Table 14

Rented Capital
(millions of dollars)

	Capital Stock		Capital Input	
	Quantity Index	Price Index	Quantity Index	Price Index
1947	571.0	.531	77.7	.611
1948	567.2	.566	80.9	.651
1949	583.8	.580	80.3	.680
1950	596.3	.603	82.7	.704
1951	676.0	.631	84.4	.732
1952	708.7	.652	95.7	.763
1953	724.8	.672	100.4	.803
1954	782.9	.691	102.6	.831
1955	830.2	.721	110.9	.843
1956	885.4	.751	117.6	.859
1957	912.7	.772	125.4	.875
1958	946.4	.792	129.3	.891
1959	983.9	.804	134.0	.904
1960	1019.2	.809	139.3	.917
1961	1060.2	.815	144.3	.929
1962	1096.2	.830	150.1	.940
1963	1118.9	.852	155.2	.950
1964	1195.5	.877	158.5	.959
1965	1293.2	.909	169.3	.969
1966	1379.9	.951	183.1	.982
1967	1516.2	1.000	195.4	1.000
1968	1648.3	1.060	214.7	1.024
1969	1843.3	1.144	233.4	1.057
1970	2057.4	1.248	261.1	1.101
1971	2201.8	1.360	291.4	1.152
1972	2370.5	1.471	311.8	1.192
1973	2530.7	1.631	335.7	1.243
1974	2667.8	1.879	358.4	1.306
1975	2862.5	2.029	377.8	1.373
1976	2918.8	2.151	405.4	1.447
1977	2922.1	2.301	413.4	1.535
1978	2855.7	2.540	413.8	1.640
1979		2.732	404.4	1.760

Table 15

Capital Stock and Capital Input

	Capital Stock			Capital Input	
Year	Quantity Index	Price Index	Composition Index	Quantity Index	Price Index
1947	11970.4	.679	.991	2101.8	.480
1948	13332.5	.702	.986	2254.9	.537
1949	14246.9	.693	.982	2500.3	.552
1950	14725.7	.738	.972	2645.2	.594
1951	15259.2	.756	.969	2726.4	.673
1952	15913.7	.747	.967	2819.9	.764
1953	16825.5	.763	.970	2949.4	.777
1954	17829.3	.770	.976	3137.5	.781
1955	18787.9	.802	.980	3338.1	.827
1956	20010.3	.830	.989	3550.9	.846
1957	21654.4	.852	.994	3799.3	.788
1958	23026.9	.859	.993	4106.6	.839
1959	24108.7	.868	.991	4361.5	.875
1960	25417.9	.873	.992	4568.6	.920
1961	26829.8	.867	.992	4819.3	.961
1962	28407.1	.874	.994	5094.6	.975
1963	29943.4	.893	.997	5410.4	.969
1964	31807.4	.902	.999	5713.1	1.036
1965	33825.2	.920	1.000	6074.5	1.020
1966	35982.2	.960	1.001	6465.5	1.004
1967	37991.6	1.000	1.000	6874.0	1.000
1968	40030.6	1.043	.999	7247.4	1.041
1969	42700.9	1.122	.999	7641.6	1.005
1970	45629.1	1.191	.998	8144.7	1.008
1971	48741.0	1.280	.995	8673.2	1.000
1972	52032.7	1.327	.990	9216.3	1.049
1973	55664.0	1.448	.987	9809.3	.964
1974	59055.4	1.635	.983	10453.9	.962
1975	61700.2	1.754	.980	11060.5	1.143
1976	63674.2	1.863	.978	11525.1	1.276
1977	65729.3	1.932	.978	11899.0	1.354
1978	68219.9	2.040	.980	12310.3	1.475
1979	71424.4	2.087	.983	12817.0	1.546

6. MEASUREMENT OF MATERIALS INPUT

Materials input includes all Bell System inputs not already included in labor or capital. We start with data on materials expenditures broken down by six categories: electricity, accounting machines, advertising, stationary and postage, Bell Telephone Laboratories (BTL) and all others. To estimate real input in each of these categories we deflate by an appropriate price index. Electricity expenditure is deflated by the Wholesale Price Index for Electricity; accounting machines by the Wholesale Price Index for Office Machines; stationery and postage by the Wholesale Price Index for Paper. Advertising is deflated by a Directory Advertising Price Index developed by AT&T. We create a price index to deflate BTL expenditures. It is a Tornqvist index of a BTL specific labor deflator and the non-financial corporate business Gross Domestic Product deflator from the Survey of Current Business. We create the BTL labor index using methodology similar to that described in Section 4 and BTL data on the number of employees, average hours and average annual salary, all broken down by occupational groups. The weights used in the Tornqvist index are the labor share in BTL expenditure and one minus this share. The remaining category, all other, is deflated by the GNP deflator. We then aggregate over these six categories using the Tornqvist procedure to arrive at aggregate real materials input. Table 16 presents the price and quantity indexes for the six materials categories as well as the aggregate price and quantity indexes.

Table 16

Materials Input
(millions of 1967 dollars)

Year	Electricity		Accounting Machines		Advertising		Stationery and Postage	
	Quantity Index	Price Index	Quantity Index	Price Index	Quantity Index	Price Index	Quantity Index	Price Index
1947	14.0	.769	.0	.726	24.8	.387	27.1	.595
1948	13.6	.905	.0	.747	22.5	.417	29.6	.655
1949	15.2	.862	.0	.748	22.2	.447	30.8	.663
1950	15.5	.871	.0	.757	22.7	.477	32.1	.679
1951	16.0	.903	.0	.806	23.0	.486	32.7	.760
1952	17.7	.901	.0	.804	25.3	.496	34.9	.791
1953	18.7	.926	.0	.821	24.2	.567	36.9	.801
1954	20.6	.913	.0	.832	27.1	.597	38.5	.808
1955	22.0	.912	.0	.855	30.2	.628	33.3	.828
1956	23.2	.940	.0	.885	34.5	.663	38.6	.876
1957	24.5	.901	.0	.923	34.5	.720	36.4	.905
1958	28.0	.953	.0	.938	30.0	.756	39.2	.907
1959	30.2	.953	.0	.949	34.3	.776	44.8	.915
1960	32.2	.961	.0	.955	37.7	.815	49.6	.927
1961	33.8	.972	.0	.960	37.5	.849	54.0	.929
1962	37.0	.967	.0	.962	37.7	.876	56.7	.933
1963	39.5	.963	.0	.970	61.6	.913	65.8	.931
1964	43.2	.937	37.5	.971	65.7	.935	74.8	.942
1965	46.0	.955	42.9	.974	63.9	.957	81.2	.946
1966	47.1	.978	46.2	.981	61.8	.979	82.1	.975
1967	49.4	1.000	56.4	1.000	60.2	1.000	83.9	1.000
1968	53.5	.989	65.4	1.007	61.2	1.027	90.4	1.020
1969	56.9	1.009	72.0	1.010	59.8	1.104	92.4	1.055
1970	59.1	1.062	87.5	1.035	55.1	1.168	94.8	1.110
1971	64.7	1.142	95.5	1.054	52.5	1.204	101.2	1.141
1972	70.8	1.186	86.8	1.065	55.0	1.231	79.2	1.163
1973	70.3	1.343	91.5	1.082	60.1	1.260	79.7	1.214
1974	58.6	2.083	104.3	1.135	58.5	1.346	75.0	1.486
1975	59.8	2.451	118.4	1.200	51.5	1.472	66.1	1.729
1976	59.3	2.655	143.5	1.210	53.4	1.608	107.5	1.823
1977	58.4	3.022	163.5	1.230	56.2	1.777	103.0	1.943
1978	57.8	3.225	194.9	1.278	66.8	1.960	105.9	2.061
1979	50.1	4.081	214.2	1.333	95.2	2.152	101.5	2.296

Table 16 (continued)

Materials Input

Year	Other		Bell Telephone Laboratories		Total Materials	
	Quantity Index	Price Index	Quantity Index	Price Index	Quantity Index	Price Index
1947	358.8	.629	27.7	.491	462.7	.596
1948	418.5	.672	30.2	.517	528.0	.640
1949	451.6	.666	32.0	.520	567.5	.635
1950	461.9	.679	27.5	.593	576.6	.652
1951	492.2	.725	25.2	.603	607.4	.695
1952	537.9	.734	29.5	.621	665.0	.706
1953	549.7	.745	32.8	.631	682.9	.719
1954	613.9	.755	37.5	.649	760.1	.729
1955	681.6	.772	40.3	.690	831.2	.746
1956	753.6	.796	49.3	.705	925.1	.771
1957	740.2	.823	51.8	.746	912.7	.800
1958	698.0	.836	48.2	.766	869.1	.812
1959	752.4	.854	51.3	.804	940.9	.830
1960	804.3	.869	58.6	.816	1012.2	.844
1961	857.0	.877	87.5	.826	1100.9	.852
1962	880.8	.893	92.5	.860	1137.1	.869
1963	958.7	.906	80.3	.877	1242.0	.881
1964	978.1	.920	80.9	.923	1260.3	.924
1965	1087.8	.941	78.9	.943	1400.9	.943
1966	1151.4	.971	87.3	.969	1475.8	.972
1967	1163.5	1.000	94.5	1.000	1507.8	1.000
1968	1215.7	1.045	106.7	1.038	1592.6	1.039
1969	1351.7	1.097	116.0	1.163	1748.9	1.093
1970	1473.8	1.156	127.0	1.243	1896.9	1.152
1971	1540.9	1.215	131.7	1.337	1985.3	1.210
1972	1643.2	1.266	143.3	1.411	2081.1	1.258
1973	1757.0	1.339	151.9	1.501	2214.0	1.331
1974	1753.9	1.473	154.5	1.648	2204.0	1.483
1975	1768.3	1.610	158.6	1.835	2219.6	1.630
1976	1933.3	1.693	175.8	1.966	2465.3	1.716
1977	2135.5	1.786	186.5	2.052	2687.1	1.814
1978	2335.2	1.924	196.4	2.211	2928.7	1.950
1979	2519.6	2.094	246.2	2.093	3188.8	2.108

7. TOTAL FACTOR PRODUCTIVITY

The data development from the previous sections can now be drawn together to provide our estimate of total factor productivity for the Bell System. The rate of growth of the Tornqvist index of TFP is specified in (23) on page 9. The cost shares of capital, labor, and materials which are used to construct the average cost shares ($\bar{w}_K$, $\bar{w}_L$, and $\bar{w}_M$) are presented in Table 17. The shares averaged over the full period and the periods before and after 1961 are presented also in Table 17. The rates of growth of output and the three input categories are presented in Table 18. The resulting index of TFP (normalized to unity in 1967) and its rate of growth are presented in Table 19. Finally, Table 19 also contains the average rates of growth of TFP, and Table 18 those for aggregate output, and the three input aggregates.

With the exception of 1949, TFP growth was positive for every year between 1947 and 1979. TFP growth has been relatively stable over the entire postwar period, averaging 3.2% per year. The average rates of growth were virgually the same before and after 1961.

The rate of growth of the three input categories can be combined and interpreted as the rate of growth of aggregate input. This aggregate input index and its rate of growth are presented in Table 20. In Table 20 the average rate of growth of aggregate input is also presented. This table also contains the ratio of the average rate of growth of aggregate input to the average rate of growth of aggregate output.

Table 17

Annual Cost Shares

Year	Capital	Labor	Materials
1947	.396	.496	.108
1948	.404	.483	.113
1949	.419	.471	.110
1950	.441	.453	.106
1951	.453	.442	.104
1952	.467	.432	.102
1953	.464	.436	.099
1954	.466	.428	.105
1955	.478	.414	.108
1956	.477	.410	.113
1957	.471	.414	.115
1958	.508	.388	.104
1959	.520	.373	.106
1960	.531	.361	.108
1961	.544	.346	.110
1962	.551	.340	.110
1963	.551	.333	.115
1964	.562	.326	.112
1965	.553	.329	.118
1966	.543	.337	.120
1967	.541	.341	.119
1968	.546	.334	.120
1969	.514	.358	.128
1970	.497	.371	.132
1971	.483	.383	.134
1972	.479	.391	.130
1973	.446	.415	.139
1974	.434	.425	.141
1975	.462	.406	.132
1976	.470	.395	.135
1977	.467	.393	.140
1978	.463	.391	.146
1979	.449	.399	.152

Average Cost Shares

	Capital	Labor	Materials
1947-61	.469	.423	.107
1961-79	.503	.369	.128
1947-79	.486	.394	.119

Table 18

Annual Growth Rates

Year	Output	Capital	Labor	Materials
1948	.100	.070	.049	.132
1949	.051	.103	.024	.072
1950	.074	.056	.006	.016
1951	.087	.030	.044	.052
1952	.069	.034	.049	.091
1953	.051	.045	.043	.027
1954	.052	.062	.010	.107
1955	.091	.062	.000	.089
1956	.087	.062	.075	.107
1957	.070	.068	-.030	-.013
1958	.049	.078	.001	-.049
1959	.082	.060	-.040	.079
1960	.071	.046	-.001	.073
1961	.057	.053	-.009	.084
1962	.065	.056	.003	.032
1963	.066	.060	-.001	.088
1964	.075	.054	.031	.030
1965	.084	.061	.034	.090
1966	.097	.062	.040	.052
1967	.074	.061	.018	.021
1968	.084	.053	.016	.055
1969	.096	.053	.054	.094
1970	.068	.064	.052	.081
1971	.052	.063	.011	.046
1972	.077	.061	.002	.047
1973	.087	.062	.017	.062
1974	.068	.064	.008	-.005
1975	.052	.056	-.005	.007
1976	.072	.041	-.013	.105
1977	.079	.032	.041	.086
1978	.092	.034	.043	.086
1979	.088	.040	.039	.085

Average Rates of Growth

	Output	Capital	Labor	Materials
1947-61	.071	.059	.016	.062
1961-79	.076	.054	.022	.059
1947-79	.074	.056	.019	.060

Table 19

Bell System Total Factor Productivity

Year	TFP Index	TFP Growth Rate
1947	.551	.000
1948	.570	.033
1949	.564	-.011
1950	.590	.045
1951	.619	.048
1952	.633	.023
1953	.639	.009
1954	.644	.008
1955	.678	.052
1956	.688	.014
1957	.724	.052
1958	.736	.016
1959	.780	.058
1960	.811	.039
1961	.829	.022
1962	.854	.030
1963	.874	.023
1964	.901	.031
1965	.927	.029
1966	.968	.043
1967	1.000	.033
1968	1.045	.044
1969	1.085	.038
1970	1.092	.006
1971	1.104	.011
1972	1.150	.040
1973	1.200	.043
1974	1.246	.037
1975	1.280	.028
1976	1.338	.044
1977	1.387	.036
1978	1.455	.048
1979	1.517	.042

Average Rate of Growth

	TFP
1947-61	.030
1961-79	.033
1947-79	.032

Table 20

Year	Aggregate Input Quantity Index	Aggregate Input Price Index	Rate of Growth
1947	5410.1	.472	.000
1948	5784.4	.518	.067
1949	6154.5	.535	.062
1950	6333.2	.563	.029
1951	6584.4	.615	.039
1952	6895.3	.670	.046
1953	7193.2	.686	.042
1954	7516.5	.699	.044
1955	7815.3	.738	.039
1956	8400.4	.751	.072
1957	8552.9	.743	.018
1958	8840.0	.768	.033
1959	9054.0	.811	.024
1960	9348.0	.846	.032
1961	9677.0	.880	.035
1962	10021.4	.900	.035
1963	10458.6	.909	.043
1964	10928.4	.965	.044
1965	11553.6	.970	.056
1966	12191.7	.981	.054
1967	12710.9	1.000	.042
1968	13238.9	1.043	.041
1969	14034.3	1.065	.058
1970	14926.5	1.106	.062
1971	15551.3	1.154	.041
1972	16124.2	1.250	.036
1973	16846.9	1.258	.044
1974	17369.4	1.334	.031
1975	17797.3	1.538	.024
1976	18299.0	1.711	.028
1977	19103.6	1.819	.043
1978	19981.0	1.962	.045
1979	20933.1	2.108	.047

	Average Rate of Growth of Aggregate Input	Ratio of Average Rate of Growth of Input to Output
1947-61	.042	.588
1961-79	.043	.561
1947-79	.042	.572

REFERENCES

American Telephone and Telegraph Company (1973), Bell System Productivity Study, 1947-1971, Economic Analysis Section.

_____ (1976), Bell System Statistical Manual, 1950-1975, May.

_____, Bell System Telephone Plant Indexes, Engineering Economics Department.

_____, Changes in Telephone Plant Accounts, Quarterly Report No. 2A, December.

_____, Current Cost of Bell System Plant, annual.

_____ (1952), Engineering Economy, Construction Plans Department, McGraw Hill (3rd edition 1977).

Afriat, S.N. (1972), "the Theory of International Comparisons of Real Income and Prices," in D.J. Daly, ed., International Comparisons of Prices and Outputs, pp. 13-69. National Bureau of Economic Research.

Bureau of Economic Analysis, The National Income and Product Accounts of the United States, 1929-1974, A Supplement to the Survey of Current Business. Washington, D.C., U.S. Department of Commerce, 1976.

_____, "National Income and Product Accounts", Survey of Current Business, July issues.

Christensen, L.R. and D.W. Jorgenson (1969), "Measurement of U.S. Real Capital Input, 1929-1967," Review of Income and Wealth, Series 15, No. 4, December, pp. 293-320.

_____ (1970), "U.S. Real Product and Real Factor Input, 1929-1967," Review of Income and Wealth, Series 16, No. 1, March, pp. 19-50.

_____ (1973a), "Measuring the Performance of the Private Sector of the U.S. Economy, 1929-1969," in M. Moss, ed., Measuring Economic and Social Performance, New York, National Bureau of Economic Research, pp. 233-338.

_____ (1973b), "U.S. Income, Savings and Wealth, 1929-1969," Review of Income and Wealth, Series 19, No. 4, December, pp. 329-362.

Christensen, L.R., D.W. Jorgenson and L.J. Lau (1971), "Conjugate Duality and the Transcendental Logarithmic Production Function," Econometrica, Vol. 39, No. 4, July, pp. 255-256.

_____ (1973), "Transcendental Logarithmic Production Frontiers," Review of Economics and Statistics, Vol. 55, No. 1, February, pp. 28-45.

Commerce Clearing House Inc. (1975), 1975 Depreciation Guide, Chicago.

Diewert, W.E. (1976), "Exact and Superlative Index Numbers," Journal of Econometrics, Vol. 4, No. 2, May, pp. 115-146.

Divisia, F. (1925), "L'indice monetaire et la theórie de la monnaie," Revue d'Economie Politique, 39e Anneé, No. 4, 5, 7; Juillet-Août, Septembre-Octobre, Novembre-Decembre, pp. 842-861, 980-1008, 1121-1151.

Fabricant, S. (1973), "Perspective on Productivity Research," Conference on an Agenda for Economic Research on Productivity, Washington, National Commission on Productivity.

Fisher, I. (1922), The Making of Index Numbers, Boston, Houghton Mifflin.

Kloek, T. (1966), Indexcijfers: enige methodologisch aspecten, The Hague, Pasmans.

Pollak, R.A. (1971), "The Theory of the Cost of Living Index," Research Discussion Paper No. 11, Office of Prices and Living Conditions, U.S. Bureau of Labor Statistics, Washington, D.C.

Ruggles, Richard (1967), "Price Indexes and International Price Comparisons," in W. Fellner, ed., Ten Economic Studies in the Tradition of Irving Fisher, pp. 171-205, New York, John Wiley & Sons.

Samuelson, P.A., and S. Swamy (1974), "Invariant Index Numbers and Canonical Duality: Survey and Synthesis." American Economic Review, Vol. 64, pp. 566-93.

Theil, H. (1965), The Information Approach to Demand Analysis," Econometrica, Vol. 33, No. 1, January, pp. 67-87.

Tornqvist, L. (1936), "The Bank of Finland's Consumption Price Index," Bank of Finland Monthly Bulletin, No. 10, pp. 1-8.