Exhibit 5
Composition of the Economy Relative to the Telecommunications Sector: Factor Inputs
(as a percent of total inputs - 1987)

	Labor	Capital*	Material
Economy-wide	**43.9%**	**5.9%**	**50.2%**
Telecommunications	**40.7%**	**22.3%**	**37.0%**

*Note: As measured by depreciation Source: Author calculations based on data defined in **Section 3.3.2**.

4.3.2 Capital Measurement

Not surprisingly, telecommunications is one of the most capital intensive industries in the economy. In **Exhibit 5** the factor input composition of the economy and telecommunications includes the current dollar value of depreciation as the measure of capital. This measure reflects the current value of capital consumed in the process of producing a given period's output. This measure most accurately reflects the amount of capital input consumed per unit of output. It is also the concept employed by the ICC in the development of the rail input price cost index with the rail's price cap formula.[74] Applying this definition, we see that telecommunications is almost four times as capital intensive as the aggregate economy: 22.3 percent versus 5.9 percent.

Other estimates of the capital composition of the telecommunications sector have been employed in the development of telecommunications input cost index. Most prevalent in the LEC proceedings is the approach used by Christensen Associates in defining capital for their proposed TFP methodology. In this analysis, Christensen Associates has proposed using a concept of an implicit price of capital. This measure results in an even higher estimate of the capital intensity of the telecommunications sector. There are several issues, however, with this approach. The concept of an implicit price of capital was developed as part of the theory of choice -- to assist in evaluating the post-tax financial costs of various factor inputs to business decision makers. Any individual unit, division or company might meaningfully need to conduct such a calculation for capital budgeting purposes. It is not clear that analyses of sectoral and aggregate productivity for a given amount of capital, particularly for public policy purposes, should be affected by tax

[74] ICC 3/22, 1989 p. 457-459. The ICC defines capital for both its price index and TFP as regulatory defined depreciation indexed to a BLS capital good price index. In addition, the ICC includes interest expense in its price index. The 1988 weights for depreciation and interest are 8.6 and 3.6, respectively. See AAR Railroad Cost Indexes, Association of American Railroads, March 1994.

policies.[75] This tax-adjustment of the price of capital is also not extended to include labor and materials, thereby further distorting the relative valuation of factor inputs by treating some as before taxes and others as after taxes.

We also find that the Christensen Associates definition of capital includes not only depreciation -- the appropriate concept of capital consumed -- but also the opportunity cost (interest) on the stock of capital and the revaluation of the stock. The former is an *implicit* financial cost not associated with evaluating the actual productivity of capital. The latter is largely an unrealizable paper gain or loss, since the stock of telecommunications capital is largely not fungible -- that is, most of these assets can not be sold outside the industry, and therefore, cannot accrue as realized gains or losses. Inclusion of these *implicit* costs doubles the perceived share of capital in total telecommunications costs.

For comparison purposes, we present a broader, but still pretax, approach to measuring factor input weights in **Exhibit 6**. This broader capital index includes depreciation, opportunity cost of capital stock, and the revaluation of that stock. This table presents the relative factor intensities of telecommunications versus the aggregate economy. As can be seen, using this definition the share of capital in telecommunications rises to 45.9 percent, with materials and labor both representing approximately 25 percent. For the U.S., capital increases to 16.2 percent, with materials at 44.7 percent and labor at 39.1 percent.

Exhibit 6
Composition of the Economy Relative to the Telecommunications Sector: Factor Inputs
(as a percent of total inputs)

	Labor	Capital*	Material
Economy-wide	**39.1%**	**16.2%**	**44.7%**
Telecommunications	**28.4%**	**45.9%**	**25.8%**

*Note: Capital is defined as Depreciation, Opportunity Cost and Revaluation. Source: Author calculations based on data defined in **Section 3.3.2**.

Employing the broader capital approach significantly changes the share of the capital input factor for both the U.S. and telecommunications relative to the depreciation method. However, regardless of which definition of capital is employed, it is clear that significant difference exists

[75] The tax code certainly impacts the amount of capital consumed. We are concerned however, with the efficiency of the capital actually consumed. The ICC explicitly addresses the need to analyze productivity in a pretax manner. Ibid.

regarding the importance of capital as a factor input to telecommunications relative to that of the economy.

Exhibit 7 presents the growth in three indexes covering various definitions of capital: the price of depreciated capital (the approach advocated in the analysis); the price of depreciated capital plus actual interest expenses for telecommunications firms (the ICC approach); and the broader definition including deprecation, the opportunity cost of capital stock, and the revaluation of that stock. The latter definition is calculated pre-tax. The first index increases at 1.72 percent per year over the 1985-93 period; the second by 0.21 percent and the last by -2.23 percent. We also note that the first index, i.e., the price of depreciation is used in our two benchmark comparisons reported in **Section 4.3.6**. That is, we apply this definition in calculating a TFP growth of 3.85 per year for telecommunications over the 1984-1991 period. In addition, in applying the price of depreciation approach to capital input price measurement we calculate an aggregate (i.e., economy-wide) TFP growth rate of .31 percent per year over the 1984-93 period -- exactly identical to the BLS estimate. Use of either other alternative definition of capital would lower the rate of growth in the total telecommunications price index and increase the differential between the growth in the aggregate input price index and the telecommunications price index reported in **Section 4.3.5**.

Exhibit 7
Comparison of Alternative Methods for Capital Input Price Measurement
(compound average annual growth rates)

	Depreciation	Depreciation & Interest	Depreciation, Opportunity Cost & Revaluation
1985-93	1.72	0.21	-2.23
1986-91	1.81	0.59	-1.10
1987-92	1.55	0.78	-0.26
1988-93	1.52	0.17	-2.09
1991-93	1.56	-0.33	-4.07

Note: Author Calculations. Sources: Depreciation and Gross Capital Stock: United States Department of Commerce, Bureau of Economic Analysis, *Detailed Industry Wealth Data Diskette*, September 13, 1994. Interest: United States Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business: Business Cycle Indicators*, various issues.

4.3.3 Materials Measurement

Returning to **Exhibit 5,** we find that materials as a component factor input make up 50 percent for the U.S. and 37 percent for the telecommunications sector. Some researchers have assumed that the price of material inputs purchased by the telecommunications sector could be represented by the GDP-PI, "...since this category is comprised of a diverse set of inputs".[76] At the same time, these same researchers calculate the "economy-wide" input price by representing GDP-PI as the price of economy-wide output and adding the change in aggregate productivity to calculate the change in aggregate inputs. However, as we have previously discussed, the GDP-PI neither represents the price of a diverse set of inputs to the productive sector nor the price of economy-wide output, but rather it measures the price of goods and services to final demand. In fact, the question is not the diverseness of the GDP-PI, but rather its accuracy as a proxy for telecommunications material prices. By definition, the GDP-PI excludes all domestic non-capital business to business transactions. Not surprisingly, in applying the double entry accounting framework to decompose the material inputs for the telecommunications sector relative to the aggregate economy, we find wide and pervasive differences in the relative material composition of the two sectors.

[76] L. R. Christensen et. al., May 1994, p. 9-10. In this study, "The Gross Domestic Price Index is used to represent the price of material, since this category is comprised of a diverse set of inputs".

Exhibit 8
Factor Material Input Shares: Top 5 Supplying Industries to GDP and the Telecommunications Sector
(share of material inputs, 1987)

GDP Material Inputs		Telecommunications Material Inputs*	
Supplying Industry	**Percent of Material Inputs**	**Supplying Industry**	**Percent of Material Inputs**
Retail Trade	16.4	Electronic Equipment	16.4
Construction	9.4	Real Estate	8.6
Health Services	9.3	Business Services	8.0
Wholesale Trade	6.6	Depository Institutions	6.9
Education	6.1	Wholesale Trade	6.0

*Note: Telecommunications Inputs net of access payments. Source: Benchmark Input-Output Accounts of the United States: 1987, U.S. Department of Commerce, Bureau of Economic Analysis and U.S. Department of Labor, Bureau of Labor Statistics, Office of Employment Projections Input/Output Data.

As **Exhibit 8** demonstrates, only one sector appears in both top 5 lists of largest sectors comprising material input purchases. In fact, telecommunications material purchases differ significantly from economy-wide material purchases, not just from GDP. For example, as presented in **Exhibit 9**, of the top five material supplying industries to the economy as a whole, not one is included within the top five material supplying industries to telecommunications. As would be expected, electronic equipment is a significant supplier of materials to the telecommunications sector, accounting for over 16 percent of telecommunications input purchases.[77] In contrast, for the economy as a whole such sectors as retail trade, construction and food make up significant shares of material purchases.

[77] When capital purchases from other industries are included, the share of inputs to the telecommunications sector originating from the electronic equipment sector is well above 40 percent.

Exhibit 9
Factor Material Input Shares: Top 5 Supplying Industries to the Economy and the Telecommunications Sector
(share of material inputs, 1987)

Economy-wide Material Inputs		Telecommunications Material Inputs*	
Supplying Industry	**Percent of Material Inputs**	**Supplying Industry**	**Percent of Material Inputs**
Construction	8.3	Electronic Equipment	16.4
Retail Trade	6.7	Real Estate	8.6
Food	6.5	Business Services	8.0
Education	4.6	Depository Institutions	6.9
Motor Vehicles	4.5	Wholesale Trade	6.0

*Note: non-telecommunications inputs. Source: Benchmark Input-Output Accounts of the United States: 1987, U.S. Department of Commerce, Bureau of Economic Analysis and U.S. Department of Labor, Bureau of Labor Statistics, Office of Employment Projections Input/Output Data.

This difference in composition of material purchases between the telecommunications sector and the aggregate economy is reflected in the overall material input prices that can be constructed. Using our framework we calculate fixed weight indices of material input prices for both the telecommunications sector and for the aggregate economy.[78] **Exhibit 10** presents a comparison of this calculated telecommunications materials input price indices with those for economy-wide materials inputs. We also include for comparison the GDP-PI, since often this measure is mistakenly employed as representing material price changes.

Over the 1984-1993 period, the price of telecommunications material input purchases has grown at less than one-third the rate of the GDP-PI and less than one-half the rate of material input price change experienced by the economy as a whole. The compositional difference among the material inputs to the telecommunications sector and to the aggregate economy, therefore, result in very different behavior in input prices. Furthermore, measurement of telecommunications material input prices by the GDP-PI, grossly overstates the change in material input prices experienced in telecommunications.

[78] Several alternative calculations were tried, including a chain weighted index, with little difference in the results.

Exhibit 10
Material Input Price Indices
(compound average annual growth rates)

	GDP-PI	Economy-wide	Telecommunications
1984-1993	3.60	2.18	1.07
1984-1989	3.59	2.15	.40
1990-1993	3.32	1.74	1.58

Source: GDP-PI: United States Department of Commerce, Bureau of Economic Analysis: Survey of Current Business. Economy-wide input price index and telecommunications: Author calculations.

Why would material input prices to the telecommunication sector exhibit such a low rate of growth relative to economy-wide material input prices and GDP-PI? Building on the earlier work of the Cambridge Growth Project,[79] recent research on the system-wide sources of U.S. productivity growth explains this phenomenon. Using a data base similar to that employed in this current analysis, the study authors analyzed the direct and linked interindustry productivity relationships and determined that the telecommunications sector is supplied by industries whose own TFPs are growing on average, faster than the TFP for the economy over the 1963-1991 interval.[80] This is true whether one analyzes only material suppliers or total suppliers, including capital.[81] In fact, telecommunications has one of the largest indirect (i.e., interindustry) productivity factors of any sector in the U.S. economy. Focusing on the estimates of sectoral TFP (i.e., direct productivity), **Exhibit 11** shows not only that telecommunications has the highest TFP of any sector over the 1963-91 period (3.0 percent per year) but that important supplying sectors such as electronic equipment (2.2 percent per year) are substantially higher than the economy-wide growth rate of TFP of .2 percent per year.

[79] Because input-output systems incorporate extensive information concerning production processes they are widely used in studies of productivity growth. In conjunction with the Cambridge Growth Project, Peterson (1979) developed comprehensive sets of direct (i.e., single sector total factor productivity) and linked interindustry (or indirect) productivity measures. The former is a system analog to the traditional single sector TFP concept. The latter measure the systemic impact of productivity changes -- i.e., quantifying the impact on all other sectors and the economy from productivity changes in any one sector. See: W. Peterson, "Total Factor Productivity in the UK: A Disaggregated Analysis" *Measurement of Capital.* New York: MacMillan Publishing Co. (1979).

[80] F. J. Cronin et al., *The Contribution of Transportation to Aggregate and Sectoral Productivity.* Prepared for the U.S. Department of Transportation, May 1994.

[81] D. Brown, F. Cronin, M. Gold, S. Lewitzky, "Estimating Sectoral and System-Wide Productivity Growth in the U.S., 1963-1991; an Input-Output Approach." Presented at the Southern Economic Association Meeting, November 1995.

Exhibit 11
Leontief Index of Direct (or Total Factor) Productivity Gains
(1963 through 1991, 1991 dollars)

	Total	Capital	Labor	Materials
Telecommunications	3.0	0.4	2.3	0.3
Instruments	2.4	-0.1	2.1	0.4
Comp. Office and Non-Electronic Mach.	2.4	0.0	2.0	0.4
Electric and Electronic Equipment	2.2	0.0	2.0	0.3
Textiles	1.0	0.0	0.8	0.3
Chemicals and Products	1.0	0.0	0.7	0.3
Rubber and Plastics	1.0	0.0	0.8	0.2
Furniture	0.8	0.0	0.6	0.2
Business Services	0.5	0.0	0.1	0.4
Paper and Paperboard	0.5	-0.1	0.6	-0.1
Agric. Food and Tobacco	0.5	0.0	0.3	0.2
Fabricated Metals	0.4	-0.1	0.4	0.1
Motor Vehicle and Misc.	0.4	0.0	0.4	0.0
Stone, Clay and Glass	0.3	0.0	0.4	-0.1
Printing and Publishing	0.3	0.0	0.3	0.0
Transportation and Warehousing	0.3	0.1	0.4	-0.3
Real Estate	0.2	-0.1	0.0	0.3
Amusements	0.2	0.0	0.2	0.0
Lumber and Wood Products	0.1	0.0	0.4	-0.3
Leather	0.1	0.0	0.5	-0.4
Mining	0.0	-0.2	0.7	-0.6
Finance and Insurance	-0.1	-0.3	0.5	-0.3
Wholesale and Retail Trade	-0.1	-0.1	0.2	-0.3
Primary Metals	-0.4	-0.1	0.3	-0.6
Personal and Misc. Services	-0.4	0.0	0.0	-0.4
Crude Pet. Mining and Ref.	-0.5	-0.1	0.1	-0.4
Construction	-0.6	0.0	-0.2	-0.4
Utilities	-0.6	-0.2	0.1	-0.4
Automotive Repair	-0.7	-0.2	-0.1	-0.3
Radio and TV	-1.2	-0.5	0.0	-0.8
TOTAL ECONOMY	**0.2**	**0.0**	**0.3**	**0.0**

Source: Cronin et al., *The Pennsylvania Infrastructure Study*. Prepared for the Pennsylvania Public Utilities Commission, 1993.

4.3.4 Labor Measurement

Christensen Associates conclude that over the 1984-1993 period, and for most intervals between those years, the price of labor for the LECs has grown more rapidly then for the aggregate economy. In reaching this conclusion Christensen employs an implicit price index for LEC labor, but a BLS fixed-weight price index, i.e., the Employment Cost Index (ECI) to measure the economy-wide price of labor. In fact, if the fixed-weight ECI price index covering telecommunications is employed with the similarly defined ECI for the aggregate economy we find that telecommunications labor prices have consistently grown more slowly than the aggregate. This is true for total compensation and for wages and salary only. In fact, a third internally consistent comparison reaches a similar conclusion. Average hourly earnings in the telecommunications sector have grown more slowly than average hourly earnings for the aggregate economy.

The LEC labor price index employed by Christensen is derived by dividing LEC labor compensation by the number of employees. If the composition of occupational employment changes due to, for example, a reduction in operators or other lower paying jobs at a higher proportional rate than higher paying jobs, average compensation per employee would appear to rise even if there were no change in the compensation of the remaining employees.[82, 83]

In contrast, the ECI "is a measure of the change in the cost of labor, free from the influence of employment shifts among occupations...The compensation series includes changes in wages and salaries and employer costs for employee benefits...Fixed employment weights are used..."[84] The ECI also provides data on a second index covering wages and salaries, excluding employee benefits. The ECI is available for the aggregate economy and for the Transportation & Public Utilities (T&PU) sector since 1985; telecommunications is included within the T&PU sector.[85]

Exhibit 12 depicts ECI growth rates for total compensation for the aggregate economy and T&PU. Prior to 1991, the growth rate for the aggregate economy exceeded that for T&PU.

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[82] Additional potential problems with this approach result from the way in which financial accounting methods recognize unusual labor related charges such as the 1993 other post-employment benefits (OPEB) and write-offs due to accrued expense for severance packages.

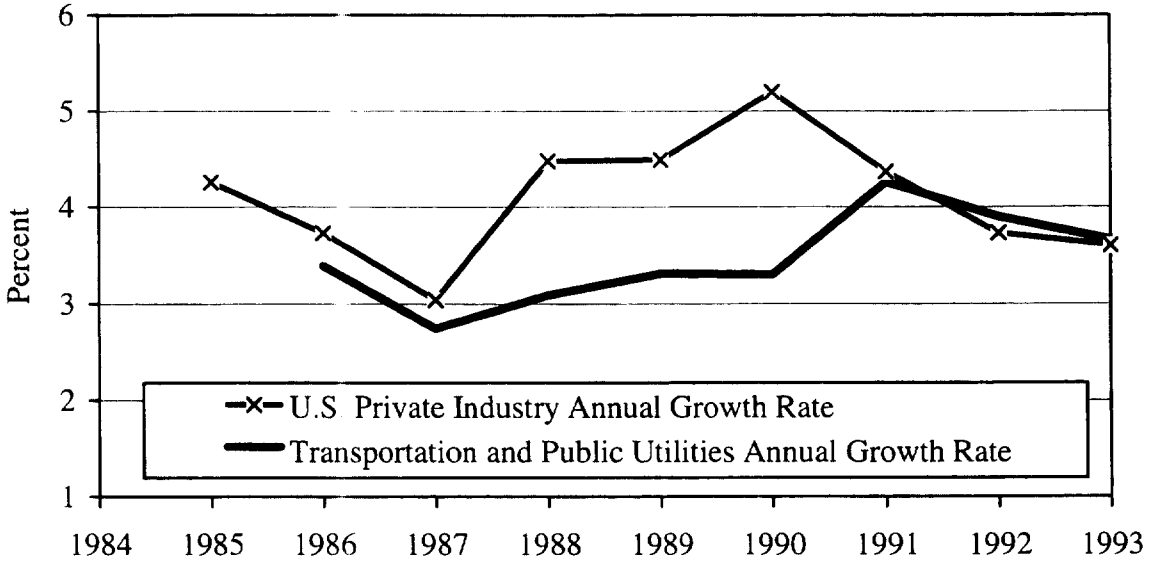
[83] The original Christensen Study divided labor into two categories, management and non-management, and then weighted these indices to develop an overall labor input index.

[84] *BLS Employment Cost Index, Complete Release -- September 1995, Explanatory Note.* U.S. Department of Labor.

[85] Telecommunications comprises 20% of the T&PU category in 1987. Note that the growth rates for the TP&U ECI closely track the growth rates in the BLS measure of average hourly earnings for the telecommunications sector.

From 1991 to 1993 the growth rate for the ECI for the aggregate economy closely mirrored that for the ECI for the transportation and public utilities sector.

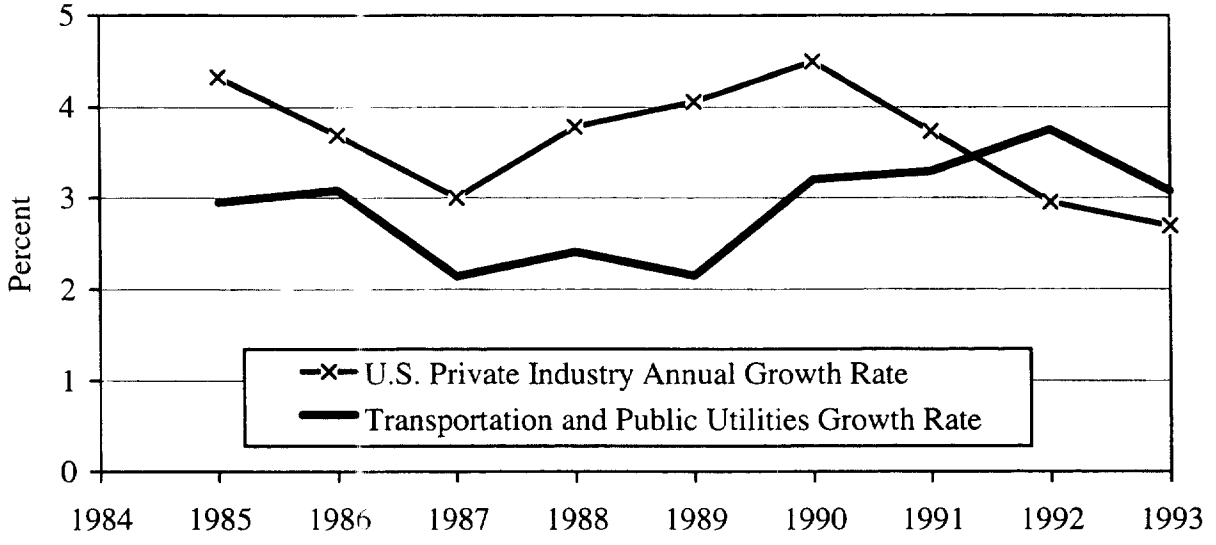
Exhibit 12
The Compensation ECI: U.S. Aggregate and the Transportation & Public Utilities



Source: Employment Cost Indexes and Levels, 1975-1993, U.S. Department of Labor, Bureau of Labor Statistics, September 1993, Table 7, pages 38, 44-45.

Exhibit 13 depicts ECI growth rates for wages and salaries for the same two sectors. Again note that the aggregate economy growth rate exceeds T&PU growth rate prior to 1992 and lagged those sectors, thereafter.

Exhibit 13
The Wages & Salaries ECI: U.S. Aggregate and the Transportation & Public Utilities



Source: Employment Cost Indexes and Levels, 1975-1993, U.S. Department of Labor, Bureau of Labor Statistics, September 1993, Table 7, pages 38, 44-45.

As **Exhibit 14** shows, over all of the relevant 5 year compound annual growth rate comparisons, the aggregate economy exceeds the Transportation & Public Utilities sector.

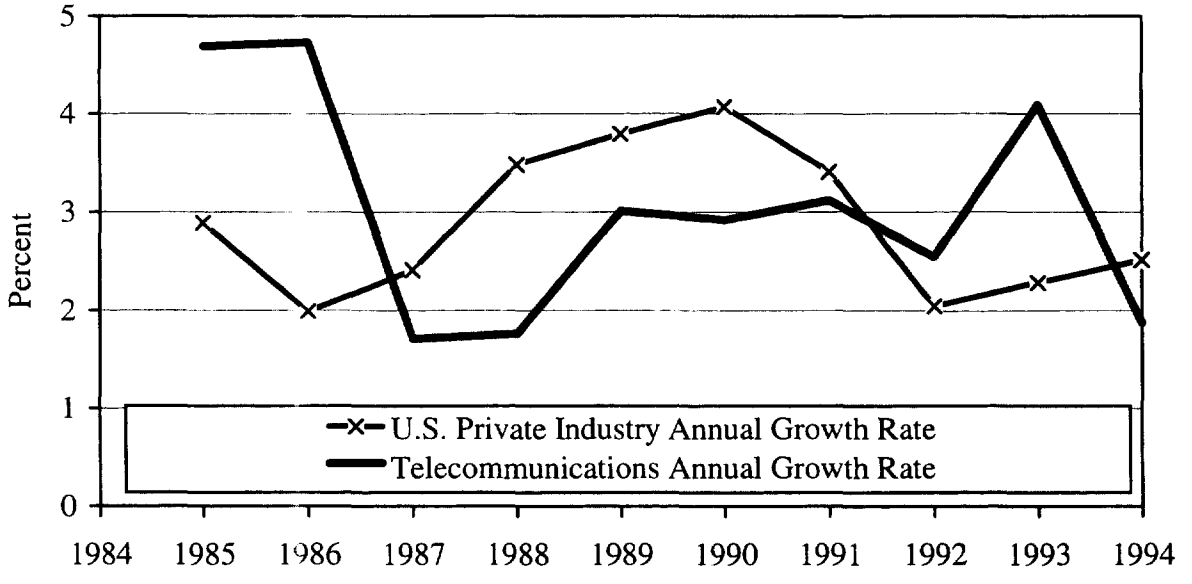
Exhibit 14
ECI: Comparison of 5-Year Compound Annual Growth Rates

	Wages & Salaries		Total Compensation	
	Economy	**T&PU**	**Economy**	**T&PU**
1985-90	3.81	2.59	4.19	3.16
1986-91	3.81	2.64	4.31	3.34
1987-92	3.80	2.96	4.45	3.57
1988-93	3.58	3.09	4.28	3.69

Source: Employment Cost Indexes and Levels, 1975-1993, U.S. Department of Labor, Bureau of Labor Statistics, September 1993, Table 8, pages 38, 44-45, 62, and 71.

Additionally, we can compare BLS average hourly earnings for production workers between the aggregate economy and telecommunications.[86] As **Exhibit 15** presents, the growth rate of average hourly earnings for the aggregate economy lagged telecommunications prior to 1987; exceeded telecommunication from 1987 through 1991 and lagged telecommunications in 1992 and 1993.

Exhibit 15
Annual Growth Rates: Average Hourly Earnings
U.S. Private Industry versus Telecommunications



Source: Employment and Earnings, U.S. Department of Labor, Bureau of Labor Statistics, Annual August Issue, Tables C-2 and B-15.

As **Exhibit 16** shows in the various 5-year periods from 1985 to 1993, growth in aggregate average hourly earnings exceeded the growth in all periods except the most recent. In the most recent period, the growth rates were nearly identical.

[86] *BLS, Employment and Earnings*, Department of Labor, annual issues. In 1987, production workers accounted for 81% of total U.S. employment and 74% of telecommunications employment.

Exhibit 16
Production Workers Average Hourly Earnings:
Comparison of 5-Year Compound Annual Growth Rates

	Economy	Telecommunications
1985-90	3.14	2.82
1986-91	3.43	2.50
1987-92	3.35	2.67
1988-93	3.12	3.14

Source: Employment and Earnings, U.S. Department of Labor, Bureau of Labor Statistics, Annual August Issue, Tables C 2 and B-15.

In summary, government information exists which allows a more appropriate and consistent analysis of labor input price changes in the telecommunications sector relative to the U.S. economy. It is essential that the consistency of definition be maintained within the comparison. The ECI approach and the BLS production worker approach to measuring the change in input prices have their limitations, yet, they offer a consistent comparison with the U.S. economy that is lacking in the previous studies.[87] Employing either the ECI approach or the BLS production worker approach we find that indices for labor input prices for the telecommunications sector have, in general, risen at a slower rate than the U.S. as a whole, particularly before 1992. In our analysis we have employed the ECI approach to capturing the change in labor input costs for both the economy and the telecommunications sector.

4.3.5 Measured Differences in Input Prices

Above we have outlined the definitional and compositional issues involved in developing an appropriate set of input price indices for the telecommunications sector and the aggregate economy. In this process we have defined a set of input price indices that will allow the determination of the input price differential for inclusion in a differential price cap approach. We find that when our consistent set of input prices for the three factors of production are appropriately weighted for the U.S. and the telecommunications, that there is a measurable

[87] For example, the limitations include: Transportation & Public Utilities sector is broader than either LEC or telecommunications services; average hourly earnings do not cover managerial or non-production employees.

difference in the respective input prices. Specifically, we find that the assumption that the input price differential is zero is not supported by the empirical evidence.[88]

Exhibit 17
Net Effect of Accounting for the Differential Between Economy-wide and Telecommunications Input Price Indices
(compound average annual growth rates)

	Economy-wide Input Prices	Telco Input Prices	Difference
1985-93	3.07	2.11	.96
1985-90	3.29	1.83	1.46
1986-91	3.70	2.06	1.64
1987-92	3.69	2.30	1.39
1988-93	3.31	2.47	.84
1990-93	2.69	2.57	.12

Source: Author calculations.

As can be seen in **Exhibit 17**, aggregate input price increases exceeded telecommunications input price increases in each of the 5-year periods examined. This difference ranged from .84 up to 1.64 percent per year. Over the 1985 to 1993 interval, the difference equaled .96 percent per year.

This empirical evidence is supported by the identified significant differences between the first-level compositional differences between the telecommunications sector's primary factor inputs and those of the aggregate economy, and on a second level by the differences in the composition of material input purchases.

As a result of these observed differences in input prices, one must question the premise that an index representing the input price changes to the economy could also accurately represent input

[88] It should be noted that most if not all of the previous debate on this issue focused on a comparison between an estimate of total LEC input price (which included the GDP-PI as a proxy for the price of materials) and an aggregate (i.e., U.S.) total input price which was not developed from the pieces as in our analysis above. Rather previous research calculated the U.S. input price index by adding an estimate of aggregate TFP to the assumed economy-wide output price index, GDP-PI -- not only an inappropriate price index for representing economy-wide output, but the same index used to represent LEC material input prices. Therefore, GDP-PI appears inappropriately on both sides of the comparison.

price changes for the telecommunications sector. If these indices are compositionally different, it must be the case that any statistical relationship of equality is simply a mathematical coincidence.

4.3.6 Benchmarking Productivity Estimates

4.3.6.1 Aggregate Productivity

The economy-wide input price index presented above can be combined with the estimated economy-wide output price index presented in **Section 4.2**, to calculate the growth in aggregate TFP. Returning to equation (2) [**Section 3.2**], we see that aggregate growth in TFP equals the difference between the growth in input and output prices. **Exhibit 18** presents our estimate of aggregate growth in TFP and compares this with the TFP estimate from the BLS. Over the 1984 to 1993 period, the two estimates are identical.

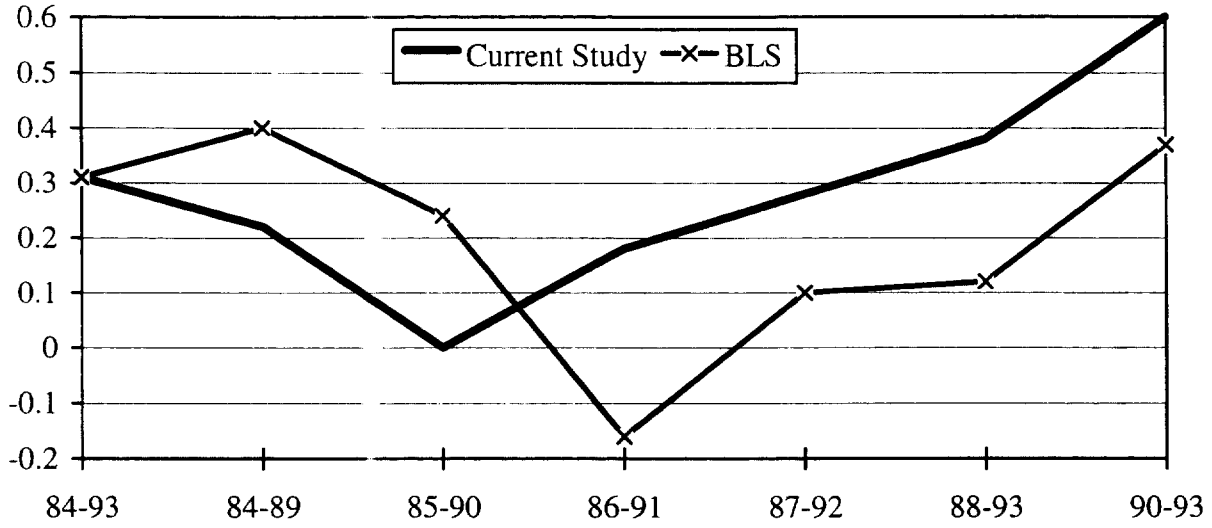
Exhibit 18
Comparison of Economy-wide TFP Measures: Current Analyses versus the BLS
(compound average annual growth rates)

	TFP: Current Study	**TFP: BLS***
1984-93	*.31*	*.31*
1984-89	.22	.40
1985-90	.00	.24
1986-91	.18	-.16
1987-92	.24	.10
1988-93	.38	.12
1990-93	.60	.37

* TFP is defined as multifactor productivity as reported by the BLS. See Monthly Labor Review, 7/95, p. 129.

In addition, as **Exhibit 19** depicts, the 5-year average growth rates for each measure of TFP reveal a very similar pattern except that the two series are one period out of phase. Since it may take some time for productivity changes to be translated into changes in price, it would not be surprising to see such a phase shift.

Exhibit 19
5-year Average Growth Rates Economy-wide TFP Measures: Current Analyses versus the BLS



Source: Current study TFP measure based on author calculations. BLS TFP measure, see Monthly Labor Review, 7/95, p. 129.

4.3.6.2 Telecommunications Productivity

Similarly, our estimate of an aggregate input price index for telecommunications can be used in estimating telecommunications TFP growth. Returning to equation (1) [**Section 3.2**], we see that telecommunications TFP growth is equal to the difference in input versus output prices. Referring to previous analysis prepared for the Pennsylvania Public Utilities Commission, we can obtain individual and composite output price indices for telecommunication services through 1991.[89] As published in this study, the compound average annual change in the composite telecommunications output price index between 1985 and 1991 is -1.89 percent. Combining this output price measure with the 1.96 annual average percent growth in telecommunications input prices over the 1985-1991 interval, we estimate that growth in telecommunications TFP equaled 3.85 percent per year between 1985 and 1991.

[89] Historically, the BLS produced several telecommunications CPIs and PPIs, but no aggregate PPI nor aggregate composite CPI/PPI measures. However, in order to calculate telecommunications TFP we need a composite price index. As part of the authors research for the PAPUC, various composite state and national telecommunications price indices were calculated through 1991. See: F.J. Cronin, et al., *Pennsylvania Telecommunications Infrastructure Study.* Prepared for the Pennsylvania Public Utility Commission, DRI/McGraw-Hill, Lexington, MA, March 1993.

5.0 Conclusion

5.1 Introduction

The FCC recognized in issuing its *Fourth Further Notice of Proposed Rulemaking*, that a number of biases may exist in the current LEC price cap framework. The intent of this current analysis is to discuss the biases that exist within the LEC price cap formula and to measure the magnitude of these biases. The overall goal is to provide policymakers with input that will support improvement in the price cap framework relative to the fundamental specification of the price cap formula and the selection of the various components of the formula.

Early in our analysis we presented background on three methods for the calculation of the price cap levels: 1) the current framework employed in the LEC price cap formula referred to as a modified differential approach; 2) a fully specified, theoretically correct full differential approach; and, 3) the direct approach employed by the ICC in rail regulation. Through the application of double entry accounting system and integrated government data sets we demonstrated that the premises that have supported the implementation of the modified differential approach within the current LEC Price Cap Plan are not defensible. Specifically, we demonstrated that the use of an aggregate inflation measure such as the GDP-PI as a proxy for the price changes in either the aggregate economy or for the telecommunications sector is not valid. Additionally, we provided analyses that revealed that the input price differential between telecommunications and the general economy is not zero, and therefore, this differential must be included in any price cap formula to avoid bias. Within the development of our analyses we also identified inconsistencies in previous measurements of various components of the price cap formula that may be corrected with the application of readily available government data.

Below, in **Section 5.2**, we present the calculated biases that originate in the application of the modified differential approach when compared to both the full differential approach and the direct approach. In **Section 5.3**, we then present the implications of applying the various price cap approachs for LEC output price changes. Then, in **Section 5.4**, we offer our recommendations regarding the issues raised in the *Fourth Further Notice*.

5.2 Calculated Biases in the Modified Differential Approach

With the set of price indices calculated in **Section 4.3**, we can compare the modified differential approach (equation (3)) with the full differential approach (equation (4)) and with the simpler direct approach to price cap regulation (equation (1)).[90] The first comparison presents two potential sources of bias -- the use of the GDP-PI in place of the EWOPI and the assumption that the differential in input prices is zero. **Exhibit 20** presents our calculated bias for each of these components and their sum. As shown, over the entire period, relative to the full differential approach, the modified differential approach overstates permitted LEC output prices by 1.79 percent per year. In two of the recent five year periods presented below the bias is greater than 2 percent per year.

Exhibit 20
Biases in the Modified Differential Approach
Relative to the Full Differential Approach to Price Cap Calculations

	GDPPI-EWOPI*	Input Price Differential**	Absolute Sum
1985-93	.83	-.96	1.79
1985-90	.70	-1.46	2.16
1986-91	.38	-1.64	2.02
1987-92	.56	-1.39	1.95
1988-93	.77	-.84	1.61
1990-93	1.05	-.12	1.17

* EWOPI is the economy wide output price index as discussed in **Section 4.2**.
** Input price differential is calculated as the telecommunications input price index less the aggregate U.S. input price index.

The second comparison entails two potential sources of bias -- the use of the GDP-PI in place of the telecommunications input price index and the deduction of aggregate TFP. **Exhibit 21** presents our calculated bias for each of these components and their sum. As shown, over the entire period the combined bias equals 1.79 percent per year, identical to the bias reported in **Exhibit 20** (as we would expect since the full differential and the direct approach should each produce equivalent correct estimates). That is, relative to the direct approach, the modified differential approach overstates LEC output prices by 1.79 percent. The bias in using the GDP-PI ranges from 1.33 to 1.96 per year for our calculated 5-year averages. Over the entire interval the bias associated with the GDP-PI is 1.50 percent per year.

[90] Refer to **Section 3.2** for equation detail.

Exhibit 21
Biases in the Modified Differential Approach
Relative to the Direct Approach to Price Cap Calculations

	GDPPI-Telco Input Index	Aggregate TFP*	Sum
1985-93	1.50	.29	1.79
1985-90	1.96	.24	2.20
1986-91	1.96	-.16	1.80
1987-92	1.73	.10	1.83
1988-93	1.33	.12	1.45
1990-93	.75	.37	1.12

*Aggregate TFP is defined as multifactor productivity as reported by the BLS. See Monthly Labor Review, 7/95, p. 129

5.3 Implications for LEC Output Price Changes

Exhibit 22 presents LEC output price changes calculated for the direct approach, the differential approach, the USTA's most recent modified differential method, and the current LEC price cap formula[91] over the 1985 to 1993 period. Our comparison of price cap approachs is developed applying consistent and clear definitions of publicly available data sets. As can be seen, both the direct approach and full differential approach calculate a compound annual reduction of more than 1.7 percent while USTA's proposed approach would have resulted in a price increase of .82 percent per year[92] -- an average difference of 2.5 percent per year. Over this same period, application of the current LEC price cap formula would have reduced rates by .39 percent per year. Thus, the USTA formula would have raised prices by .82 percent per year, the current LEC price cap formula would have lowered prices by .39 percent per year, and the two correctly specified alternatives would have lowered prices by about 1.7 percent per year.

[91] In order to standardize our analysis over the 1985-1993 period (i.e., to consistently use revised data), we have employed the annual average change in GDP-PI, rather than the fourth quarter to fourth quarter change employed in the LEC price cap formula.

[92] If we standardize TFP offsets, we obtain a bias of 1.79 between the direct and full differential approaches relative to USTA's method.

Exhibit 22
Comparing LEC Price Changes Generated by Alternative Price Cap Formulas
(Compound average annual growth rates)

Year	Direct Equation (1)	Full Differential Equation (4)	Modified Differential Equation (3)	
			USTA	Current LEC Formula
	I	II	III	IV
1985	NA	NA	NA	NA
1986	-2.44	-3.13	0.05	-1.16
1987	-2.54	-1.96	0.36	-0.85
1988	-2.08	-1.93	1.13	-0.08
1989	-1.69	-1.37	1.71	0.50
1990	-1.34	-1.15	1.74	0.53
1991	-1.30	-1.26	1.24	0.03
1992	-1.35	-1.57	0.38	-0.83
1993	-1.20	-1.33	-0.02	-1.23
1985-93	-1.74	-1.72	0.82	-0.39
1988-93	-1.38	-1.34	1.01	-0.20

Note: Column (I) uses a Telecommunications TFP of 3.85; Column (II) uses a Telecommunications TFP of 3.85 and an Economy-wide TFP of 0.31 Column (III) uses a LEC TFP of 3.1 and an Economy-wide TFP of 0.31; Column (IV) uses an offset of 4.0.[93]

[93] The TFP measure of 3.85 for the telecommunications is consistent with the specification of equation (1) in **Section 3.2** and the calculations discussed in **Section 4.3.6.2.** This measure was developed for the 1985 to 1991 time frame using a national composite output price calculated through 1991 in a previous study by the authors. See: F.J. Cronin, et al., *Pennsylvania Telecommunications Infrastructure Study.* Prepared for the Pennsylvania Public Utility Commission, DRI/McGraw-Hill, Lexington, MA, March 1993. In this same study, the authors calculated a longer term measure of productivity gains in the telecommunications sector over the 1963-1991 time frame of 3.0. The 3.85, although not directly corresponding to the timeframe presented in **Exhibit 22** is more appropriate in the current comparison than the 3.0. However, the focus of this current study is not to calculate TFP for the telecommunications sector. The 3.1 measure of LEC TFP applied in Column III was developed by Christensen Associates for USTA.

5.4 Recommendations

Measurable and significant biases can be calculated between the modified differential approach embedded in both the LEC price cap formula and USTA's proposed TFP method and either the direct approach or full differential approach. In fact, these biases overstate permitted LEC prices under either the current LEC price cap formula or the USTA proposed TFP methodology. The operational validity of a LEC price cap regime could, as a result, be greatly improved by the adoption of a correctly specified approach to price cap calculations. Since the direct approach to price cap calculation is simpler, requires less information and would be subject to fewer potential biases in implementation, this approach would appear to have significant advantages relative to the full differential approach. However, a fully specified differential approach will also overcome the identified biases and will provide a workable, though more cumbersome, approach to LEC price cap calculations.

Additional care must be taken going forward to develop an appropriately defined and consistent data set that accurately measures the intended concepts embodied within the correctly specified price cap framework. The inconsistencies and definitional problems with data applied in previous analysis can be directly credited with biases in the specification of the modified differential approach. The use of government published data provides a consistent and verifiable set of information for price cap calculations. And, it also provides an accurate view of the productivity gains and input and output price changes experienced by the telecommunications sector over history -- an important starting point and benchmark for any price cap regime. Perhaps, as the ICC implemented with the railroads, an historically correct price cap formula based on correctly defined published and verifiable information could be updated on an ongoing basis through the cooperative efforts of LECs and regulators.

Appendix A

Data Description

1. Illustrative Two Dimensional Representation of Total Economic Activity

2. The Composition of Economy-Wide Output Relative to Gross Domestic Product

Sources: Economy-Wide Output: Author calculations based on data from the United States Department of Labor, Bureau of Labor Statistics, Office of Employment Projections.

Gross Domestic Product: *Benchmark Input-Output Accounts of the United States: 1987,* United States Department of Commerce, Bureau of Economic Analysis.

3. Net Effect of Using the Economy-Wide Output Price Measures Relative to GDP-PI

Year	GDP-PI	EWOPI
1984	0.91	0.95
1985	0.94	0.97
1986	0.97	0.97
1987	1.00	1.00
1988	1.04	1.04
1989	1.09	1.09
1990	1.14	1.13
1991	1.18	1.16
1992	1.22	1.19
1993	1.25	1.21

Sources: GDP-PI: United States Department of Commerce, Bureau of Economic Analysis: *Survey of Current Business*, various issues.
EWOPI: Author calculations based on data from the United States Department of Labor, Bureau of Labor Statistics. Office of Employment Projections.

4. The GDP-PI, the PPI, and the Economy Wide Output Price Index (Graph)

Sources: GDP-PI: United States Department of Commerce, Bureau of Economic Analysis: *Survey of Current Business*, various issues.
PPI: United States Bureau of Labor Statistics, *Producer Prices Indexes*, various issues.
Economy Wide Output Price Index: Author calculations based on data from the United States Department of Labor, Bureau of Labor Statistics, Office of Employment Projections.

5. **Composition of the Economy Relative to the Telecommunications Sector: Factor Inputs (millions of current $)**

Year	Economy-Wide			Telecommunications		
	Labor	Capital	Material	Labor	Capital	Material
1987	2,949,521	394,807	3,373,411	44,141	24,172	40,107

Description: We have chosen 1987 as the weight year because it is a base year for the BEA's Input-Output Accounts. Capital is measured by depreciation. Telecommunications Material inputs exclude access charges.

Sources: Author calculations made from data from the United States Department of Commerce, Bureau of Economic Analysis (*Benchmark Input-Output Accounts of the United States: 1987*, November 1994; *Survey of Current Business*, Tables 6.4b and 6.2C, various issues and *Detailed Industry Wealth Data Diskette*, September 13, 1994); Federal Communications Commission (*Statistics of Communications Common Carriers*, Table 2.9, 1988-89 edition); and the United States Department of Labor, Bureau of Labor Statistics, Office of Employment Projections' input/output time series data.

6. **Composition of the Economy Relative to the Telecommunications Sector: Factor Inputs (millions of current $)**

Year	Economy-Wide			Telecommunications		
	Labor	Capital	Material	Labor	Capital	Material
1987	2,949,521	1,218,495	3,373,411	44,141	71,385	40,107

Description: We have chosen 1987 as the weight year because it is a base year for the BEA's Input-Output Accounts. Capital is measured as the sum of depreciation, opportunity cost, and revaluation. Telecommunications Material inputs do not include access charges.

Sources: Author calculations based on data from the United States Department of Commerce, Bureau of Economic Analysis (*Benchmark Input-Output Accounts of the United States: 1987*, November 1994; *Survey of Current Business*, Tables 6.4b and 6.2C, various issues, and *Detailed Industry Wealth Data Diskette*, September 13, 1994); Federal Communications Commission (*Statistics of Communications Common Carriers*, Table 2.9, 1988-89 edition) and the United States Department of Labor, Bureau of Labor Statistics, Office of Employment Projections' input/output time series data.

7. Comparison of Alternative Methods for Capital Input Price Measurement

Year	Depreciation	Depreciation & Interest	Depreciation, Opportunity Cost & Revaluation
1984	0.94	1.03	1.21
1985	0.96	1.01	1.12
1986	0.98	0.97	0.95
1987	1.00	1.00	1.00
1988	1.02	1.02	1.04
1989	1.04	1.03	1.04
1990	1.05	1.04	1.06
1991	1.07	1.05	1.03
1992	1.08	1.04	0.99
1993	1.10	1.03	0.94

Description: Depreciation: Annual total depreciation of capital.
Interest: Yield on new issues of high-grade corporate bonds.
Opportunity Cost: Beginning of period values for gross capital stock multiplied by corporate bond yield.
Revaluation: Change in the value of capital stock.

Sources: Depreciation: United States Department of Commerce, Bureau of Economic Analysis, *Detailed Industry Wealth Data Diskette*, September 13, 1994.
Interest: United States Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*: *Business Cycle Indicators,* various issues.
Gross Capital Stock: United States Department of Commerce, Bureau of Economic Analysis, *Detailed Industry Wealth Data Diskette*, September 13, 1994.

8. Factor Material Input Shares: Top 5 Supplying Industries to GDP and the Telecommunications Sector

Source: *Benchmark Input-Output Accounts of the United States: 1987*, United States Department of Commerce, Bureau of Economic Analysis. United States Department of Labor, Bureau of Labor Statistics, Office of Employment Projections' Input/Output Data.

9. Factor Material Input Shares: Top 5 Supplying Industries to the Economy and the Telecommunications Sector

Source: *Benchmark Input-Output Accounts of the United States: 1987*, United States Department of Commerce, Bureau of Economic Analysis. United States Department of Labor, Bureau of Labor Statistics, Office of Employment Projections' Input/Output Data.

10. Material Input Price Indices

		Material Price Index	
Year	GD-PPI	Economy - Wide	Telecommunications
1984	0.91	0.98	0.99
1985	0.94	0.99	1.02
1986	0.97	0.97	1.01
1987	1.00	1.00	1.00
1988	1.04	1.05	1.00
1989	1.09	1.09	1.01
1990	1.14	1.13	1.04
1991	1.18	1.14	1.05
1992	1.22	1.17	1.07
1993	1.25	1.19	1.09

Sources: GDP-PI: see Exhibit 3.
Economy-Wide and Telecommunications: Author Calculations from *Benchmark Input-Output Accounts of the United States: 1987,* Bureau of Economic Analysis. Bureau of Labor Statistics Office of Employment Projections (output time series data).

11. Leontief Index of Direct (or Total Factor) Productivity Gains

Source: Cronin et al., *The Pennsylvania Infrastructure Study.* Prepared for the Pennsylvania Public Utilities Commission, 1993.

12. The Compensation ECI: United States Aggregate and Transportation & Public Utilities

Source: *Employment Cost Indexes and Levels, 1975-93,* United States Department of Labor, Bureau of Labor Statistics, September 1993, Table 7, pages 38, 44-45.

13. The Wages & Salaries ECI: United States Aggregate and the Transportation & Public Utilities

Source: *Employment Cost Indexes and Levels, 1975-93,* United States Department of Labor, Bureau of Labor Statistics, September 1993, Table 8, pages 62 and 71.