3 | TFP VS. ALTERNATIVE METHODS OF CALCULATING THE PERMANENT X-FACTOR

A properly-specified and supported TFP approach calculated using objective, verifiable data and which appropriately recognizes the effect of input price changes would provide an acceptable basis for calculating the X-factor in a long-term price cap plan; in the absence of an acceptable TFP measure, however, the Commission may need to continue to rely on alternative methods.

The Commission's tentative conclusion, as first indicated in the *First Report and Order*, and now reiterated in the *Fourth Further Notice,* "that a TFP approach should be used to compute the X-factor in the future,"[44] is a sound one, provided that the TFP approach selected by the Commission fully satisfies the Commission's general evidentiary criteria for the X-factor as set forth in the FFNPRM. To the extent the TFP approach is not properly-specified and supported, does not rely upon objective, verifiable data, or does not appropriately recognize the effect of input price changes on LEC output price levels — all problems that exist with both the original and revised Christensen/USTA studies — the Commission's general criteria will not be satisfied. The TFP approach with its direct measurement of productivity growth rates may be preferable to alternative approaches on economic and public policy grounds. However, a TFP approach that does not fully satisfy the Commission's general criteria offers no real advantages, and in fact has many disadvantages relative to other simpler methods of calculating the X-factor identified by the Commission in the FFNPRM, such as the historic revenue or historic price methods.

The Commission indicates its concern that using a moving average to update a TFP-based X-factor might require substantial resources to periodically recalculate the X-factor.[45] These concerns, while valid, are secondary when compared with the formidable problems underlying the calculation of the X-factor itself. The significant problems that exist with respect to Christensen's TFP Study exist independently of the use of a fixed TFP

44. FFNPRM, para. 25.

45. *Id.*

vs. a moving average method. It is premature to consider use of a moving average approach given that the proper methodology for calculating the X-factor is still elusive.[46] Much work is yet needed in order to develop an acceptable TFP measure. An acceptable TFP model, among other attributes, will be reasonably simple, be based on accessible and verifiable data, and use sound methodologies for calculating input and output prices and quantities. Only after an acceptable TFP model is developed can the Commission begin to evaluate the relative benefits of a fixed TFP measure vs. a moving average TFP.

The presence of many problems in the Christensen/USTA approach has not escaped the Commission's attention. Indeed, in the FFNPRM the Commission raised numerous specific questions relating to data and methodology, seeking comments on essentially all components of the Christensen/USTA study. The analysis that follows addresses the questions raised by the Commission, focusing upon the identification of serious infirmities with the Christensen/USTA study and correspondingly of the significant changes that would be required in the study to produce an acceptable TFP model for use in calculating the X-factor in a long-term price cap plan. Where possible, we estimate the quantitative effect upon the X-factor that results from specific corrections to the Christensen/USTA study, or at a minimum, the direction of the bias that results from specific errors made by Christensen. Since even a small percentage change in the X-factor has a significant dollar impact on rates for interstate services, the sensitivity of Christensen's results to specific corrections or improvements will be highly significant and must be taken into account.

The results of our analysis demonstrate that once a number of key corrections are made to the Christensen/USTA study, the correct X-factor will be found to be considerably greater than the paltry 2.1% claimed by USTA and even the highest 5.3% value adopted by the Commission in the *First Report and Order*. As shown in Section 4 of this report, the X-factor for interstate LEC services (including the input price differential (IPD) and a 0.5% Consumer Productivity Dividend (CPD)) increases from 5.1% based on the "1993 Update" Christensen/USTA study to 9.9%. Failure to adopt these corrections will result in LEC overcharges in the range of $12-billion over a four-year period, creating unprecedented windfall profits for these companies.[47]

46. A moving average of a flawed number is going to be a flawed number.

47. See footnote 39, *supra*, for an explanation of this calculation.

Output Index Issues

The Commission seeks comment on the reasonableness of Christensen's output price indices, noting that the construction of Christensen's indices do not follow conventional economic formulas and that price indices for local services, intrastate access, and long distance service appear to be based on an *ad hoc* method that the Commission finds difficult to replicate.[48] We agree with the Commission's findings. The empirical-related problems identified by the Commission with respect to the output index reflect the general problems with the data and overall approach used by Christensen as discussed in Section 2 of this Report. As found by the Commission, it not clear how the price indices used by Christensen to deflate revenues were derived. Moreover, to the extent public sources of price information, such as CPI indexes developed by the BLS for telecommunications services, are relied on to derive price indices to deflate revenues, those price indices are likely to overstate price growth and correspondingly to understate quantity growth. For example, as noted in a recent report by the Industry Analysis Division, the CPI for telephone services "has under weighted the dramatic reductions in toll rates that have occurred since 1984."[49] Another related problem with public sources of price data is their reliance on nominal "list" or tariff prices which fail to reflect the actual prices being paid for contract-based, discount, or non-tariffed services. Inasmuch as these prices will almost surely be lower than the published tariff rates, the use of tariff rates in calculating the annual change in LEC price levels will tend to produce an overstatement of the annual LEC price increase which, in turn, will have the effect of understating the growth in LEC physical output.

An alternative approach to Christensen's indirect method of measuring output by deflating revenue would be the use of physical output measures, such as minutes of use and lines. Such a method would offer the advantage of providing a direct measure of output that could be more readily replicated and avoid the need to use unverifiable and likely inaccurate price indices. In addition, such a method would alleviate problems associated with the categorization (and weighting) of outputs. In fact, in the case of *interstate* services (the subject of this proceeding and the purview of this Commission), switched access is the *dominant* component of output, representing some 64% of total LEC interstate revenues over the 1984 to 1993 period.[50] Output of switched access can be appropriately measured

48. FFNPRM, para 26.

49. Susan E. McMaster and James Lande, Industry Analysis Division, Common Carrier Bureau, *Reference Book: Rates, Price Indexes, and Household Expenditures for Telephone Service*, November 1995, page 130.

50. See USTA Response to the November 10, 1995 Information Request of the Ad Hoc Committee, Question 1, "Annual Revenue Shares" Data. However, from revenue data provided by the price cap LECs with their *First*

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in terms of minutes of use and lines.[51] If it is determined that more than one output dimension should be incorporated into an aggregate output index, revenue-weighted physical output measures of the principal interstate services could be used, and would still be far superior to Christensen's output price index method. Thus, switched access output could be measured in terms of minutes of use and lines, switched transport output could be measured in terms of minute-miles, and special access output could be measured in terms of voice-grade-equivalent circuit miles. Any direct output measurement along these lines, perhaps with further refinements as needed, would be far superior to continued use of the output price index method.

Input Index Issues: Capital

Cost of Capital

The Commission seeks comments on the appropriate measure of cost of capital and specifically whether Christensen's use of the Moody's Yield on Public Utility Bonds is appropriate.[52] As recognized by the Commission, Christensen's measure of the cost of capital is based solely upon the cost of *debt*. There would appear to be no valid economic rationale for relying solely upon the cost of debt.

The use of the cost of capital in the Christensen/USTA study is limited to the rental price formula.[53] From an economics standpoint, and consistent with the theory of efficient

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50. (...continued)
Report and Order compliance filing in May, 1995, it would appear that interstate switched access (including SLC) revenues may represent in the range of 75% of total LEC interstate revenues. See *Telecommunications Reports*, May 15, 1995, at 4.

51. If this approach is adopted, physical output growth can be determined by weighting minutes and line growth by the relative shares of traffic-sensitive (TS) and non-traffic-sensitive (NTS) costs, respectively.

52. FFNPRM, para 34.

53. The measurement of the capital input in the Christensen\USTA Study is based on the application of neoclassical capital theory which holds that the cost of the capital input is not reflected by the asset price of the capital input, but rather the annual flow of real capital services provided by the capital asset over time. The first step in this process is to construct annual user costs or rental prices for each of the six classes of capital assets identified in the Christensen Study. This so-called "implicit rental price" is intended to reflect the hypothetical price of renting the capital stock in a competitive market. The rental price formula used by Christensen depends on the rate of return or cost of capital, the rate of decay as reflected by the annual depreciation rate, various tax rates and tax rate components, and the economic reevaluation of the plant as reflected by the relevant asset price deflator or TPI. (See "Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation," Laurits
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capital markets, the cost of capital or rate of return used in the rental price formula should be the expected or *ex ante* rate of return (alternative cost of funds plus a risk premium suitable to the industry) sufficient to attract capital to the industry.[54] Accordingly, the appropriate cost of capital for use in a TFP study would be a combination of debt and equity weighted by the LEC's (or LECs') debt/equity ratio.

One method of calculating a cost of capital that combines debt and equity is to use, as the Commission suggests, the Commission-prescribed rate of return in effect during each of the years analyzed in the TFP study. The problem with this approach, however, is that the Commission did not represcribe the rate of return annually. Thus, it cannot be assumed that the Commission's prescribed rate of return would be a valid measure of the external cost of funds facing the LECs in every year.

However, since the use of the cost of capital in the Christensen/USTA study is limited to the rental price formula, there is another adjustment that can be made to correctly reflect the debt/equity distinction. Such an adjustment is especially appropriate given Christensen's use of a debt-only cost of capital measure. In particular, under the U.S. tax code, interest payments on debt are tax exempt, whereas the return to equity holders is taxed. This distinction should be recognized in the calculation of the rental price of capital by adjusting the tax effect component of the rental price formula to correctly reflect the ratio of equity to total debt and equity.[55] As demonstrated in Section 4 of this report, the debt/equity adjustment produces a significantly higher X-factor result.

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53. (...continued)
R. Christensen, Philip E. Schoech, and Mark E. Meitzen, May 3, 1994, pages 7-8.) Having calculated rental prices for each of the six classes of capital assets, Christensen then obtains his measure of capital service flows as being the product of these rental prices times the relevant capital stock amounts (themselves calculated using the "perpetual inventory method" as discussed as a separate matter below). The final step is to aggregate the capital service flows for each of the six classes of assets into one index of capital input quantity, using the rental prices for the various types of capital input as components in their respective cost share weights.

54. See J.R. Norsworthy and Tsai, D.H. (forthcoming) Macroeconomic Policy as Implicit Industrial Policy. (Kluwer Academic Publishers, Norwell, Mass.), Chapter 3.

55. *Id.* The tax component of the rental price formula, $(1-\mu)$ as designated in "Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation," *op cit*, page 7, note 8, is appropriately adjusted to $(1 - \mu\ \varepsilon)$ where ε represents the ratio of equity to the total of debt and equity.

Depreciation

The Commission seeks comment on the appropriate depreciation rates to use in the TFP Study. In particular, the Commission asks whether it is more appropriate to rely on rates prescribed by the Commission vs. the "economic depreciation" rates selected by Christensen.[56] The Commission's prescribed depreciation rates are more appropriate, because they more accurately reflect depreciation rates applicable to the LECs and are consistent with the RORR benchmark upon which the price cap paradigm is constructed.[57]
The Commission's prescribed rates have been set based upon studies conducted by the LECs relating specifically to the capital assets used by the LECs in providing telecommunications services. The rates selected by Christensen are based upon a chain of studies conducted by various economists for business assets for the economy as whole:

- According to the FFNPRM, the rates employed by Christensen were taken from a study conducted by D. W. Jorgenson, entitled *Productivity and Economic Growth*;[58]

- The cited Jorgenson study indicates it relies on "economic" depreciation rates from a 1990 Jorgenson and Yun study, *Tax Policy and the Cost of Capital*;[59]

- Further research finds the referenced economic depreciation rates in a related work by Jorgenson and Yun, entitled *Tax Reform and the Cost of Capital*, published a year later in 1991 by the same publisher.[60]

- The depreciation rates in the 1991 Jorgenson and Yun study were in turn derived from a 1981 study by Hulten and Wykoff, *The Measurement of Economic Depreciation*, which used the "best geometric approximation approach for all assets distin-

56. FFNPRM, para 38.

57. The use of any depreciation rates other than those prescribed by the Commission will produce a systematic bias that will lead to over- or under-earnings even if all other aspects of the price cap formula are correctly specified.

58. FFNPRM at 16, citing D.W. Jorgenson, "Productivity and Economic Growth," in *Fifty Years of Economic Measurement*, (E.R. Berndt and J.E. Triplett, eds., 1990), at 19-118 (Jorgenson).

59. Jorgenson, *op cit*, at 44, citing D.W. Jorgenson and Kun-Young Yun, *Tax Policy and the Cost of Capital*, New York: Oxford University Press, 1990.

60. D.W. Jorgenson and Kun-Young Yun, *Tax Reform and the Cost of Capital*, New York: Oxford University Press, 1991, pages 76-80.

guished by the Bureau of Economic Analysis (BEA) in constructing the U.S. national income and product accounts;"[61]

- The Hulten and Wykoff study referenced in both the Jorgenson and Jorgenson and Yun studies estimates the form and rate of economic depreciation using an econometric technique as explained in yet another 1981 Hulten and Wykoff study, *The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of the Box-Cox Power Transformation*;[62] and finally,

- The later-referenced Hulten and Wykoff study indicates that the Box-Cox Power Transformation regression technique was applied to data from the 1956 to 1971 time period.[63]

There are a number of serious problems with the underlying data upon which Christensen relied on in his study of LEC productivity. As evident from the above chain of references, the economic depreciation rates relied upon in the Christensen study of LEC productivity ultimately can be traced to a 1981 econometric analysis of data for the period 1956 to 1971 performed by two economists not specifically studying assets used by the telephone companies. The rates employed by Christensen are therefore based upon conditions from a much earlier time period than the post-divestiture time period of Christensen's study.

Furthermore, according to the Jorgenson and Yun Study, the asset categories applicable to the LECs (and specifically used by Christensen in his study of LEC productivity), including communication equipment and telephone and telegraph structures, belong to a third class of assets for which "little or no reliable information was available" to Hulten and Wykoff when they did their study.[64] Absent reliable information for this class of assets, Jorgenson and Yun indicate that Hulten and Wykoff made certain assumptions regarding depreciation rates based on "averages for assets in the first two groups," which they, Jorgenson and Yun,

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61. *Id.*, citing Charles R. Hulten and Frank C. Wykoff, "The Measurement of Economic Depreciation," in *Depreciation, Inflation, and the Taxation of Income from Capital*, ed. Charles Hulten, 81-225, Washington, D.C.: Urban Institute Press.

62. Hulten and Wykoff, *op cit*, citing Charles R. Hulten and Frank C. Wykoff, "The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of the Box-Cox Power Transformation," *Journal of Econometrics* 15, no. 3, April, 1981, pp.367-96.

63. Hulten and Wykoff, "The Estimation of Economic Depreciation," *op cit*, pages 389-394.

64. Jorgenson and Yun, *op cit*, p. 78.

maintained in their study.[65] These two groups of assets cover a wide range of BEA asset categories pertaining to the U.S. economy as a whole.[66] Jorgenson and Yun did make certain revisions to the depreciation rates from Hulten and Wykoff to incorporate what was at that time, "the most recent revision of asset lives by the BEA."[67] However, these revisions by Jorgenson and Yun appear to have had the effect of lowering the depreciation rates for asset categories applicable to the LECs. Of the three depreciation rates applied by Christensen to LEC capital assets, two represent reductions from the "old" depreciation rates for those same categories.[68] Thus, the depreciation rates relied upon by Christensen for the six categories of capital assets used by the LECs appear to be based not only upon pre-divestiture conditions, but conditions applicable to a wide range of BEA asset categories generally revised to incorporate longer lives.

By contrast to the "economic" depreciation rates used by Christensen, the LECs have regularly and consistently sought significant increases in depreciation rates for their capital assets over time, citing the high rates of technological change and changes in industry structure in the telecommunications industry. The Commission has recognized these changes and the connection between them and the acceleration of LEC depreciation.[69] As succinctly stated by the Commission, "the goal of the depreciation prescription process is to

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65. *Id.* In particular, Hulten and Wykoff "assumed rates of depreciation equal to 1.65 times declining balance rates based on BEA asset lifetimes for equipment and 0.90 times these rates for structures."

66. Appendix A provides a complete listing of the BEA asset categories utilized by Jorgenson and Yun, numbered sequentially from 1 to 51. The two groups of assets upon which assumptions for the third group of assets (which included the categories used by Christensen) were based include asset classes: 6, 7, 9, 11, 13, 20, 21, 28, 29-32 (in Group 1), and asset classes 14, 22, 25, 26, 27, 35, 36, 37, 38, 43, and 44 (in Group 2). *Id.*

67. *Id.*, p. 78.

68. Specifically, Christensen applies the "new" rate for the BEA category "communications equipment" of 11.00% to LEC investment in central office equipment, transmission equipment, and information origination/termination equipment, whereas the "old" rate listed for communications equipment is 11.79%. Similarly, Christensen applies the "new" rate for the BEA category "telephone and telegraph structures" of 2.25% to LEC investment in buildings and cable and wire, whereas the "old" rate listed for telephone and telegraph structures is 3.33%. See D. W. Jorgenson, *Productivity and Economic Growth, op cit*, Table 3.6, page 44, or the identical to the table appearing in Jorgenson and Yun, *Tax Reform and the Cost of Capital, op cit*, Table 3.19, pages 79-80, reproduced as Table A1 in Appendix A to this report. As shown in Table A1, the BEA asset classification scheme includes some 50 categories of non-residential assets. Table A1 provides a complete listing of the BEA asset categories and the depreciation rates identified in the Jorgenson and Yun study and used by Christensen. The third depreciation rate identified as being used by Christensen, a rate of 15.46% applied to LEC investment in general support equipment, does not appear listed in either of the Jorgenson studies and is not explained in the Christensen study.

69. Report and Order, CC Docket 92-296, In the Matter of Simplification of the Depreciation Prescription Process, October 20, 1993, para. 56.

accurately reflect the actual rate of plant retirement."[70] It has long been the practice of this Commission to consider LEC-specific conditions in authorizing depreciation rates and methods. The extensive body of evidence and experience relating to this issue invalidates the use of any "economy-wide" depreciation conditions.

According to the Commission, the depreciation rates selected by Christensen are significantly lower than rates prescribed by the Commission.[71] The prescribed rates, however, are historically even lower than those requested by the LECs, and the LECs have been subject to depreciation reserve deficiencies.[72] Thus, to the extent prescribed rates are reasonable reflections of the fundamental economic conditions of capital recovery facing the LECs, it would be incorrect to rely upon rates selected by Christensen that do not reflect those fundamental economic conditions and that portray a pattern inconsistent with that which the LECs have proposed and the Commission has adopted. For these same reasons, it would be appropriate for the Commission to require that depreciation rates for future updates be within the bands established by the Commission for streamlined treatment.

In the TFP model, depreciation enters into the calculation of both the TFP and input price differential components of the X-factor. The effect on results of using Commission-prescribed depreciation rates cannot be determined *a priori*, but rather is an empirical issue. However, to the extent the Christensen/USTA study understates depreciation rates relative to prescribed rates in the manner found by the Commission, Christensen's results can be shown to be biased downward; as demonstrated in the next section of this Report, the use of higher depreciation rates consistent with Commission prescriptions produces a significantly higher X-factor result.

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70. *Id.*

71. FFNPRM, para. 38, note 59. As set forth in note 59:

> Based on the depreciation rate as prescribed by the Commission for the period from 1984 to 1992, the average composite depreciation rate of the BOCs, GTE, and SNET was 7.1%. For that period, the average composite depreciation rate in USTA's February 1, 1995 TFP study for those LECs was 5.7%.

Thus, according to the Commission (we have not been able to replicate the Commission's calculations), the depreciation rates used by Christensen are some 20% to 25% lower than those prescribed by the FCC on the basis of average composite depreciation rates.

72. See Report and Order, CC Docket 92-296, In the Matter of Simplification of the Depreciation Prescription Process, October 20, 1993, para. 51. The Commission specifically acknowledges that "in the past, our depreciation practices and rates may have lagged behind changes in the telecommunications markets."

Capital Stock/Economic Stock Adjustment Factors

The Commission seeks comments on the most reasonable method to estimate capital stock, and in particular, on the most appropriate methods and data sources for determining replacement values.[73] The Commission also seeks comment on the economic stock adjustment factors used in the Christensen/USTA study to derive the capital stock replacement values. The Commission's concerns with respect to the reliability of Christensen's method is underscored by the very large swing in the capital replacement value data series that occurred between the original and revised Christensen studies. The data problems so evident with the capital replacement value series reflect the general problems with the data and approach used by Christensen as discussed in Section 2 of this report, and provide further evidence of the inappropriateness of relying upon the Christensen/USTA study in a long-term price cap plan.[74]

Indeed, replacement or reproduction values are fundamentally "soft" figures that cannot be directly gleaned from LEC accounting data, yet the values computed for them have a material and decisive impact upon the resulting TFP value. Also, the Commission does not have the data necessary to replicate the calculations or to audit or verify the underlying data and assumptions that were used, or to test for consistent and unbiased application of those assumptions. As discussed in Section 2 of this report, Christensen himself cannot explain, for example, how the values for 1984 were calculated, who did the calculations, or what engineering assumptions were used to determine "reproduction cost." The conversion from book to reproduction cost was made by the individual LECs and not by Christensen Associates, and furthermore, Christensen does not know what specific methodology was used to accomplish these conversions or, for that matter, whether they were even done consistently from one LEC to the next. We do know that there were apparently major problems with at least some of the figures used in the May, 1994 study, because of the wild swings in some of the individual LEC numbers in the "1993 Update."[75] The existence of these problems confirm the inappropriateness of relying upon the type of data and analysis methodologies used in the Christensen/USTA study for a long-term price cap plan.

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73. FFNPRM, para.41-43.

74. See, e.g., November 10, 1995 Information Request of the Ad Hoc Committee to USTA, Questions 3 and 4. No responses to these requests had been provided by USTA as of the date of this writing. In USTA's *Ex Parte* letter to the Commission, dated November 28, 1995, concerning its response to the Ad Hoc Information Request, USTA indicated only that it is "considering whether to purchase consultant services in this regard."

75. For example, NYNEX reduced its 1984 base capital stock by some $13.5-billion from the original May 1994 Christensen/USTA study to the January 1995 "update." See footnote 31, *supra*.

There are alternatives to using unauditable replacement capital price data. In particular, historical cost data, and specifically the net book value of plant in service, is available in ARMIS or from the U.S. Department of Commerce, Bureau of Economic Analysis (BEA),[76] and could be used for this purpose.

Investment

The Commission notes similar problems with the data on investments (plant additions) that was used in the Christensen/USTA study, and has requested USTA to provide more detailed information concerning the sources of the data and of the errors corrected in the revised study.[77] The investment series used in the TFP study must come directly from publicly available sources, otherwise results can be easily manipulated. Until USTA provides the additional level of detail sought by the Commission, further analysis of issues surrounding the investment data series is premature.

Telephone Plant Indices (TPIs)

Quite appropriately, the Commission expresses concern that the TPIs used in the Christensen/USTA study to deflate capital asset categories were calculated by the LECs and were thus not subject to external controls or validation.[78] The Commission expresses particular interest in whether the TPIs can be calculated in a timely manner and from publicly available data, and whether the Commission can rely upon present methods of calculating TPIs for calculating the X-factor. The Commission has asked the LECs to provide more detail concerning the calculation of the TPIs. Once again, the data problems cited in the FFNPRM with respect to the TPIs reflect the general problems with the data and approach used by Christensen as discussed in Section 2 of this report, and provide further evidence of the inappropriateness of relying on the Christensen/USTA study in a long-term price cap plan. As discussed in Section 2 of this report, the TPIs were based upon highly confidential information from the individual LECs, and Christensen was not provided with any

76. See, U.S. Department of Commerce, Bureau of Economic Analysis, *Fixed Reproducible Tangible Wealth in the United States*, 1925-89. Washington, DC: U.S. Government Printing Office, January 1993. The estimates in this publication cover the stock of privately owned and government-owned durable equipment and structures and of durable goods owned by consumers in the United States and are "consistent, definitionally and statistically with the national income and product accounts (NIPA's)." (page M-1). "Several measures of gross and net stocks, depreciation, and discards that reflect different valuations — historical cost, constant cost, and current cost" are shown in the publication. (page M-3)

77. FFNPRM, para. 44.

78. *Id.*, para. 45.

supporting documentation concerning the development of the TPIs. Of particular concern was the fact that Christensen did not appear to have applied any sort of reality or sanity check on the data that was furnished to him. As we noted earlier, he testified (in California) that he had no specific basis upon which to conclude that the anomalous TPI for Bell Atlantic, which showed a 49% increase in the prices for central office equipment (COE) plant over the study period as against price *decreases* for the other LECs, was accurate. He merely accepted Bell Atlantic's representation that it was.

It is important to emphasize that the TPI series have a critical impact upon the results of the Christensen/USTA estimate of LEC TFP.[79] As we discuss in Section 4 of this report, we have been able to assess the sensitivity of the TPI values to the resulting TFP estimate, and have found that adjustments to the TPIs have a material impact upon the TFP result.

USTA's reliance upon these confidential, proprietary, unverifiable, internally-generated price indices is particularly suspect in view of the fact that there are alternative price deflator data available from other, public sources, including the Bureau of Economic Analysis (BEA) and Bureau of Labor Statistics (BLS), that could be used in lieu of the unauditable LEC TPI series. The BEA/BLS data offer the critical advantage of being compiled by an objective, independent source. Appendix B to this report presents the BEA/BLS price deflator series that track categories of LEC investment, and compares those data series to the TPIs used in the Christensen/USTA study. The BEA assets categories we have selected match those used by Christensen for depreciation rates.[80] Because the TPIs have a significant effect upon the calculation of the X-factor under Christensen's approach, use of the BLS data in lieu of the LEC TPI data will produce different X-factor results. As demonstrated in the next section of this Report, the substitution of the BLS price deflator series for the LEC TPI data produces a significantly higher X-factor finding.

As discussed below, further refinement to the price deflator data used to calculate the X-factor in a long-term price cap plan is required to reflect hedonic price changes which account for changes in quality and/or capacity of the plant in each category. Such adjustments are especially necessary for the types of capital inputs used in the telecommunications industry, i.e., inputs containing computer chips, digital electronics, fiber optics, digital

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79. Christensen uses the "composite" TPI series (compiled from individual LEC TPIs) for each plant category to deflate annual dollar expenditures to constant 1984 dollars. Thus, inaccuracies in the TPIs will lead to erroneous capital input quantities, which are derived from the current dollar expenditure amounts. Hence, inaccurate TPIs will produce correspondingly inaccurate TFP, input price differential, and X-factor results.

80. See footnote 68, *supra*. Our criticisms of Christensen's choice of depreciation rates were not related to his choice of BEA asset categories to apply to his six LEC plant categories, but rather the fact that the depreciation rates presented in the studies that Christensen relied upon for the selected BEA asset categories were based on data from an earlier time period and from a wide range of other asset categories pertaining to the economy as a whole.

switching equipment, and other high-technology items, whose specifications and characteristics have evolved rapidly over time. For these types of inputs, the adjustment of price indexes to account properly for changes in quality and/or capacity over time is a very significant issue and, as discussed later in this section, one that the government is now dealing with. While this report does not develop specific hedonic adjustments to use in the calculation of the X-factor, as discussed below, research in related industries such as the computer industry provides evidence that hedonic price adjustments for LEC inputs would have the effect of substantially reducing input price growth for the LECs. Sensitivity analysis of Christensen's results indicates that incorporation of hedonic price adjustments would result in a significantly higher X-factor.

Perpetual Inventory Method/Implicit Rental Price

The Commission seeks comment on the validity of the perpetual inventory method used by Christensen. Under this method, capital services are imputed from the capital stock rather than from capital consumption.[81] The Commission also seeks comment on the related issue of the implicit rental price. Under the perpetual inventory method, the capital stock is multiplied by the implicit rental price to arrive at the value of capital services.

There is no inherent problem with Christensen's use of the perpetual inventory method, and the formula, while complex, is easily programmed for spreadsheet use.[82] As discussed in many contexts above, the problem once again lies in the data used in the Christensen/USTA study. The construction of the implicit rental price includes the cost of capital, the depreciation rate, various tax rates, and the TPI. Therefore, the problems discussed above with the data used by Christensen for cost of capital, depreciation, and TPIs affect the validity of the implicit rental price and consequently the reliability of the perpetual inventory method.

81. FFNPRM, para. 46.

82. As discussed in Section 4 of this report, see footnote 158, *infra*, software is also available which effortlessly calculates capital stock series based upon the perpetual inventory method.

Input Index Issues – Labor

The Commission seeks comments on a number of different aspects regarding the development of the labor index in the Christensen/USTA study.[83] The Commission notes a particular concern about how post-employment benefits (OPEB) costs, and other accounting rules changes, might affect the labor index.

Analysis of the updated labor expenditure data series from the Christensen/USTA study confirms the need for adjustments relating to OPEB and other one-time events. For example, there is a dramatic increase in labor expenditures between 1992 and 1993. The principal source of the increase is in the benefits area — in particular, management benefits increased by some 43% from 1992 to 1993. This is likely due to various "golden handshakes" offered to encourage early retirements and that are included as part of expensed benefits due to restructuring efforts and force reductions, as well as the OPEB accounting change mentioned by the Commission. "Golden handshake" payoffs should not be charged to the single year in which they are paid, but should be amortized into the future over some number of years. Christensen admitted during cross-examination in California that some of these types of expenses are included in the labor expenditure data.[84] Similarly, OPEB-related accruals should be amortized back, since the SFAS 106 revision represents a correction for the failure to accrue these costs as the obligation to pay them was incurred. Productivity measurement rules of the Interstate Commerce Commission (with which Christensen has been involved) require such amortization treatment.[85]

The incorrect "current" treatment of benefits creates a systematic upward bias in the growth of the labor input over time — particularly when the 1993 data is included — which has the effect of understating the X-factor. At a minimum, the failure to amortize OPEB and "golden handshake" payments incorrectly increases the apparent growth in LEC input prices as well as labor's share in the input mix, reducing the apparent input price differential. It also appears that this misstatement of labor costs results in an overstatement of labor input growth rates and hence an understatement of TFP.

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83. *Id.* para. 52.

84. California PUC, I.95-05-047, Transcript, September 27, 1995, at 264.

85. *See*, USTA *ex parte* filing, CC Docket 94-1, December 29, 1994, transmitting Christensen Associates documents on Interstate Commerce Commission (ICC) railroad cost adjustment factor (RCAF).

Input Issues – Materials

The Commission seeks comment on whether it is preferable to construct a price index for materials directly instead of using Christensen's method of deflating material costs by the GDP-PI.[86] From a theoretical perspective, it would be preferable to construct an index that provided a direct measurement of the quantity of materials. To the extent this may not be practical due to data limitations, at a minimum, more careful consideration should be given to the choice of deflator used to construct the material index. The GDP-PI does not necessarily reflect the price growth of materials used by the LECs. In addition, as discussed further below, the GDP-PI is subject to quality change bias because it relies upon price series which do not reflect quality-adjusted price changes.

Input Price Adjustment

The Commission seeks comment on all analyses and conclusions regarding estimation and use of the input price differential: What is the most reasonable way to account for changes in LEC input prices for use in a TFP approach to calculating the X-factor;[87] whether the long-term trend of the input price differential is zero;[88] whether the trend in LEC input prices has changed since divestiture;[89] whether an X-factor should be based upon the input price differential data from the same period as the TFP study;[90] whether the input price differential should be calculated using data from the Christensen/USTA study;[91] whether there are other sources of LEC input price data that would be preferable to the Christensen/USTA study;[92] and whether the Commission, USTA, or some other entity could construct this index?[93]

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86. FFNPRM, para. 53.

87. *Id.*, para. 56.

88. *Id.*, para. 57.

89. *Id.*, para. 57.

90. *Id.*, para. 58.

91. *Id.*, para. 59.

92. *Id.*, para. 60.

93. *Id.*, para. 60.

An input price adjustment is a critical component of a properly-specified X-factor adjustment.

In the two ETI reports submitted in the first phase of this proceeding, we demonstrated that the correct calculation of a TFP-based X-Factor must reflect the historic post-divestiture LEC productivity growth rate adjusted to recognize the decreasing real price of LEC inputs, and explained why failure to incorporate an input price adjustment based upon post-divestiture conditions would result in an understated productivity offset and a correspondingly excessive annual price cap rate adjustment, creating a direct and inappropriate transfer of wealth from ratepayers to the LECs.[94] The FCC, in its *First Report and Order*, correctly found that the X-factor should include an adjustment to reflect differences in LEC input prices. As succinctly stated by the Commission:

> If the trend in LEC input costs is consistent with the performance of the national economy as a whole, that trend should be reflected in the GNP-PI factor used to adjust PCIs annually. *But, if the inflation factor does not accurately reflect changes in the carrier's input costs, an X-factor based on productivity changes alone will not capture the full extent of the differences between changes in LEC unit costs and the economy-wide inflation adjustment.*[95]

In competitive markets, any differential in the cost of industry inputs vis-a-vis the economy-wide inflation rate will be flowed through in the price of the industry's outputs in addition to any productivity gains being experienced within the industry, *and this will occur even if there are no other productivity gains.* While the effects of productivity and input prices operate in similar ways in competitive markets, they are distinct components and their respective impacts upon the price of a firm's product are cumulative, a conclusion reached both by ETI and by FCC Common Carrier Bureau economists C. Anthony Bush and Mark Uretsky.[96]

In the price cap system, input price changes are supposed to be captured through the use of an external inflation index, such as the GDP-PI, which is then offset to capture LEC

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94. Economics and Technology, Inc., *LEC Price Cap Regulation: Fixing the Problems and Fulfilling the Promise*, May, 1994; *An Empirical Estimate of the LEC Price Cap "X-factor" based upon Historic National LEC Productivity and Input Price Trends*, June, 1994.

95. *In the Matter of Price Cap Performance Review for Local Exchange Carriers*, FCC CC Docket No. 94-1, *First Report and Order*, Released April 7, 1995 (FCC Price Cap Review decision), paras. 160-161 (emphasis supplied).

96. See ETI June 1994 Study, at 5-7; also see, C. Anthony Bush and Mark Uretsky, "Input Prices and Total Factor Productivity," ("Bush/Uretsky analysis"), *First Report and Order*, Appendix F, at 1.

productivity gains reflective of historical experience. However, because the GDP-PI is a measure of *output* price changes and not input price changes, the GDP-PI must be converted into an input price index.

In the case of the telecommunications industry, LEC input prices are growing far more slowly than input prices confronting the overall economy. The phenomenon of slower growth in input prices in the telecommunications industry is due, in part, to the substantial productivity and technological gains being experienced in those segments of the telecommunications industry that supply equipment and other capital resources to the LECs, as well as to the capital intensiveness of the local exchange telephone business and telecommunications generally. Accordingly, the appropriate way to capture LEC input price changes is by including an input price differential in the X-factor formula that accurately reflects the lower input cost conditions experienced by the LECs. Failure to capture the appropriate input price differential in the X-factor creates a windfall gain for the price cap LECs in the amount of that differential, something that could not occur in a competitive market.

It is important to note that all parties in the price cap review proceeding, including USTA and its economic consultants, Christensen and NERA, appear to agree with the fundamental principles that in competitive markets changes in output prices reflect changes in input prices as well as changes in TFP, and that in order to replicate the results of a competitive market, the X-factor must reflect input price changes as well as TFP changes.[97] The problem with USTA and its consultants, however, is that having conceded these basic principles, they go on to argue unconvincingly that the X-factor should ignore post-divestiture measurements of LEC input price changes.[98] Specifically, they contend that the X-factor should incorporate the long-run difference between LEC and economy-wide input prices, which they claim to be zero (based upon 30-40 year trends, not upon data limited to the post-divestiture period).[99] Indeed, rather than recognizing LEC input price growth as *below* the economy-wide inflation rate, USTA's assumption that the input price differential is zero leads to formulaic machinations by USTA that have the effect of setting LEC input price growth *above* the economy-wide inflation rate.[100]

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97. See Bush/Uretsky at 1.

98. They also ignore important hedonic (i.e., quality-related) effects on LEC input prices, which if taken into account, would show a lower rate of price decline for LEC inputs vis-a-vis unadjusted price index series.

99. See USTA *Ex Parte* Filing to the FCC in CC Docket 94-1 dated February 1, 1995, at 9-10.

100. USTA's economic consultants asserted that the proper measure of the X factor over the 1984-92 period was 2.1%, or the difference between the LEC TFP growth of 2.4% and US economy-wide TFP growth of 0.3. This construct assumes (without proof) that LEC inputs do not benefit from economy-wide productivity growth, and are therefore experiencing price growth that exceeds GDP-PI by the aggregate economy-wide productivity growth

(continued...)

The LEC input price differential (vis-a-vis GDP-PI) should be incorporated into the X-factor on the basis of post-divestiture conditions (the same period as the TFP Study) and not on long-term historical experience.

Fundamental industry changes took place at the time of the break-up of the former Bell System, rendering pre-divestiture experience largely non-comparable to conditions in the post-divestiture period. In particular, the telecommunications equipment market has become highly competitive in the post-divestiture environment, since the MFJ's "manufacturing restriction" was imposed and Bell Operating Companies could no longer purchase inputs internally, but instead had to acquire inputs at arm's length prices from outside suppliers. Hence, pre-divestiture input price data is not comparable to post-divestiture input price data.[101]

In addition to the important structural changes that occurred in the telecommunications industry specifically, general principles of competitive markets support the concept of relying upon a short-term input price differential. In a competitive market, the relevant time frame for reflecting any input price effects is clearly the short run. In competitive markets, individual firms react to the prices that they currently pay (and that their competitors also confront) for their inputs. The long term trend in the price of inputs is essentially immaterial. For example, the local gas station raises the price of a gallon of gasoline by 3 cents in response to a price hike by its supplier, and because it knows that the competing gas station on the next block is facing the same situation. The fact that gasoline prices may be trending upward by so-many-cents a gallon per year over a 30-year time frame is entirely immaterial to the price-setting process that is employed by an individual firm.

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100. (...continued)
rate. In other words, if GDP-PI, which is a measure of *output* price growth, is increasing at an average of 3.7% annually, and as a measure of *output price* growth reflects the economy-wide productivity growth rate of 0.3%, then economy-wide input prices must (they reason) be growing at 3.7% *plus* 0.3%, or 4.0%. In fact, LEC input prices are growing at only 1.4%; therefore, the Christensen/NERA analysis has the effect of understating combined LEC and supplier productivity growth by some 2.6% [i.e., 4.0% minus 1.4%], without reflecting any of the other corrections that must be made and that are quantified in Section 4 of this report.

101. According to one study, price indices for telephone company switching equipment are said to show "markedly greater decline after January 1, 1984, when AT&T's ownership of operating companies expired," all of which suggest to the author that "market structure has been a chief determinant of technical innovation." See Kenneth Flamm, "Technological Advance and Costs: Computers versus Communications," in Robert W. Crandall and Kenneth Flamm, Eds. *Changing the Rules: Technological Change, International Competition, and Regulation in Communications*, The Brookings Institution/Washington, D.C., 1989, page 5.

Hence, even if Christensen/NERA were factually correct in their portrayal of LEC input price movements, which they are not, the relevant, competitive outcome input price movements are necessarily those that occur in the short-term. And by their own admission, short-term LEC input prices have risen and continue to rise well short of the economy-wide inflation rate. USTA's rejection of an input price differential based upon the post-divestiture experience is totally at odds with the irrefutable facts that (1) Dr. Christensen's own study develops and incorporates the very same post-divestiture LEC input price data in the calculation of the LEC TFP for that same period, and (2) LEC input price data for the post-divestiture period shows a clear pattern of input price growth that is much smaller than the annual GDP-PI growth rate.

The issue of relying on short-run (post-divestiture) versus long-run data to forecast the future trend in LEC input prices was specifically analyzed by Bush and Uretsky.[102] Based upon numerous statistical tests of the data, Bush and Uretsky confirmed that pre-divestiture input price conditions should be discarded and that the X-factor should include an input price adjustment derived from Christensen's TFP data for the same period as Christensen's measure of LEC TFP:

> Based on these considerations, we believe that an input price differential based on long-run, pre-divestiture data is not a reasonable basis on which to calculate the input price differential for the post-divestiture period. We believe that the input price differential for the post-divestiture period should be calculated using post-divestiture data. In particular, we believe that the input price differential for the 1984-1990 period should be based on data from that period.[103]

Bush and Uretsky also addressed and dismissed USTA's assertions that short-run (i.e., post-divestiture) measures of the input price differential are inaccurate and therefore should not be relied upon in calculating the X-factor. They concluded:

> Based on the record before us, we have no reason to conclude that the measurement problem that NERA describes affects the calculation of input price differential for the 1984-1990 period.
>
> In summary, USTA's economic consultants' descriptions of problems in measuring changes in post-divestiture input prices fails to convince us that

102. See Bush/Uretsky at 11-14.

103. *Id.*, Appendix F, at 14.

> the problems are serious enough to warrant rejection of the measurements for use in calculating an X-factor.[104]

The Bush/Uretsky analysis explicitly tested the hypothesis that post-divestiture LEC input price movements differed fundamentally from the pre-divestiture condition against the Christensen hypothesis. Their results provide strong empirical support for the anecdotal, intuitive conclusion that post-divesture conditions are different. Significantly, nothing in the testimony offered in the California price cap proceeding by Drs. Christensen or Schmalensee for Pacific Bell or by Dr. Duncan for GTEC refutes the Bush/Uretsky/FCC conclusion.[105]

Other empirical evidence refutes USTA's claim of a zero input price differential.

Other empirical evidence refuting the USTA assertion that LEC input prices will increase at the same rate as overall economy-wide input prices comes from Dr. Christensen's own data and previous studies. Dr. Christensen's seminal study of long-term labor and capital costs confirms sustained and substantial differences in long-term price growth as between these two input categories for the private US economy.[106] According to Christensen's data, over the 38-year period 1929 to 1967, the labor input price index for the US economy grew by 3.90% as compared with capital input price growth of only 2.26%.[107] Data available from the US Bureau of Labor Statistics (BLS) confirms that this trend has continued to the present. The BLS data shows that for the post-divesture period 1984 to

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104. *Id.*, Appendix F, at 11.

105. Only Dr. Gregory Duncan for GTE-California attempted to address the Bush/Uretsky analysis. In empirical tests which Dr. Duncan claims support Christensen's finding of no long run difference in the input price series for the LECs as compared with the US economy, Dr. Duncan used a different statistical technique for modeling time series data, i.e, Autoregressive Integrated Moving-Average ("ARIMA") analysis, as compared with Dr. Christensen's use of standard regression analysis. However, the empirical tests performed by Dr. Duncan rely upon the same long run data series and suffer from the same infirmities as the Christensen analyses previously considered and rejected by the FCC in its price cap review proceeding. As such, Dr. Duncan's use of a different statistical technique than that adopted by Dr. Christensen does nothing to support the validity of Dr. Duncan's arguments, which are essentially the same as those made by Dr. Christensen in the first phase of the FCC's price cap proceeding.

106. Laurits R. Christensen and Dale W. Jorgenson, "U.S. Real Product and Real Factor Input 1929-1967," *Review of Income and Wealth*, Series 16, March 1970, pp. 19-50.

107. *Id.*, Table 4, Column 6 for Labor price growth; Table 5, Column 5 for Capital price growth.

1992, labor input prices for the US economy have grown by 4.24%, roughly *two and one-half times* the rate of capital input price growth (1.71%).[108]

Given these marked differences in input price growth as between capital and labor inputs, the critical piece of empirical evidence on input price growth for the LECs vs. the economy generally turns on relative intensities (i.e., cost shares) of capital and labor inputs for the LEC sector vs. the total US economy. Once again, compelling evidence is available from Christensen's own data. As shown in Table 1, for the US economy as a whole for the post-divestiture period 1984-1992, the annual input cost share for capital is only .314, with labor's cost more than double at .686.[109] For the LECs, based on Christensen/USTA study data for that same post-divestiture time period, the comparable annual input cost shares are a cost share for capital of .621, and a significantly smaller cost share for labor of .379.[110]

Thus, there is clear empirical evidence (from Christensen's own data) that capital input prices have grown at a significantly lower rate than labor input prices, and that the LECs are more capital-intensive than the US economy as a whole. These two pieces of empirical data provide compelling evidence that input prices grow at different rates in different sectors of the economy, and in particular, that LEC input prices have and are likely to increase more slowly than overall economy-wide input prices.

Table 1

CAPITAL/LABOR INPUT COST SHARES

	Capital	Labor
LECs	.621	.379
US Econ	.314	.686

108. Bureau of Labor Statistics, Office of Productivity and Technology, data prepared for February, 1995 Publications.

109. BLS data, *op cit.*

110. See Laurits R. Christensen, Philip E. Schoech, and Mark E. Meitzen, "Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation, 1993 Update, January 16, 1995, Table 2, Annual Input Cost Shares. To make the LEC input cost share data provided in the Christensen study comparable to national input/output accounting data produced by the BLS, I have excluded the materials category. When the materials category is included for the LECs, the annual input cost shares are as follows: .470 capital, .287 labor, and .243 materials.

Reflection of hedonic price changes would widen the downward trend in LEC input prices relative to economy-wide price changes.

The capital input price indexes used by Christensen — the Telephone Plant Indices (TPIs) — make no adjustment for changes in the nature of the input over time. By assuming that the nature of each of the items included within the TPIs remain constant, the TPIs fail to reflect changes in the character of the plant under study from one year to the next. Where the nature of the input is relatively stable — e.g., office furniture — this type of index may provide useful results. However, for many of the types of capital inputs used by LECs, i.e., inputs containing computer chips, digital electronics, fiber optics, digital switching equipment, and other high-technology items whose specifications and characteristics have evolved rapidly over time, the adjustment of price indexes to properly account for changes in quality and/or capacity is very significant. Indeed, failure to do so may have the effect of overstating price level increases and/or understating price decreases. In the economics and statistics literature, such adjustments for changes in quality and/or capacity are referred to as *hedonic* adjustments. Failure to make hedonic price adjustments will necessarily overstate input price growth and result in an X-factor that is misspecified and biased downward.

Recognition of hedonic-adjusted price changes is well-established in the economics literature. The Bureau of Economic Analysis (BEA) of the US Department of Commerce and the Bureau of Labor Statistics (BLS) have long recognized the importance of including quality change measurements in price indexes. BLS has studied hedonic methods as a way of dealing with quality change since the 1960s. Hedonic methods were first accepted and used in 1968 in the price index of new single-family houses. This index is currently also used as a proxy to deflate various construction activities. Hedonic methods won official acceptance in 1986, when the BEA announced a revision of the US National Income and Product Accounts to incorporate the use of a new computer equipment price index based upon hedonic methods. As a result, the BEA began using the hedonic price indexes of computers for deflation within the National Income and Product Accounts. By doing this, the BEA aimed at creating a better measurement to capture the effects of rapid technological advances in the computer market.

Failure to recognize quality effects in the capital input price indexes creates two separate, but not unrelated, sources of bias — the "substitution bias" and the lack of measurement of quality change. Substitution bias occurs because the weights in the index are based upon input expenditure patterns from prior years. As a result, the price index does not reflect changes in buying patterns in response to changes in relative prices. For example, "...even if the price of cellular phone calls drops relative to the price of postage stamps, so that consumers make more cellular phone calls and send fewer letters, the relative weight of cellular phones and postage stamps in the CPI will be based on expenditures in some

remote base year."[111] As another example, "the ability of firms using electronic components to substitute transistors for tubes, and then integrated circuits for transistors, and then successively more powerful integrated circuits for less powerful circuits, is not taken into account at all" in price indexes unadjusted for quality changes.[112]

Quality change bias occurs when improvements in the quality of products are inadequately measured or not measured at all. In fact, quality change measurements are basically non-existent. Changes in quality of new goods and services are not accounted for. Therefore, a bias occurs when a good is replaced by a new or improved good. For example,

> "...if the price of a tire increases but the quality of the tire is improved, then the change in the cost of living cannot be measured as simply a change in price. If the price doubles but the tire lasts twice as long, and other important qualities of the tire (traction, ride, and the like) are also better, then the quality-adjusted price change may in fact be zero or even negative."[113]

These biases have a direct impact on the various measurements that use price indexes, including productivity. Indeed, a recent report by the Advisory Commission to Study the Consumer Price Index suggested that when adding all the estimates of each source of CPI bias, the CPI overstated the actual rate of inflation by about 1.5% per year, with the quality change bias alone estimated at 0.2 to 0.6 of the total source of bias.[114] In recent years, there has been extensive debate about the negative impact to the economy of the so-called "CPI bias." Most economists agree that the CPI has been inflated due to methodological

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111. Gordon, Robert J.. "Measurement Errors in the CPI: Causes and Consequences," *Northwestern University and National Bureau of Economic Research*, Testimony presented before Senate Finance Committee, March 13, 1995 at 3.

112. Robert Gordon, "The Measurement of Durable Good Prices," University of Chicago Press, 1990, page 30. Gordon notes, as a consequence, that there was no accounting for the implicit price reduction that the invention of these new components implied, and that "the late introduction of integrated circuits as a totally new product and the use of obsolete weights helped account for the remarkable fact that the PPI group index (1178) for "electronic components and accessories" displays a 1967-83 price increase, while the price of virtually every type of final electronic product covered in this study (computers, PCs, electronic calculators, electronic typewriters, VCRs) declines at a double digital annual rate during the same interval.

113. O'Neill, June E., "Statement of June E. O'Neill Director Congressional Budget Office on the Consumer Price Index before the Committee on Finance United States Senate," Congressional Budget Office Testimony, March 13, 1995 at 8.

114. "Toward a More Accurate Measure of the Cost of Living," Interim Report to the Senate Committee from the Advisory Commission to Study the Consumer Price Index, September 15, 1995 at Executive Summary and page 27.

problems, particularly related to the failure of the CPI to incorporate hedonic adjustments. The CPI bias is also manifest in other indexes, such as the GDP-PI, that incorporate the CPI.[115]

The BEA's efforts to create more objective and accurate measurements have led to the recent announcement of a comprehensive revision of the national income and output accounts due at the end of 1995. The revision will result in new improved measurements of output and prices, using chain-type annual-weighted indexes. These improvements have been designed to deal particularly with the above described substitution bias. According to a recent article, "[b]y minimizing the substitution bias, the new measures of real GDP growth will also improve analysis of issues such as productivity, returns to investment, and the long-term growth potential for the economy."[116]

Hedonic price indexes are an attempt to measure changes in the characteristics of specific commodities. As alluded to above, much of the recent work in this field has focused on the computer industry — one of the fastest growing industries and one with rapid growth in technological change, both in terms of quality and capacity of the products.[117] According to one study, "...the quality-adjusted real prices for personal computers

115. For a discussion of the several causes of bias in the CPI, see, Diewert, Erwin W.. Written Testimony for the United States Senate Committee on Finance, April 6, 1995; Gordon, Robert J.. "Measurement Errors in the CPI: Causes and Consequences," *Northwestern University and National Bureau of Economic Research*, Testimony presented before Senate Finance Committee, March 13, 1995; O'Neill, June E.. "Statement of June E. O'Neill Director Congressional Budget Office on the Consumer Price Index before the Committee on Finance United States Senate," Congressional Budget Office Testimony, March 13, 1995; and "Toward a More Accurate Measure of the Cost of Living," Interim Report to the Senate Committee from the Advisory Commission to Study the Consumer Price Index, September 15, 1995.

116. Landefeld, J. Steven and Robert Parker. "Preview of the Comprehensive Revision of the National Income and Product Accounts: BEA's New Featured Measures of Output and Prices," *Survey of Current Business*, July 1995.

117. See, e.g., Ernst R. Berndt, Zvi Griliches and Neal J. Rappaport. "Economic Estimates of Price Indexes for Personal Computers in the 1990's," *Journal of Econometrics*, Vol. 68, 1995, pp. 243-268; Berndt, Ernst R. and Zvi Griliches. "Price Indexes for Microcomputers: An Exploratory Study," Chapter 2 in Murray F. Foss, Marilyn E. Manser and Alan H. Young, eds., *Price Measurements and their Uses*, Studies in Income and Wealth, Vol. 57, University of Chicago Press, 1993; Cohen, Jeremy Michael. "Rapid Change in the Personal Computer Market A Quality-Adjusted Hedonic Price Index 1976-1987," S.M. thesis, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, May, 1988; and Cole, Rosanne, Y.C. Chen, Joan A. Barquin-Stollemen, Ellen Dulberger, Nurhan Helvacia and James H. Hodge. "Quality-Adjusted Price Indexes for Computer Processors and Selected Peripheral Equipment," *Survey of Current Business*, January, 1986.

have been dropping at an annualized cumulative rate of about 25%."[118] Another study found that since the late 1950s the trend in annual decline may have been as high as 28% for mainframe computers of a given speed and capacity, and noted the widespread belief within the industry that for supercomputers and for minicomputers and microcomputers the decreases may have been even greater.[119] Yet another more recent study on personal computers in the 1990s concluded that "...on average these quality-adjusted price indexes based on econometrically estimated hedonic price equations decline at about 30% per year."[120] The official BEA price index for the commodity aggregate of computers and computer-peripheral equipment types, based largely on hedonic regression procedures, continues the steady decline over time revealed for the period 1953-1972: Over the 1972-1984 era, the average annual growth rate (AAGR) of this quality-adjusted price index is -13.8%.[121] Moreover, if one combines the results for the 1953-1972 time interval with those for the 1972-1984 epoch, one finds that quality adjusted computers that cost $531.88 in 1953 cost only $1.00 in 1982; in other words, what would have cost more than a half a million dollars in 1953 cost only $1,000 in 1984.[122] Moreover, since the calculations involve only mainframe and minicomputers and exclude personal (micro) computers, it is possible that this price index understates the amount of quality improvement.[123]

Clearly, the importance of accurate and objective indexes for telecommunications inputs is of particular concern in the development of a TFP-based long-term price cap plan. Indeed, as noted in an important work on technological advance in the telecommunications industry: "In terms of technological intensity, measured by R&D investment as a percentage of sales, communications equipment (at 9 percent) is second only to computers (at 12

118. Cohen, Jeremy Michael. "Rapid Change in the Personal Computer Market A Quality-Adjusted Hedonic Price Index 1976-1987," S.M. thesis, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, May, 1988 at 62.

119. Kenneth Flamm, "Technological Advance and Costs: Computers versus Communications," in Robert W. Crandall and Kenneth Flamm, Eds. *Changing the Rules: Technological Change, International Competition, and Regulation in Communications*, The Brookings Institution/Washington, D.C., 1989, page 16.

120. Berndt, Ernst R., Zvi Griliches and Neal J. Rappaport. "Economic Estimates of Price Indexes for Personal Computers in the 1990's," *op cit*, 1995.

121. Ernst Berndt, *The Practice of Econometrics: Classic and Contemporary*, "The Measurement of Quality Change: Constructing an Hedonic Price Index for computers Using Multiple Regression Methods," (Chapter 4), Addison-Wesley Publishing Company, 1991, page 125.

122. *Id.*, pages 125-126.

123. *Id.* page 126.