LEC adjusts its prices** to result in a level of services that **maximizes profits**; the **rate of return** of the LEC is equivalent to that which **would be earned in any other industry**, no more and no less; total revenues are exactly enough to provide this rate of return **with no excess or deficiency in profits**; and there are **no costs of adjusting the level of production** or the combination of inputs to **new technology**, to the **mix of services**

demanded by customers, and to **changes in the regulatory environment**. The regulatory record has many filings and other submissions by the LECs plainly recognizing that these conditions are *not* fulfilled at the present time. Most obviously, the LECs are not permitted by the FCc to adjust prices to profit-maximizing levels.

By contrast, the Performance-Based Model allows the capital stock to be what it is, with the following possibilities: the LECs have market power; their capital stocks are not necessarily at the long run cost-minimizing level; there may be excess network capacity or bottlenecks from time to time; the rates charged to customers are administered through a regulatory process; the LEC's rate of return is determined by the actual difference between its costs and revenues; the rate of return in a given year may be result in sub- or super-normal profits; significant adjustments to new technologies take place; and changing patterns of customer demand or changes in regulation may absorb resources.

These differences between the Performance-Based and USTA models have consequences that cause the TFP and the X-Factor measurements to differ materially between the two models.

b. All costs assessed on ratepayers are used in the TFP calculation.

In the Performance-Based Model, all of the revenues of the LEC are assigned to costs, and thus appear as payments to one of the inputs: labor, materials or capital. The cost of capital includes the residual income, or property income, that is realized after all other costs have been met. This pattern is exactly as specified in the short run theory of production outlined by

Brown and Christensen (1981), and elaborated by Berndt and Fuss (1986). As noted above (pp. 46-47, supra), the USTA model assumes a cost of capital based on the Moody's Utility Bond Index, with adjustment for depreciation and tax effects. This assumed cost of capital will not usually equal the cost paid by the ratepayers, which includes any excess or deficiency in the rate of return.

c. Depreciation used in the TFP calculation is that prescribed by the FCC.

In the Performance-Based Model, the depreciation of the capital stock is based on amounts reported in ARMIS, and therefore is the depreciation authorized by the regulatory authorities, federal and state. As noted in Part I above, if this authorized depreciation was less than "economic" depreciation, the economic rate of return would be lower than the returns authorized by regulators and the depreciation expense would be higher than regulatory-approved depreciation amounts. Perhaps a case can be made that authorized rates of depreciation are different from economic depreciation, but as noted in Part I, USTA has not made such a case. It has simply used outdated and inapplicable depreciation rates from a study that antedates divestiture, and does not even involve telecommunications plant and equipment.[40]

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[40] To appraise an alternative methodology that includes different depreciation rates, work has begun to augment and supplement the Performance-Based Model by a module that applies the perpetual inventory method of determining the capital stock. When the results from this work are available, it will be possible to measure the effects of alternative depreciation assumptions on the TFP and X-Factor measures computed by the Performance-Based Model. The structure of that model makes the X-Factor computed insensitive to differences in the depreciation of capital, in contrast to the USTA model.

d. Costs of capital are based on the LECs' actual costs, with debt and equity costs separately determined.

The Performance-Based Model uses the costs reported to ARMIS by the LECs. These costs include interest expense paid on debt, which is treated by the corporate income tax laws as a business expense, and thus tax-deductible. The return on equity, however, is treated as taxable under the tax laws. By adopting this approach, the AT&T model accurately captures the tax liability of the LECs.

By contrast, the USTA model does not distinguish between debt and equity capital. It treats the assumed after-tax return on capital as if the federal corporate tax were paid on the full pre-tax return, rather than just on the equity portion. In 1991 and 1992, the ratio of debt to equity and debt combined for the RBOCs averaged 0.52 according to ARMIS reports. As shown in Part I above, USTA's ignoring the tax-deductible status of interest paid on debt (and thus assuming an all-equity capital structure of the LECs) overstates the user cost of capital by about 30% of its correct value. The implied rate of return on investment should then be reduced by about 23% from the value calculated in the USTA model. As a result, the USTA model overstates the cost of capital and therefore the share of capital in total costs. The quantitative effect on the TFP measurement arising from this error in USTA's approach cannot be determined without full access to the USTA data and procedures.

e. **The Performance-Based Model takes into account quality improvements in capital goods.**

The available data suggest that there have been important quality improvements in recent years in at least two key categories of capital equipment: switching and transmission equipment. The economics literature has many studies showing that the prices of telecommunications equipment, when adjusted for performance change, decline when compared to the price indices for that equipment reported by the Bureau of Labor Statistics, or by various studies undertaken on behalf of telecommunications companies. From the perspective of quantitative economics, the preferred approach is to estimate quality improvement based on the performance characteristics of the equipment.

There are two main approaches to quality adjustment based on statistical techniques, both of which are categorized in the literature as hedonic methods. Berndt, Griliches and Rappaport (1995) have applied hedonic methods to determine quality change in personal computers based on the array of opportunities to purchase PCs with various performance characteristics. Norsworthy and Jang (1993) applied a different type of hedonic input adjustment to semiconductors used in producing telecommunications equipment and computers, which adjustment relies on estimating the hedonic weights in the context of a cost function. Norsworthy et al. (1993) applied a quite similar technique to measure a hedonic price adjustment for capital input at eleven large LECs for the period 1980 to 1990. The last study shows a fairly rapid decline in the effective price per unit of capital input for the LECs -- about 3.3 percent per year when extended to the 1985-1994 period. The results of this last study were applied to adjust the capital inputs in the Performance-Based Model to reflect quality changes in the capital equipment.

5. Additional Work Is Being Conducted To Refine Further The Performance-Based Model.

As noted above in Part I, there are other deficiencies in the USTA model involving (1) its use of revenue weights exclusively to aggregate outputs, and (2) its failure to recognize declines in the LECs' service quality. In connection with these two points, we are currently commencing work on other refinements to the Performance-Based Model.

I pointed out previously that the USTA model used **revenue weights** to aggregate outputs into an index of total output. The economic theory of production shows that the correct weights to use for this purpose are **marginal cost weights**.[41] Only under circumstances of competition in the markets for outputs will there be a tendency for the marginal cost for each output to be equal to its price. This condition is not met presently in the markets for local telephone service, or in the markets for access to the local loops. In principle, there is little disagreement on this issue. We recognize that stable estimates of marginal cost for output aggregation in telecommunications may be difficult to achieve, but we believe that the effort is warranted. Therefore, work has now been initiated to estimate marginal cost weights for the Performance-Based Model.

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[41] Fisher and Shell (1972); Diewart (1993) ch. 13, Diewart and Nakamura (1993).

As I observed in Part I above, there is evidence suggesting that the LECs tend to reduce quality of service in order to increase their efficiency and profitability. The incentive to make this trade-off has been recognized in the theoretical literature on regulation in discussing incentive regulation of utilities. The trade-off, found in the investigation noted in Part I, occurred during the post-divestiture period *but before* the LEC price cap regulation was introduced by the FCC in 1991. If anything, the incentives appear to be stronger now under price cap regulation for the LECs to exchange service quality for profitability. Some elements of the quality of service provided by the LECs necessarily impact upon the quality of service that can be provided by the interexchange carriers. For this reason, the Commission should give consideration to analyzing the feasibility of measuring the relationship of the LECs' service quality and their productivity measures. This may be done through separate analyses or through augmentation of the Performance-Based Model.

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