Volume Title: Postwar Productivity Trends in the United States, 1948–1969

Volume Author/Editor: John W. Kendrick

Volume Publisher: NBER

Volume ISBN: 0-87014-240-2

Volume URL: http://www.nber.org/books/kend73-1

Publication Date: 1973

Chapter Title: Interrelationships of Productivity with Associated Variables, by Industry

Chapter Author: John W. Kendrick

Chapter URL: http://www.nber.org/chapters/c3576

Chapter pages in book: (p. 105 - 144)

6

INTERRELATIONSHIPS OF PRODUCTIVITY WITH ASSOCIATED VARIABLES, BY INDUSTRY

Our final chapter starts with an examination of relative changes in output by industry segments and groups and their relationship to relative productivity changes. A positive correlation, working through relative price changes, is found to prevail within—but not across—the broad industry segments. Consequently, while above-average productivity changes are not generally associated with relative declines in employment in the industry groups, the same generalization does not hold for the broader industry segments.

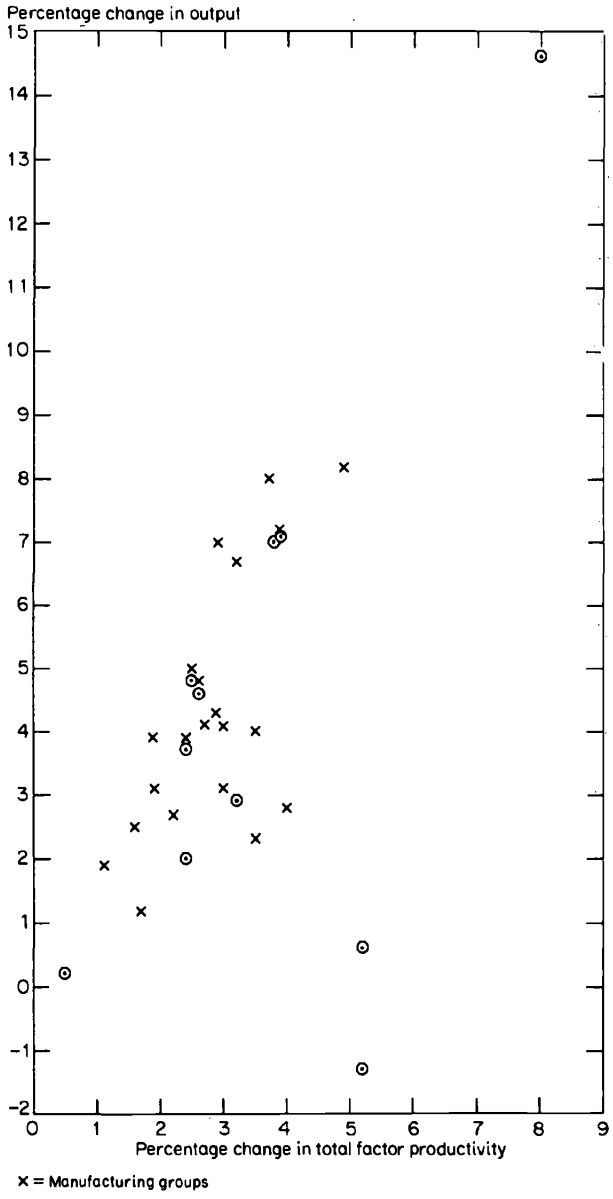
In the latter part of the chapter the chief causal factors that may account for differential industry rates of productivity change are analyzed. In this connection, the results of some experimental regression analyses for twenty-one manufacturing industry groups are also introduced. We emphasize that the results are less than definitive, due to multicollinearity and other statistical problems, but hope that the industry estimates will serve as a basis for further attempts at cross-sectional analysis of causal forces, which provides a useful supplement to aggregative analysis.

Patterns of Output Change, by Industry

Before analyzing the interrelationships between industry productivity and output changes, a look at industry patterns of rates of change in output will be helpful.

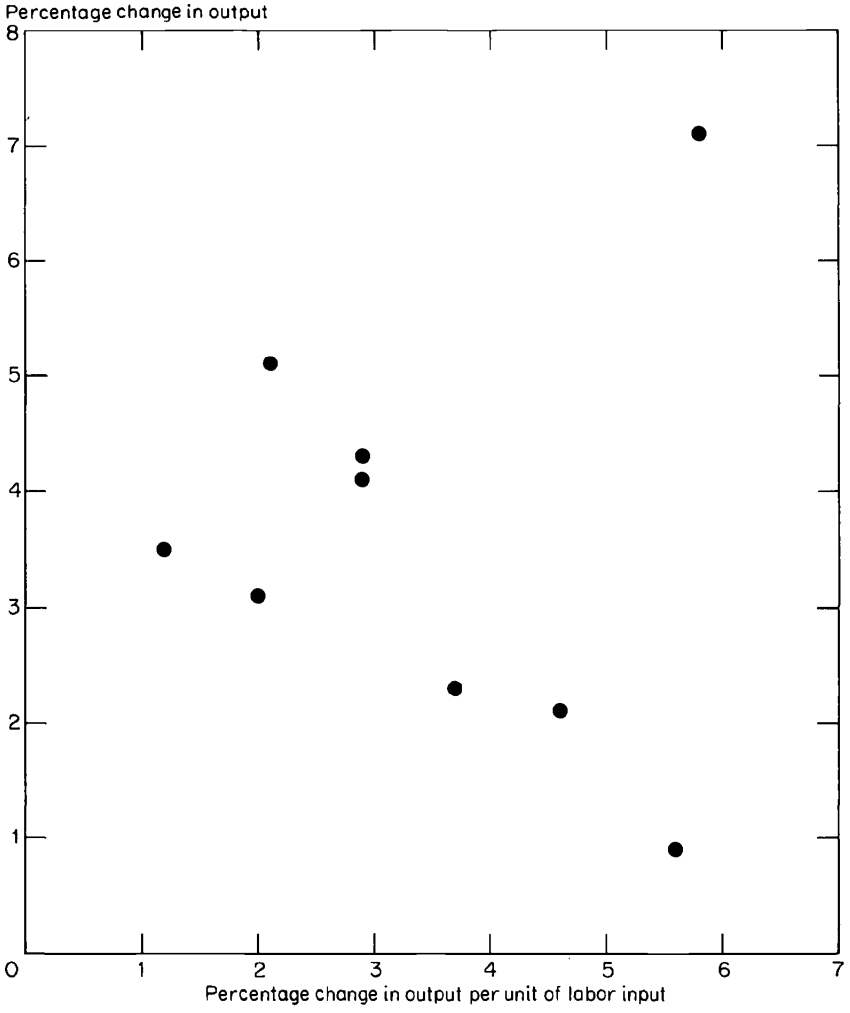
It will be recalled that the rate of growth of real product in the private domestic business economy averaged 4.0 per cent a year during the 1948-66 period. Growth rates of the major segments ranged from about 1 per cent in farming to about 7 per cent in communication and public utilities. Manufacturing and trade were close to the business economy average. In terms of the

Chart 6-1: Private Domestic Nonfarm Business Economy, Thirty-two Industry Groups: Relationship Between Rates of Change in Output and in Total Factor Productivity, 1948–66



Source: Tables 5-1 and 6-1.
[a] Excludes contract construction; finance, insurance, and real estate; and services.

Chart 6-2: Private Domestic Business Economy, Nine Industry Segments: Relationship Between Rates of Change in Output and in Labor Productivity, 1948–66



Source: Tables 5-5 and 6-1.

TABLE 6-1

Private Domestic Business Economy: Real Product,
by Industry Segment and Group,
Average Annual Percentage Rates of Change

	1948-66	1948-53	1953-57	1957-60	1960-66	Average Deviation
Private domestic business economy	4.0	4.6	2.5	2.6	5.2	1.1
Farming	0.9	1.1	0.2	2.5	0.5	0.6
Mining	2.1	2.3	3.0	-1.0	2.8	1.0
Metal	2.0	2.7	2.3	-1.7	3.0	1.2
Coal	-1.3	-6.3	1.5	-6.1	3.8	4.5
Oil and gas	2.9	4.8	3.5	-0.3	2.6	1.3
Nonmetal	4.6	5.3	6.3	3.8	3.3	1.1
Contract construction	3.1	6.0	2.8	0.9	2.0	1.6
Manufacturing	4.3	6.0	1.1	1.2	6.5	2.4
Nondurables	3.8	3.7	2.7	2.9	5.1	0.9
Foods	3.1	2.4	3.6	3.9	2.9	0.5
Beverages	2.7	0.7	1.8	2.8	5.0	1.5
Tobacco	1.9	1.5	0.7	4.2	1.9	0.8
Textiles	2.8	1.1	0.8	3.4	5.4	1.9
Apparel	3.1	2.3	1.8	3.6	4.3	1.0
Paper	5.0	4.8	4.1	4.0	6.2	0.8
Printing, publishing	4.1	2.7	5.3	4.2	4.5	0.8
Chemicals	8.2	9.6	6.7	6.9	8.7	1.1
Petroleum refining	4.1	5.3	3.6	3.6	3.6	0.7
Rubber products	7.2	6.6	5.9	5.0	9.8	1.7
Leather products	1.2	0.6	2.2	-0.1	1.8	0.8
Durables	4.7	7.6	0.1	0.6	7.5	3.4
Lumber products	2.3	2.2	-0.5	3.8	3.5	1.3
Furniture	4.3	2.8	4.8	4.4	5.3	0.9
Stone, clay, glass products	3.9	4.1	3.6	3.2	4.5	0.4

Primary metals	2.5	3.6	0.1	-3.0	6.1	3.0
Fabricated metals	3.9	5.4	0.7	1.1	6.3	2.4
Machinery except electric	4.8	6.4	0.8	0.5	8.3	3.2
Electric machinery	8.0	11.4	3.0	5.7	9.8	3.0
Transportation equipment and ordnance	6.7	16.5	-0.4	-0.4	7.5	5.8
Instruments	7.0	9.1	4.8	6.3	7.0	1.2
Miscellaneous	4.0	3.2	1.7	4.8	5.9	1.5
Transportation	2.3	0.5	1.5	0.0	5.6	2.2
Railroads	0.6	-1.1	-1.2	-2.6	4.9	2.8
Nonrail	3.7	2.1	3.6	2.0	5.9	1.5
Local transit	-4.8	-4.0	-5.4	-7.9	-3.5	1.3
Intercity bus lines	0.0	-0.2	-3.2	-2.4	3.6	2.4
Intercity trucking	8.5	12.6	5.3	6.8	8.0	2.3
Water transportation	0.2	0.0	2.9	-4.2	0.8	1.6
Air transportation	14.6	17.9	15.1	7.6	15.3	2.4
Pipeline transportation	6.0	8.9	6.3	1.6	5.8	1.7
Communication and public utilities	7.1	8.4	6.7	6.0	6.8	0.7
Communication	7.0	7.2	6.5	5.5	8.0	0.8
Electric, gas, and sanitary services	7.1	9.2	7.2	6.3	5.8	1.2
Electric and gas	8.0	9.7	8.9	6.9	6.7	1.3
Trade	4.1	3.7	3.7	3.1	5.2	0.6
Wholesale	4.8	3.4	4.8	4.6	6.0	0.8
Retail	3.7	3.8	3.1	2.1	4.7	0.8
Finance, insurance, real estate	5.1	5.2	5.3	4.0	5.3	0.3
Services	3.5	2.0	3.1	3.7	4.8	1.0
Average deviation:						
9 industry segments	1.4	2.2	1.5	1.8	1.7	
40 industry groups	2.2	3.5	2.4	2.9	2.2	

more detailed industry groups, local transit and coal mining showed decline, while positive rates ranged from less than 1 per cent for intercity bus lines, water transportation, and railroads to almost 15 per cent a year for air transportation. (See Table 6-1.)

Dispersion as measured by the average deviation of segment and group rates from their means was 1.4 and 2.2 per cent, respectively. This was well above the dispersion in rates of change of factor productivity in both segments and groups, and above that of the partial productivity rates for the industry groups.

Dispersion of output growth rates averaged considerably higher for subperiods than for the overall period. (See bottom of Table 6-1.) While well above the degree of dispersion for total factor and labor productivity ratios, the average growth rate for subperiods was about the same as that for rates of change in capital productivity and capital per unit of labor input. Output dropped during one or more subperiods in about one-quarter of the industry groups and, of course, showed higher rates of growth in at least one subperiod than the average rate 1948-66. Dispersion was significantly greater in the first subperiod, 1948-53, which was affected both by post-World War II readjustments and the Korean conflict, than in subsequent subperiods. This contrasts with the productivity rates, which generally were as dispersed in the last subperiod, 1960-66, as in the first.

Variability in subperiod rates of growth in real product was somewhat above that in the total factor and labor productivity ratios. The average deviations of subperiod rates from the period rate were 1.2 and 1.5 for segments and groups, respectively (see Table 5-2, addendum). This represented significantly less variability in growth rates than for earlier subperiods, as noted previously.[1]

Average annual mean deviation of output rates for the segments, at 3.1, while much above the subperiod deviations, was still below the trend rate; the comparable deviation for the industry groups, at 4.8 per cent, was greater than the trend rate—reflecting the fact that the majority of groups showed declines in output during contractions, although total and labor productivity declined only in some of them. Variability of annual changes in output was less than that in capital productivity, however.

Interrelation of Output and Productivity Changes

A significant positive correlation between relative industry changes in productivity and in output within broadly similar sectors was found in *Productivity*

[1] See *Productivity Trends*, Table 58, pp. 204-05.

Trends, in the earlier studies by Fabricant,[2] and in the more recent work by Fuchs.[3] It has been suggested that the relationship is reciprocal: relative advances in output affect productivity through differential scale economies; and relative changes in productivity, mirrored in relative price changes for the outputs of the various industries, in turn affect relative changes in sales and output.

Fuchs pointed out that the relationship does not hold with respect to ten major one-digit industry segments.[4] Our study confirms his findings, and we suggest some explanations later, following an analysis of the relationship for two-digit industry groups in the "industry" sector (excluding contract construction but including wholesale and retail trade) and for two-digit and four-digit industries in the manufacturing segment alone.

Our results for the period 1948-66 are broadly in line with the results of the earlier studies. The regression between average annual percentage rates of change in output and total factor productivity for thirty-two industry groups yields a coefficient of correlation of 0.55. (The relationship is depicted in the scatter diagram shown in Chart 6-1.) With rates of change in output related to output per man-hour for thirty-six industry groups, the coefficient is 0.60. Finally, the correlation between rates of change in output and capital productivity for thirty-two groups is 0.54. All these correlations are significant at the 0.01 level. (See Table 6-2).

Confining the analysis to manufacturing, for the twenty-one two-digit industry groups the coefficient of correlation between rates of change in output and total factor productivity is higher than in the industry segment including trade: 0.65; using rates of change in output and labor productivity, the coefficient is 0.54. The first correlation is significant at the 0.01 level, and the second, at the 0.05 level. The relationship between relative changes in output and in capital productivity for the manufacturing groups is not significant at the 0.05 level.

Moving down to the correlation between rates of change from 1954 to 1963 in output and in output per man-hour for 395 four-digit manufacturing

[2] Solomon Fabricant, *Employment in Manufacturing, 1899-1939: An Analysis of its Relation to the Volume of Production*, New York, NBER, 1942.

[3] V. R. Fuchs, *The Service Economy*, New York, NBER, 1969, Chapter 4.

[4] Ibid., Chapter 3. In our analysis, we use nine industry segments, combining government enterprises with private service industries. Fuchs combines the segments into three sectors: agriculture, industry, and service (ibid., Table 1, p. 18). His "industry" sector comprises mining, construction, manufacturing, transportation, communications and public utilities, and government enterprises. Our analysis of two-digit industries relates broadly to the "industry sector" so defined, except that in addition to shifting government enterprises to the "services sector," we include wholesale and retail trade. Also, since we do not have any further breakdown of the contract construction segment, we exclude it from our two-digit industry analysis.

TABLE 6-2

Private Domestic Nonfarm Business Economy:[a] Rates of Change, Productivity Ratio Versus Output, Regression Results, 1948-66, by Subperiod

		1948-66	1948-53	1953-57	1957-60	1960-66
	A. Total Factor Productivity Versus Output					
32	Industry groups					
	Coefficient of correlation	0.552	0.663	0.343	0.220	0.620
	t value	3.760[b]	4.850[b]	2.000	1.230	4.330[b]
	Slope	0.261	0.301			0.444
	Intercept	1.971	1.461			0.873
21	Manufacturing groups					
	Coefficient of correlation	0.649	0.649	0.490	0.598	0.748
	t value	4.888[b]	4.888[b]	2.811[c]	4.061[b]	7.411[b]
	Slope	0.295	0.224	0.312	0.431	0.335
	Intercept	1.538	1.441	2.191	1.567	0.950
	B. Labor Productivity Versus Output					
36	Industry groups					
	Coefficient of correlation	0.595	0.544	0.531	0.445	0.616
	t value	4.320[b]	3.780[b]	3.650[b]	2.900[b]	4.560[b]
	Slope	0.346	0.271	0.256	0.273	0.479
	Intercept	2.184	2.225	2.861	2.883	1.210
21	Manufacturing groups					
	Coefficient of correlation	0.539	0.515	0.606	0.575	0.390
	t value	3.315[b]	3.054[b]	4.174[b]	3.747[b]	2.005
	Slope	0.287	0.189	0.338	0.436	
	Intercept	2.113	2.136	2.705	2.113	

395	Manufacturing industries	(1954-63)		(1954-58)	(1958-63)	
	Coefficient of correlation	0.505		0.490	0.374	
	t value	13.49[b]		12.830[b]	8.65[b]	
	Slope	3.56		2.90	5.35	
	Intercept	-91.8		-30.5	-53.4	
		C. Capital Productivity Versus Output				
32	Industry groups					
	Coefficient of correlation	0.544	0.688	0.067	0.561	0.421
	t value	4.234[b]	7.154[b]	0.368	4.481[b]	2.803[b]
	Slope	0.932	0.769		0.490	0.412
	Intercept	3.300	3.677		2.526	4.777
21	Manufacturing groups					
	Coefficient of correlation	0.384	0.491	0.336	0.516	0.549
	t value	1.962	2.819[c]	1.652	3.065[b]	3.425[b]
	Slope		0.678		0.424	0.594
	Intercept		4.219		2.585	4.901

Note: If the coefficient of correlation is not significant at the .05 level, the coefficients of the regression equation (intercept and slope) are not given.

Source: Tables A-26–29, A-37–57, A-60–61, A-64–69, A-71, A-73, A-76–77; and Henry Linsert, "An Empirical Study of the Relationship between Output per Man-Hour and Related Variables in Manufacturing Industries, 1954-1963," June 1970, on file at The George Washington University library.

[a] Excludes contract construction; finance, insurance, and real estate; and services.

The thirty-six industry groups include all other nonfarm two-digit industries and one-digit industries that are not subdivided.

The thirty-two industry groups exclude local transit, intercity bus lines, intercity trucking, and pipeline transportation.

The 395 manufacturing industries are four-digit industries for which indexes were prepared by H. Linsert.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

industries, the coefficient is 0.51, lower than for the twenty-one groups, but still significant at the 0.01 level.

The coefficient of correlation between rates of change in output and in the productivity ratios averages less for the subperiods than for the period as a whole. In the case of total factor productivity and output, the coefficients are higher in the first and last subperiods, 1948-53 and 1960-66, than in the two intervening subperiods. This reflects the fact that relative changes in productivity and in price were also less closely correlated in the subperiods than over the whole period, and that the coefficients were lower in the middle subperiods.

Fuchs also found a significant positive correlation between rates of change in output and output per man-hour within the service sector. Using seventeen service industries (eight service industries proper and nine retail trades) for the periods 1939-63 and 1948-63, he obtained coefficients of rank correlation of 0.91 and 0.69, respectively.[5]

Productivity and Prices of Factors and Products

The general theoretical presupposition behind the associations just described is that, at least over longer periods of time, rates of change in productivity and in factor prices are not correlated to any significant degree, since mobility of resources tends to equalize rates of change in factor prices, including profits. Consequently, relative changes in productivity tend to be reflected in relative price changes, and thus in relative output changes. Actually, if total factor productivity measures are used, it is relative changes in unit value added ("net price") that would be negatively correlated with relative changes in productivity. Relative gross output prices are also affected by relative changes in prices of purchased intermediate products to which value is added.

The hypothesis that relative changes in productivity and in factor prices are not significantly correlated is at least partially confirmed by the evidence shown in Table 6-3. Over the entire eighteen-year period for thirty-two industry groups, the coefficient of correlation between rates of change in total factor productivity and in average (combined) factor prices was only 0.18, not significant at the 0.05 levels. The coefficients in the subperiods averaged almost twice that for the longer period. This indicates that it takes a substantial period of time for shifts of resources in response to relative factor price changes to tend to equalize price changes in similar resources employed by industry groups within the various segments.

[5] Ibid., Table 34, p. 92.

The coefficients of correlation between industry rates of change in the partial productivity ratios and in the corresponding prices of labor and capital are substantially higher—0.34 in both cases—but still not significant at the 0.05 level. This is consistent with the lower degree of correlation on a total factor basis, since relative changes in labor and capital productivity are negatively correlated, and the relative prices of labor and capital therefore tend to show a similar negative association. The table of correlation coefficients also shows that the tendency for coefficients to be higher in the subperiods than over the longer period holds only for the relation between changes in capital productivity and capital price. As we measure it, the price of capital is a compound of the prices of capital goods and the rate of return on net capital assets (see appendix text). It seems reasonable that, over shorter periods, the rate of return component of capital price would tend to reflect rates of change in output (and presumably net income) relative to the stock of capital. But over long periods, movements of capital into areas where rates of return have been rising relatively would tend to bring the increases back down closer to the average rate.

In the case of average hourly labor compensation, labor productivity in specific industries is only one of many influences at work in wage determination, and there is no reason to believe it to be a stronger influence over shorter periods than over longer periods of time. The coefficients of correlation are low for both the 1948-66 period and the subperiods, and are generally not significant at the 0.05 level.

When the industry sample is confined to the twenty-one manufacturing groups, the findings just noted are somewhat more pronounced (see Table 6-3, part B). In the case of the 395 four-digit manufacturing industries for which only labor data are available, the coefficient of correlation between rates of change in output per man-hour and average hourly compensation is only 0.22, and lower when ranks are used. But due to the large size of the sample, the coefficient, while low, is significant at the 0.05 level.

These results make sense; after all, if wage-rate changes in the various industries strongly reflected their productivity changes, the entire wage structure of the economy would be out of kilter within relatively few years. Actually, the ranking of industries by levels of average hourly labor compensation has not generally changed very much since 1948 (see Table 6-4). This confirms evidence with respect to still longer time spans for earlier periods.[6] In other words, rates of change in wage rates show much less dispersion than

[6] See *Productivity Trends*, Table 54, p. 197.

TABLE 6-3

Private Domestic Nonfarm Business Economy:[a] Rates of Change, Average Input Price Versus Productivity Ratio, Regression Results, 1948-66, by Subperiod

		1948-66	1948-53	1953-57	1957-60	1960-66
	A. Average Price of Total Input Versus Total Factor Productivity					
32	Industry groups					
	Coefficient of correlation	0.182	0.388	0.007	0.327	0.452
	t value	1.03	2.31[b]	0.38	1.89	2.78[b]
	Slope		0.478			0.292
	Intercept		3.362			2.968
21	Manufacturing groups					
	Coefficient of correlation	−0.203	0.0	−0.016	0.535	−0.077
	t value	0.923	0.0	0.070	3.266[b]	0.339
	Slope				1.500	
	Intercept				−2.029	
	B. Average Hourly Earnings Versus Labor Productivity					
32	Industry groups					
	Coefficient of correlation	0.339	0.199	−0.104	0.223	0.434
	t value	1.97	1.11	0.57	1.25	2.640[c]
	Slope					0.138
	Intercept					3.018
21	Manufacturing groups					
	Coefficient of correlation	0.251	0.208	−0.216	0.264	0.226
	t value	1.167	0.948	1.039	1.237	1.038

395	Manufacturing industries	(1954-63)		(1954-58)	(1958-63)	
	Coefficient of correlation	0.218		0.135	0.470	
	t value	4.56[b]		2.74[b]	12.01[b]	
	Slope	0.09		0.07	0.21	
	Intercept	34.46		18.64	9.47	
		C. Price of Capital Versus Capital Productivity				
32	Industry groups					
	Coefficient of correlation	0.340	0.754	0.482	0.556	0.277
	t value	2.107[c]	9.565[b]	3.439[b]	4.409[b]	1.645
	Slope	0.695	2.261	1.745	1.363	
	Intercept	0.609	-3.541	-0.950	-2.266	
21	Manufacturing groups					
	Coefficient of correlation	0.195	0.535	0.450	0.549	0.090
	t value	0.884	3.266[b]	2.464[c]	3.425[b]	0.396
	Slope		1.500	0.660	1.303	
	Intercept		-2.029	-0.378	-1.334	

Note: If the coefficient of correlation is not significant at the .05 level, the coefficients of the regression equation (intercept and slope) are not given.

Source: For productivity measures, see source for Tables 6-2. Factor prices derived from Department of Commerce compensation estimates and our factor input estimates.

[a] Excludes contract construction; finance, insurance, and real estate; and services.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

TABLE 6-4
Private Domestic Business Economy: Ranking of Average Hourly Compensation in Thirty-four Industry Groups, 1948-66, by Subperiod

	1948-66	1948-53	1953-57	1957-60	1960-66
Farming	1	1	1	1	1
Mining					
Metal	22	21	26	24	21
Coal	30	33	33	30	28
Oil and gas	16	23	16	15	12
Nonmetal	9	8	9	9	9
Contract construction	21	18	18	18	23
Manufacturing					
Foods	11	9	10	11	11
Beverages	25	32	29	23	22
Tobacco	7	3	7	8	10
Textiles	3	5	3	3	4
Apparel	4	6	4	4	3
Paper	13	14	13	14	13
Printing and publishing	23	26	24	22	20
Chemicals	31	28	30	31	31
Petroleum refining	34	34	34	34	34
Rubber products	17	22	21	19	17
Leather products	6	7	6	6	5
Lumber	5	4	5	5	6
Furniture	8	10	8	7	7
Stone, clay, glass products	14	13	14	16	15
Primary metals	33	30	32	33	32
Fabricated metals	20	20	20	21	18
Machinery, except electric	26	27	28	26	26
Electric machinery	18	19	19	20	19
Transportation equipment and ordnance	32	31	31	32	33
Instruments	24	24	23	25	25
Miscellaneous	10	11	11	10	8
Transportation					
Railroads	28	17	25	29	29
Water transportation	27	25	22	28	27
Air transportation	29	29	27	27	30
Communication and public utilities					
Communication	12	12	12	12	16
Electric, gas, sanitary services	19	15	17	17	24
Trade					
Wholesale	15	16	15	13	14
Retail	2	2	2	2	2

Note: For 1948-66, rank of absolute hourly earnings in subperiods is weighted by length of each subperiod. Hourly earnings for each subperiod represent an average of hourly earnings in the termina years of the subperiod.

Source: Hourly earnings derived from Department of Commerce labor compensation estimates and our labor input estimates.

rates of productivity change, and relative changes in the two variables are only weakly associated.

Given the weak association between industry rates of change in productivity and in factor prices, one would expect a fairly high degree of correlation between relative industry changes in productivity and in product prices. As noted earlier, unit value added (net price) is the more relevant variable. In computing rates of change, we use two versions of unit value added: one is the implicit price deflator for industry GNP as calculated by OBE; the other is current dollar GNP by two-digit industry, divided by our output measures, which differ somewhat from the OBE real product measures, as explained in the appendix. Our adjusted unit value added (net price) index is thus consistent with our productivity and related measures. Price indexes are available for one group fewer than productivity indexes.

As shown in Table 6-5, the coefficient of correlation between rates of change in total factor productivity and in the implicit industry product price deflator rounds to -0.70 for the period 1948-66, significant at the 0.01 level. The coefficient is substantially lower in most subperiods, which is consistent with the higher correlation between changes in productivity and factor prices in the subperiods than over the period as a whole. The coefficient of correlation between industry rates of change in labor productivity and in the product price deflators during 1948-66 is virtually the same as that obtained when total factor productivity is used. This is to be expected in view of the high degree of correlation between labor productivity and total factor productivity. In the subperiods, however, the coefficients are higher than when total factor productivity is used, though still below the coefficient for the whole period, except in the final subperiod 1960-66, when it is the same.

The coefficients of correlation are higher when the adjusted net output price deflator is used: -0.88 in the regression on total factor productivity, and -0.76 in the regression on labor productivity. The subperiod coefficients are also higher relative to those for the period as a whole. (See Table 6-5.)

Similar results are obtained for the twenty manufacturing groups shown in the table. With regard to the 395 manufacturing industries, the coefficient of correlation between rates of change in output per man-hour and unit value added is lower: -0.60 for the period 1954-63. The shorter length of the period could partially explain the lower coefficient. Also, value added in the Census of Manufactures is more of a gross concept than the OBE industry product concept, which also tends to lead to somewhat different results in correlations.

TABLE 6-5

Private Domestic Nonfarm Business Economy:[a] Rates of Change, Net Price (Unit Value Added) Versus Productivity, Regression Results, 1948-66, by Subperiod

	1948-66	1948-53	1953-57	1957-60	1960-66
A. Net Price Versus Total Factor Productivity					
31 Industry groups					
Coefficient of correlation	−0.695	−0.389	−0.236	−0.048	−0.681
t value	7.23[b]	2.27[c]	1.31	2.59[c]	5.01[b]
Slope	−0.614	−0.388		−0.055	−0.483
Intercept	3.261	3.314		1.343	2.376
20 Manufacturing groups					
Coefficient of correlation	−0.500	−0.205	−0.170	−0.180	−0.050
t value	2.827[c]	1.498	0.741	0.788	0.212
Slope	−0.608				
Intercept	3.375				
B. Adjusted Net Price Versus Total Factor Productivity					
31 Industry groups					
Coefficient of correlation	−0.877	−0.689	−0.408	−0.238	0.813
t value	9.83[b]	5.12[b]	2.40[c]	1.32	7.52[b]
Slope	−1.133	−1.008	−0.693		−0.676
Intercept	4.461	4.533	3.393		2.736
20 Manufacturing groups					
Coefficient of correlation	−0.735	−0.453	−0.552	−0.242	−0.670
t value	6.774[b]	2.416[c]	3.367[b]	1.090	5.156[b]
Slope	−0.946	−0.865	−0.776		−0.894
Intercept	3.952	4.399	3.296		3.252

	C. Net Price Versus Labor Productivity				
34	Industry groups				
	Coefficient of correlation	−0.696	−0.351	−0.488	−0.302	−0.697
	t value	5.48[b]	2.12[c]	3.16[b]	1.79	5.50[b]
	Slope	−0.588	−0.325	−0.811		−0.518
	Intercept	3.627	3.535	4.681		2.876
20	Manufacturing groups					
	Coefficient of correlation	−0.509	−0.359	−0.419	0.167	−0.012
	t value	2.912[b]	1.747	2.156[c]	0.728	0.051
	Slope	−0.525		−0.902		
	Intercept	3.420		5.634		
	D. Adjusted Net Price Versus Labor Productivity					
31	Industry groups					
	Coefficient of correlation	−0.756	−0.655	−0.596	−0.142	−0.716
	t value	6.22[b]	4.66[b]	3.99[b]	1.20	5.43[b]
	Slope	−0.867	−0.888	−1.012		−0.704
	Intercept	4.116	4.595	5.078		3.193
20	Manufacturing groups					
	Coefficient of correlation	−0.643	−0.570	−0.789	−0.023	−0.483
	t value	4.643[b]	3.580[b]	8.849[b]	0.098	2.670[c]
	Slope	−0.703	−0.950	−1.277		−0.593
	Intercept	3.633	5.055	5.711		2.794
395	Manufacturing industries	(1954-63)		(1954-58)	(1958-63)	
	Coefficient of correlation	−0.60		−0.60	−0.37	
	t value	18.66[b]		18.66[b]	8.53[b]	
	Slope	−0.35		−0.49	−0.36	
	Intercept	24.9		15.5	7.5	

Note: If the coefficient of correlation is not significant at the .05 level, the coefficients of the regression equation (intercept and slope) are not given.

Source: See source for Table 6-3.

[a] Excludes contract construction; finance, insurance, and real estate; and services.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

Unit Value Added, Output, and the Scale Effect

To complete the cycle of relationships, unit value added must be regressed on output. A significant negative relationship between rates of change in these two variables, given the negative relationship between rates of change in productivity and in unit value added, would explain at least part of the positive relationship between output and productivity. It is to be expected that relative changes in average market prices would show a closer relationship to relative changes in output than do relative changes in implicit product price deflators. But there is a fairly close relationship between relative changes in unit value added and in prices, by industry—not only because unit value added is, on the average, the chief component of price but also because there tends to be a positive correlation between relative changes in unit value added and in unit cost of intermediate products, in real terms.[7]

The coefficient of correlation between industry rates of change in the implicit product price deflators and in output is -0.45 when the OBE deflators are used, and -0.49 when the deflators are adjusted as described above. The coefficients are lower in the subperiods, on the average, than over the entire period covered. (See Table 6-6.) Although significant, the coefficients of correlation are not very high for the industry groups, and are even lower for the manufacturing groups and industries. This reflects the fact that sales and output are affected not only by relative changes in prices (given a set of price elasticities of demand) but also by differential income elasticities of demand and by shifts of preferences.

Actually, the degree of correlation between relative industry changes in output and productivity is higher than can be explained by the negative relationships between productivity and net price, and between net price and output. This supports the presumption that scale effects reinforce the positive relationship between relative industry changes in productivity and in output.

Productivity and Inputs

If output increased at the same rate in all industries, inputs would obviously fall relatively in industries with above-average productivity advance and rise relatively in industries with below-average productivity advance. This was not the case in the period 1948-66. The positive association between rates of change in output and in productivity was strong enough to obviate any systematic relationship between relative industry changes in productivity and in the tangible factor inputs, separately or in combination.

[7] See *Productivity Trends*, Table 56, p. 200.

TABLE 6-6

Private Domestic Nonfarm Business Economy:[a] Rates of Change, Output Versus Net Price, Regression Results, 1948-66, by Subperiod

	1948-66	1948-53	1953-57	1957-60	1960-66
A. Rates of Change: Output Versus Net Price					
34 Industry groups					
Coefficient of correlation	−0.452	−0.221	−0.356	0.048	−0.266
t value	2.870[b]	1.280	2.160[c]	0.270	1.560
Slope	−0.901		−0.428		
Intercept	5.523		4.011		
20 Manufacturing groups					
Coefficient of correlation	−0.042	0.045	0.151	−0.302	0.220
t value	0.178	0.191	0.655	1.408	0.980
B. Rates of Change: Output Versus Adjusted Net Price					
31 Industry groups					
Coefficient of correlation	−0.489	−0.191	−0.477	0.157	−0.503
t value	3.463[b]	1.130	2.920[b]	0.860	3.130[b]
Slope	−0.803		−0.601		−0.828
Intercept	5.080		4.188		5.983
20 Manufacturing groups					
Coefficient of correlation	−0.182	0.126	−0.403	−0.348	−0.521
t value	0.798	0.543	2.039	1.678	3.030[b]
Slope					−0.818
Intercept					6.339
395 Manufacturing industries	(1954-63)		(1954-58)	(1958-63)	
Coefficient of correlation	−0.41		−0.42	−0.26	
t value	9.810[b]		10.140[b]	5.55[b]	
Slope	−1.24		−0.72	−0.44	
Intercept	61.4		18.1	20.7	

Note: If the coefficient of correlation is not significant at the .05 level, the coefficients of the regression equation (intercept and slope) are not given.

Source: See source for Table 6-3.

[a] Excludes contract construction; finance, insurance, and real estate; and services.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

For the industry groups, the coefficients of correlation between rates of change in total factor productivity and in total factor input, and in labor and capital input separately, during 1948-66 have small positive values, but are not significant (see Table 6-7). It is interesting that, in the subperiods, the coefficients in the relationships involving total input and labor input have

TABLE 6-7

Private Domestic Nonfarm Business Economy:[a] Rates of Change, Inputs Versus Productivity, Regression Results, 1948-66, by Subperiod

	1948-66	1948-53	1953-57	1957-60	1960-66
A. Total Factor Input Versus Total Factor Productivity					
32 Industry groups					
Coefficient of correlation	0.090	0.245	−0.120	−0.263	−0.121
t value	0.49	1.38	0.66	1.49	0.67
21 Manufacturing groups					
Coefficient of correlation	0.240	0.356	−0.164	−0.157	0.397
t value	1.079	1.777	0.735	0.701	2.055
B. Labor Input Versus Total Factor Productivity					
32 Industry groups					
Coefficient of correlation	0.083	0.260	−0.047	−0.230	−0.066
t value	0.46	1.48	0.260	1.29	0.36
21 Manufacturing groups					
Coefficient of correlation	0.249	0.376	0.061	−0.068	0.388
t value	1.157	1.908	0.297	0.298	1.990
C. Labor Input Versus Labor Productivity					
32 Industry groups					
Coefficient of correlation	0.006	0.091	0.281	−0.332	−0.165
t value	0.033	0.502	1.672	2.044[c]	0.929
Slope				−0.608	
Intercept				1.157	
21 Manufacturing groups					
Coefficient of correlation	0.013	0.163	0.078	−0.210	−0.137
t value	0.057	0.968	0.342	0.958	0.736

395	*Manufacturing industries*	(1954-63)		(1954-58)	(1958-63)	
	Coefficient of correlation	-0.132		-0.202	-0.079	
	t value	2.670[b]		4.19[b]	1.56	
	Slope	-0.145		-0.237		
	Intercept	12.00		3.51		
	D. Capital Input Versus Total Factor Productivity					
32	Industry groups					
	Coefficient of correlation	0.177	-0.037	-0.191	-0.359	-0.225
	t value	0.98	0.20	1.07	2.11[c]	1.26
	Slope				-0.766	
	Intercept				4.840	
21	Manufacturing groups					
	Coefficient of correlation	0.239	0.173	-0.432	-0.329	0.026
	t value	1.104	0.778	2.317[b]	1.607	0.113
	Slope			1.015		
	Intercept			5.013		

Note: If the coefficient of correlation is not significant at the .05 level, the coefficients of the regression equation (intercept and slope) are not given.

Source: See source for Table 6-2.

[a] Excludes contract construction; finance, insurance, and real estate; and services.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

small negative values (except for the first subperiod), and are negative for all subperiods in the relationship involving capital input. This is consistent with the lesser degree of correlation shown in the subperiods than for the period as a whole between relative changes in output and productivity. In the case of the 395 manufacturing industries, the negative coefficients of correlation for the periods 1954-58 and 1954-63, while quite low, were significant at the 0.01 level.

We stated earlier that, as pointed out by Fuchs, there is virtually no correlation between relative changes in output and in productivity for the major one-digit industry segments (see Chart 6-2). The coefficient of correlation using relative changes in total factor productivity and output during 1948-66 in seven major segments is 0.05; using relative changes in labor productivity and output in all nine segments, it is 0.06. This lack of correlation is not the result of perverse price relationships. As is true of the two-digit industry groups, the coefficient of correlation between relative changes in productivity and input prices is insignificantly small: -0.07. As would be expected, there is a much higher coefficient of correlation between relative changes in productivity and in output prices: -0.43 when total factor productivity is used as the independent variable, and -0.70 when labor productivity is used for all nine segments.

The point where the causal chain breaks is in the relationship between relative changes in output and average prices of output—the coefficient of correlation for the period 1948-66 is a positive 0.49. Although the coefficient is not significant at the 0.05 level due to the small number of segments, it strongly suggests that there is but small cross-elasticity of demand for output across major industry segment lines, and that price elasticities are heavily out-weighed by high income elasticities of demand for products of industries with below-average productivity gains and above-average price increases. In the case of products of industries with above-average productivity gains and below-average price rises, the effects of low price elasticity of demand tend to be accentuated by low income elasticities.

The most striking examples of this effect are farming (or extractive industry as a whole, including mining) on the one hand, and services on the other. Between 1948 and 1966, total factor productivity in farming rose by 3.3 per cent a year on the average, well above the 2.5 per cent average in the private domestic economy as a whole. Despite price support programs, input prices rose somewhat less than in the economy as a whole, and product prices fell by an average 4.2 per cent a year, contrasted with the 1.7 per cent average increase in the private domestic economy as a whole. Despite the

relatively favorable price trends, real product in farming rose at only one-quarter the 4.0 per cent growth rate of real domestic business product.

The other extreme is apparent in the case of the services sector, including finance. Here productivity rose less than half as fast as that in the domestic business economy. Despite a somewhat smaller increase in wage rates, average prices of services rose at an average annual rate of 3.2 per cent a year during 1948-66, compared with the 1.7 per cent business economy rate. Nevertheless, real product in the finance and services sector rose at an average annual rate of approximately 4.5 per cent a year, topping the 4.0 per cent average rate in the business economy. It is clear that price elasticities were heavily outweighed by income elasticities of demand and shifts in preferences, which resulted in a relative increase in demand for, and output of, services, despite the relative increase in their average prices.[8]

Productivity and Employment

Given the output changes in the various industry groupings during 1948-66, productivity and associated ratios can explain the changes in labor input and employment, as shown in Table 6-8. With reference to index numbers for 1966 on a 1948 base, by dividing output (O, in column 1) by total factor productivity (O/I, in column 2), total input (I) is obtained. By dividing the total input quotient by the ratio of total input to labor input (I/L, column 3), which measures the substitution of capital for labor, labor input (L, column 4) is obtained. It will be recalled that labor input is man-hours in component industry groups weighted by base-period average hourly compensation. But our chief interest is in employment change (E, column 6), obtained by dividing labor input by the ratio of labor input to employment (L/E, column 5), which reflects both changes in average hours worked and the interindustry shift effect.

We shall illustrate the use of the table by tracing through the behavior of the variables for the communication and public utilities group. Real product of this group rose by 242 per cent between 1948 and 1966. Total factor productivity doubled and factor substitution increased by 36 per cent over the period, so labor input rose by 25 per cent. Labor input per person engaged rose by 2 per cent—a drop in average hours having been more than offset by a relative shift of man-hours toward the higher-pay segments of the group. Thus, employment (persons engaged) rose by almost 23 per cent over the eighteen years.

[8] Fuchs attempts to estimate roughly the price, income, and substitution elasticities of demand for goods and services in his *The Service Economy*, Chapter 2.

TABLE 6-8

Private Domestic Business Economy: Output, Productivity, Persons Engaged, and Related Variables, 1966
(index numbers, 1948=100)

	Real Product *O* (1)	Total Factor Productivity *O/I* (2)	Factor Substitution *I/L* (3)	Labor Input *L* (Col. 1÷Col. 2÷Col. 3) (4)	Labor Input per Person *L/E* (5)	Persons Engaged *E* (Col. 4÷Col. 5) (6)
Private domestic business economy	203.0	156.6	110.4	117.4	102.9	114.1
Farming	118.1	180.8	147.2	44.4	88.2	50.3
Mining	144.6	209.0	106.7	64.8	100.2	64.7
Contract construction	173.3	130.1	109.5	121.7	97.2	125.2
Manufacturing	213.8	156.6	107.7	126.8	103.2	122.8
Nondurables	195.8	159.0	111.1	110.8	101.2	109.5
Durables	227.2	153.3	106.7	139.0	103.6	134.1
Transportation	150.7	183.8	103.9	78.9	92.6	85.2
Rail	111.5	248.5	111.2	40.4	83.8	48.2
Nonrail	191.1	145.5	103.8	126.6	103.8	121.9
Communication and public utilities	342.2	201.0	136.4	124.9	101.9	122.6
Trade	206.1	156.4	106.7	123.5	97.0	127.3
Finance, insurance, and real estate	243.3	145.9[a]		166.8	101.7	164.1
Services	184.4	123.1[a]		149.8	96.8	154.7

Source: Tables A-20, A-22, A-24, A-30–31, A-33, A-35, A-58, A-60, A-62, A-70, A-75, A-78–79.

[a] Output per unit of labor input.

It is even more informative to view the changes in relation to those for the private domestic business economy. This is done in Table 6-9, where the index numbers for each industry group and segment are divided by those for the private domestic business economy to show the relative changes. To illustrate again by the communication and public utilities group, the 23 per cent increase in employment was 7.4 per cent greater than the 14 per cent increase in the domestic business economy. This explains the expansion in the group's share of total persons engaged from 2.5 per cent in 1948 to 2.7 per cent in 1966 (column 8). The relative change in employment is, of course, the result of the interaction of the relative movements of the several variables we already reviewed in connection with Table 6-8. Thus, the relative output of the industry rose by 69 per cent, while productivity and factor substitution showed relative increases of 28 and 24 per cent, respectively, resulting in a 6.3 per cent relative increase in labor input. This reconciles with the 7.4 per cent increase in persons engaged when account is taken of the 1 per cent relative drop in weighted man-hours per person.

We have also compared proportionate employment changes for the aggregate of industries with above-average productivity advance with the aggregate of those with below-average advance. Looking first at the nine one-digit groupings, the results show a negative relationship. The industrial segments with above-average productivity advance (farming, mining, transportation, and communication and public utilities) registered a 34 per cent drop in employment between 1948 and 1966. The segments with below-average productivity advance (contract construction, finance, and services) showed a 48 per cent rise in employment. Manufacturing and trade, which had the same 2.5 per cent rate of productivity advance as the private domestic business economy, together showed a 25 per cent employment increase, compared with only 14 per cent for all private domestic industries.

The results are quite different when the tabulations are made for the two-digit industries within the manufacturing, mining, transportation, and utility segments. The twenty-one industries with above-average rates of advance in total factor productivity increased employment by 16.5 per cent during 1948-66, while the nine industries with below-average productivity advance raised employment by 11 per cent. The aggregates of the two sets of thirteen and seven manufacturing industries showed somewhat higher rates of increase in employment—26.6 and 12.8 per cent, respectively. One manufacturing industry, paper products, was not included since it showed the average 2.5 per cent rate of productivity advance.

TABLE 6-9

Private Domestic Business Economy, by Industry Segment and Group:[a]
Factors Influencing Relative Changes in Employment, 1948-66

	Real Product *O* (1)	Total Factor Productivity *O/I* (2)	Factor Substitution[b] *I/L* (3)	Labor Input[c] *L* (4)	Labor Input per Person *L/E* (5)	Persons Engaged[d] *E* (6)	Per Cent Distribution of Persons Engaged (PDBE = 100) 1948 (7)	1966 (8)
Farming	58.2	115.4	133.3	37.8	85.7	44.1	15.58	6.87
Mining	71.2	133.5	96.6	55.2	97.4	56.7	2.01	1.14
Metal	69.9	98.2	99.3	71.7	96.4	74.3	0.21	0.15
Coal	39.2	159.4	99.7	24.7	104.3	23.7	1.06	0.25
Oil and gas	82.8	113.3	76.4	95.7	100.7	95.1	0.55	0.52
Nonmetal	110.9	102.0	100.4	108.4	100.2	108.2	0.20	0.22
Contract construction	85.4	83.1	99.2	103.7	94.5	109.7	6.50	7.13
Manufacturing	105.3	100.0	97.6	108.0	100.3	107.6	31.24	33.62
Nondurables	96.5	101.5	100.7	94.4	98.4	95.9	14.42	13.84
Foods	85.0	109.6	95.5	81.2	94.2	86.2	3.14	2.70
Beverages	79.6	94.5	103.0	81.8	94.6	86.5	0.46	0.40
Tobacco	68.9	77.5	120.9	73.5	98.7	74.5	0.20	0.15
Textiles	81.2	130.0	95.7	65.2	103.0	63.3	2.59	1.67
Apparel	84.8	89.5	96.1	98.5	97.4	101.1	2.41	2.44
Paper	117.8	100.1	99.2	118.8	95.6	124.2	0.92	1.14
Printing, publishing	102.2	102.3	92.1	108.6	91.0	119.3	1.58	1.89
Chemicals	203.6	150.1	109.9	123.4	94.9	130.1	1.27	1.65
Petroleum refining	100.9	108.8	138.3	67.1	92.7	72.4	0.44	0.31
Rubber products	172.6	128.0	92.0	146.6	101.4	144.5	0.61	0.87
Leather products	61.4	85.9	91.5	78.2	100.2	78.0	0.80	0.62
Durables	111.9	97.9	96.6	118.4	100.7	117.5	16.82	19.77
Lumber products	73.8	118.0	97.9	63.9	96.9	66.0	1.85	1.22
Furniture	105.2	107.7	90.3	108.1	94.8	114.0	0.73	0.83

Primary metals	76.6	84.7	100.1	90.3	97.7	92.5	2.50	2.31
Fabricated metals	98.4	88.9	95.9	115.3	99.2	116.2	2.02	2.34
Machinery except electric	113.4	101.1	92.5	121.2	100.7	120.4	2.81	3.38
Electric machinery	197.2	123.0	97.5	164.5	98.6	166.9	1.95	3.25
Transportation equipment and ordnance	159.1	111.5	91.6	155.7	102.2	152.3	2.48	3.78
Instruments	165.5	107.2	104.1	148.3	99.6	148.9	0.49	0.74
Miscellaneous	100.0	117.7	98.8	86.0	93.9	91.5	0.86	0.79
Transportation	74.2	117.4	94.1	67.2	90.0	74.7	5.90	4.40
Railroads	54.9	158.7	100.7	34.4	81.5	42.2	2.93	1.24
Nonrail	94.1	92.9	94.0	107.8	100.9	106.8	2.96	3.17
Water transportation	50.9	70.3	93.3	77.6	103.8	74.7	0.50	0.38
Air transportation	575.9	254.7				246.1	0.18	0.44
Pipeline transportation	141.4			51.4	97.7	52.6	0.06	0.03
Communication and public utilities	168.6	128.4	123.6	106.3	99.0	107.4	2.50	2.69
Communication	166.8	126.0	119.7	110.6	101.6	108.9	1.45	1.58
Telephone, telegraph	167.0	131.2	123.7	102.9	99.6	103.3	1.36	1.40
Electric, gas, sanitary services	170.1	127.7	131.7	101.2	96.1	105.3	1.05	1.11
Trade	101.5	99.9	96.6	105.2	94.3	111.6	21.29	23.76
Wholesale	113.8	99.3	100.7	113.8	99.2	114.7	5.23	6.00
Retail	94.1	98.1	94.9	101.1	91.5	110.5	16.07	17.76
Finance, insurance, and real estate	119.8			142.1	98.8	143.8	3.81	5.47
Services	90.8			127.6	94.1	135.6	9.16	12.38

Source: For columns 1-6, Tables A-20, A-22, A-24, A-26–31, A-33, A-35, A-37–58, A-60, A-62, A-64–73, A-75–79; for columns 7 and 8, Table A-7 and Department of Commerce.

[a] Index numbers (for 1966 on a 1948 base) for the several segments and groups are expressed as percentages of corresponding index numbers for the private domestic business economy.

[b] Capital for labor.

[c] Column 1 divided by column 2 divided by column 3.

[d] Column 4 divided by column 5, or column 8 divided by column 7.

These results are consistent with the mild positive correlation found between rates of change in productivity and in labor input for the thirty-two two-digit industries. So we may conclude that within the industry groups, rates of technological advance as reflected in productivity indexes are at least neutral and possibly positive relative to employment changes. The opposite conclusion for the one-digit industry segments reflects the factors mentioned above in explanation of the lack of correlation between relative changes in productivity and output.

Causal Factors

The estimates of productivity change by industry provide an opportunity for quantitative analysis of causal factors beyond that provided by the global estimates for the private domestic economy. That is, if estimates of those causal forces which are prominent in theoretical explanations can be developed on an industry basis, they can be related through regression analysis to the differential industry rates of productivity change. This will make possible identification of the significant independent variables and quantification of their impacts.

Generally, it would be desirable to measure not only the average levels of the causal variables during the period under consideration but also their rates of change. There are many problems associated with this kind of multivariate analysis, of course, which we shall point out after discussing the chief independent variables it would be desirable to quantify on an industry basis, if possible.

Starting from the general theoretical framework sketched at the end of Chapter 4, it would be essential to try to measure the real stocks of intangible capital embodied in the tangible factors employed in the various industries. In particular, it would be desirable to try to measure the real intangible stocks resulting from research and development designed to improve the quality or productive efficiency of the producers' goods and processes used in the various industries, and the real stocks of knowledge and know-how per employee in the various industries resulting from education and training. It would also be of value to estimate the real stocks per employee resulting from health and mobility outlays, by industry, since these also influence productive efficiency.

Unfortunately, intangible capital stock estimates have not been prepared on an industry basis, so proxy variables have to be used. Another problem is posed by the fact that the intangible investments and resulting capital

affecting productive efficiency in a given industry may have been financed in a different industry, or by government. For example, farmers have benefited greatly from research and development outlays by manufacturers of farm machinery, fertilizers, et cetera, as well as by public education, government and university research, extension services, and so on. This complicates the problem of estimating intangible capital *used* in an industry.

Next, attempts would have to be made to measure industry differences and changes in the variables that affect the rate of return on total capital, intangible and tangible, employed in the several industries. As mentioned in Chapter 4, chief among these are differences and changes in the degree of economic efficiency in the allocation of resources among and within industries. If economic efficiency cannot be measured directly, measures can be assembled relating to institutional forms and practices affecting the degree of competition, changing competitiveness, and other elements of efficiency among industries.

The scale factor, as it interacts with changes in productivity, can readily be quantified in terms of differences in levels or rates of change in output or capacity, by industry. The problem here is that scale is not only a causal factor but also a result of productivity advance, as explained earlier in this chapter.

Also of possible significance over cyclical and intermediate time periods are differences in levels, and changes in rates, of capacity utilization. In the period 1948-66, for example, the various industries had different average capacity-utilization rates for the period as a whole, as well as in the first and last years, which may well have influenced the estimated rates of productivity advance, particularly when the compound-interest formula is used to compute the rates of change.

Finally, it would be relevant to attempt to measure possible changes in the average inherent quality of human resources, and of natural resources, especially in extractive industries, used in production. With regard to the former, the content of the labor input unit, the man-hour, may have been influenced by changes in average hours worked per year, as argued by Denison; so this variable might well be included in the regression analysis in lieu of a direct average man-hour quality measure. Similarly, measures of the changing composition of resource stocks and inputs may be associated with changes in average quality.

Even if one had valid estimates for all the variables set forth above, or for those specified in any other theoretical schema, there would inevitably be various qualifications attaching to the empirical results of a multivariate

analysis. In the first place, the theoretical framework itself may be deficient, and fail to specify all the significant variables, or the correct form of particular variables with respect to lags, et cetera. Secondly, available econometric techniques may be inadequate to deal with certain difficult problems, particularly collinearity reflecting complex interactions among the independent variables. Finally, alternative models may produce equally good results.

Furthermore, as a practical matter, it may not be possible to compile or prepare direct estimates for all the variables specified in the model. Some of these may be approximated by proxy variables, with varying degrees of accuracy. Even the direct estimates will generally be subject to varying (and often unknown) margins of error.

For all these reasons, the results of multivariate analysis must be interpreted with caution. It is chiefly as a spur to further theoretical and statistical work that we present in the final section the results of some statistical analyses of the rates of productivity change 1948-66 in the twenty-one manufacturing industry groups.

An Experiment with Regression Analysis

The points of departure for the regression experiments described in this concluding section are the theoretical framework discussed above, as well as an earlier cross-sectional regression analysis by Nestor Terleckyj, reported in *Productivity Trends.* Using our earlier estimates of rates of change in factor productivity in twenty manufacturing industry groups for the period 1919-53, Terleckyj regressed a variety of independent variables, and found two to be significantly correlated with the industry rates of productivity change: ratios of research and development outlays to sales, and the cyclical variability of output.[9] In addition to these variables, we use eight others suggested by our theoretical analysis. As will be seen in the following discussion, it was seldom possible to obtain direct estimates of the "ideal" variables, and more or less reasonable proxies were used.

The independent variables will be discussed in the order they are shown in the column headings of Table 6-10, which presents the values of the variables. Following the first column, showing rates of change in total factor productivity, we enter the rates of change in output and in real tangible capital stock (columns 2 and 3). These variables are intended to represent the

[9] The findings, and limitations, of Terleckyj's study are pointed out in *Productivity Trends*, pp. 177-88.

scale factor. As mentioned earlier, the problem with using rates of change of output is that it is the result as well as a cause of productivity advance. Because of this interaction, we ran the multiple regressions both including and excluding it. The use of the rate of change in the capital variable was likewise an attempt to get away from the output-productivity interaction by using the volume of fixed capital as a measure of scale.

Variability in rates of change of output is one of the variables found to be significant by Terleckyj, except that we measure it by the average deviation of annual percentage changes in output from the mean per cent change (column 4). This variable would be closely related to the average rate of utilization of capacity, mentioned in the theoretical discussion. We do not have measures of the changes in percentage utilization of capacity, by industry, between 1948 and 1966, which, if marked, could also influence the rates of productivity advance.

Although we did not have estimates of the real stock of educational capital embodied in tangible labor by industry, we were able to obtain estimates of the average number of years of education per employee (column 5) from the 1960 Census 1/1,000 sample. Likewise, although industry estimates of the real stock of knowledge resulting from research and development were not available, industry estimates of ratios of R&D outlays to sales were available for the base period, 1958 (column 6). For neither of these variables were data available to permit calculation of rates of change between 1948 and 1966.

Estimates relating directly to the inherent quality of human resources and inputs are not available. But we do include the variable "average hours worked per year" (column 7), calculated from the Census 1/1,000 sample, which may be relevant to the energy content of each hour worked, as discussed above.

The last three variables are relevant to possible changes in economic efficiency, as well as to the rate of introducing innovations into firms and plants in the various industries. Concentration ratios in the base period (1958) and changes in concentration over the period 1947-66 are computed from Census Bureau data, as detailed in the notes to Table 6-11. The table shows that the average concentration ratio in manufacturing as a whole did not change significantly over the nineteen-year period, so changes in the ratio could hardly have influenced changes in productivity for the segment as a whole. But given the widely different levels of the concentration ratios within the two-digit manufacturing industries, and the frequently significant changes in the degree of concentration within these industries over the period, the

TABLE 6-10

Rates of Change in Total Factor Productivity, 1948-66, and Associated Variables, Twenty-one U.S. Manufacturing Industry Groups

Manufacturing Industry Groups	Rates of Change 1948-66[a]			Variability of Output Changes[b]	Average Education per Employee, 1959[c]	Ratio of Research and Development to Sales, 1958	Average Hours Worked, 1959[d]	Concentration Ratios, 1958[e]	Rate of Change in Concentration, 1947-66[f]	Unionization Ratio, 1958[g]
	Total Factor Productivity (1)	Output (2)	Real Tangible Capital Stocks (3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Foods	3.0	3.1	1.3	0.5	9.6	0.31	2025	30.36	0.34	48.0[g]
Beverages	2.2	2.7	1.7	1.5	9.9	0.25	1989	32.04	0.98	38.0[g]
Tobacco	1.1	1.9	2.0	0.8	8.4	0.09	1789	73.94	-0.60	55.0
Textiles	4.0	2.8	0.1	1.9	8.7	0.52	1885	26.37	1.45	27.0
Apparel	1.9	3.1	4.0	1.0	8.8	0.06	1669	12.95	1.66	52.0
Lumber products	3.5	2.3	2.0	1.3	8.1	0.32	1756	20.63	1.72	37.0
Furniture	2.9	4.3	1.6	0.9	8.9	0.55	1939	15.75	-0.64	40.0
Paper	2.5	5.0	4.0	0.8	10.0	0.70	2000	39.23	-0.30	60.0
Printing, publishing	2.7	4.1	2.3	0.8	11.0	0.24	1624	21.41	-0.72	40.0

Chemicals	4.9	8.2	5.4	1.1	11.5	3.80	1986	45.51	−0.66	41.0
Petroleum refining	3.0	4.1	3.1	0.7	11.6	1.10	2024	31.87	−0.73	60.0
Rubber products	3.9	7.2	3.9	1.7	10.3	1.80	1925	68.29	−1.00	60.0
Leather products	1.7	1.2	0.2	0.8	8.8	0.50	1716	23.85	−0.62	44.0
Stone, clay, glass	2.4	3.9	4.1	0.4	9.6	1.40	1977	51.30	0.23	60.0
Primary metals	1.6	2.5	3.2	3.0	9.5	0.70	1784	46.16	0.16	71.0
Fabricated metals	1.9	3.9	4.2	2.4	10.1	1.70	1968	32.55	−1.25	53.0
Machinery except electric	2.6	4.8	2.9	3.2	10.5	3.60	2010	40.86	0.00	47.0
Electric machinery	3.7	8.0	6.5	3.0	11.0	10.50	1902	61.43	0.18	48.0
Transportation equipment and ordnance	3.2	6.7	5.2	5.8	10.5	4.20	1946	63.94	0.59	61.0
Instruments	2.9	7.0	7.7	1.2	11.1	7.50	1954	59.19	0.49	34.0
Miscellaneous	3.5	4.0	3.4	1.5	9.8	2.90	1889	26.95	0.61	40.0

Source: Tables 6-1, 6-11, A-37–A-57; 1/1000 sample of 1960 Census tabulated by NBER; the National Science Foundation's *Funds for Development in Industry 1959,* Table XIII; and H. G. Lewis, *Unions and Relative Wages in the United States,* 1963, Table 79.

[a] Average annual percentage rates of change computed by compound interest method.

[b] Average deviation from mean value of output.

[c] Average number of years of education per employee.

[d] Average hours worked per employee per year.

[e] Percentage of concentration by largest four companies in four-digit industries weighted by value of shipments.

[f] Average annual percentage rates of change in concentration ratio computed by compound interest method.

[g] Percentage of unionization weighted by value of shipments.

cross-sectional analysis provides a means of testing the effect of concentration on innovation. The direction of the effect is controversial in the literature. Some economists claim that a high degree of competition spurs innovation and productivity advance; others follow the lead of Schumpeter in arguing that a small number of large firms in an industry are in a better position to engage in the research, development, and engineering activities that result in innovation. Terleckyj found no significant influence of the degree of concentration on interindustry rates of productivity advance. But since we have a somewhat different collection of independent variables, and for a more recent period, we have included the concentration variables.

Finally, we include estimates of the percentage of employees belonging to unions in the base period, 1958, a variable not included by Terleckyj. As in the case of concentration, there appears to have been little trend in the unionization ratio for all manufacturing over the period.[10] We did not have the data for estimating changes in unionization ratios by industry, but the differences in ratios in 1958 are considerable and make it possible to test for a possible effect of these differences in rates of productivity advance.

Here, again, views differ on possible effects of unionization. The work rules of some unions may affect productivity levels. But, unless the relative incidence of these practices changes significantly, they would presumably not affect rates of productivity change. But to the extent that unions are able to affect rates of innovation in the plants of an industry out of their understandable concern about immediate employment impacts, they obviously could have an effect on rates of productivity advance. Unions may also take actions which promote productivity advance. To the extent that wage rates may rise faster in more heavily unionized industries, for example, this could spur a higher rate of substitution of capital for labor and thus a faster growth of labor productivity, if not of total factor productivity. Only quantitative analysis can indicate what has been the *net* effect of unionization on productivity.

We have had to confine our regression analyses to the twenty-one manufacturing industry groups shown in Table 6-10, since some of the variables are not available for the nonmanufacturing groups. As the first step in the analysis, we ran simple correlations between the average annual percentage rates of change in total factor productivity, as the dependent variable, against

[10] See H. G. Lewis, *Unionism and Relative Wages in the United States*, Chicago, The University of Chicago Press, 1963, Table 72, p. 244. Lewis estimates that union membership as a percentage of persons engaged in the U.S. civilian economy was 25.6 in both 1947 and 1960.

TABLE 6-11

Concentration Ratios in Manufacturing, by Industry Group,[a] 1947, 1958, and 1966[b]

	Weights (1958)[c]		Percentage Concentration		
	(A) Value of Shipments (In Millions of Dollars)	(B) Value Added (In Millions) of Dollars)	1947	1958	1966
'oods	23,615	14,696	28.94	30.36	30.86
ieverages	5,024	2,836	30.76	32.04	36.99
'obacco	3,722	1,413	83.45	73.94	74.45
'extiles	6,812	4,858	23.57	26.37	30.90
ıpparel	7,983	6,004	13.57	12.95	18.55
ıumber products	1,431	3,177	15.42	20.63	21.26
'urniture	2,355	2,349	18.93	15.75	16.78
'aper	375	5,707	43.57	39.23	41.12
'rinting, publishing	7,756	7,923	23.64	21.41	20.63
'hemicals	12,658	12,270	47.40	45.51	41.89
'etroleum refining	15,110	2,518	36.91	31.87	32.17
tubber products	257	3,277	81.44	68.29	67.43
,eather products	3,401	1,897	26.52	23.85	23.57
tone, clay, glass	5,256	5,529	49.42	51.30	51.58
'rimary metals	9,463	11,671	42.73	46.16	44.02
'abricated metals	7,340	9,412	36.41	32.55	28.79
lachinery except electric	4,040	12,391	40.29	40.86	40.07
'lectric machinery	6,351	10,395	60.75	61.43	62.91
'ransportation equipment and ordnance	13,518	15,284	58.38	63.94	65.34
nstruments	1,790	2,906	55.40	59.19	60.82
liscellaneous	3,814	4,754	27.13	26.95	30.50
'otal manufacturing (A) weights	142,071		38.18	38.10	38.56
'otal manufacturing (B) weights		141,267	40.88	41.07	41.28

Source: Computed from *Annual Survey of Manufactures–1966: Value of Shipment Concentration Ratios by Industry*, U.S. Department of Commerce, Bureau of the Census. The (B) weights, value added, come from *1958 Census of Manufactures*, Volume II, U.S. Department of Commerce, Bureau of the Census.

[a] Average percentages of shipments in each of the selected groups originating in the largest four firms of the component four-digit industries.

[b] 1954 ratios were used for 1947 in twenty-one cases, and 1963 ratios were used for 1966 in twenty cases out of 225 industries in the total for all of the three years.

[c] The (A) weights represent the value of shipments of the sample of industries in each group. The (B) weights represent total value added in each of the groups as a whole.

each of the nine independent variables. The results are summarized in the matrix of coefficients of correlation in Table 6-12.

Some of the simple correlation results are of considerable interest. The only independent variable showing a significant direct degree of correlation with rates of productivity change is the rate of change in output. To the extent that there are errors in the output variable, the correlation may be spurious in part, since output is the numerator of the productivity ratio. As also noted earlier, the correlation reflects an interaction, the relative output changes being a result (through associated relative price changes) as well as a cause of the relative productivity changes.

It should also be noted that the output changes are rather highly correlated with rates of change in real capital stocks (the other scale variable), average education, the research and development ratios, and, to a lesser degree, with concentration ratios. The same intercorrelations exist for capital changes.

Because of collinearity, and the reciprocal aspect of the relationship, we ran the multiple correlations described below both with and without the output-change variables.

With regard to the other variables, average education per employee shows a significant degree of correlation, at the 0.05 level, with average hours worked and, at the 0.01 level, with the rates of change in output and capital as well as with the R&D ratio. The latter is not only significantly correlated with all the independent variables mentioned previously but also with the concentration ratio (at the 0.05 level). Average hours worked per year is significantly correlated only with average education, as cited above, while the concentration ratio is correlated, also at the 0.05 level, with the three variables already cited. No significant correlation with any of the other variables is shown for variability of output change, rate of change in concentration, and unionization ratio.

The multicollinearity among the several independent variables makes it difficult to arrive at meaningful multiple regression equations. When the rate of change of output is included in the correlations, its influence tends to suppress that of other variables to which it is related, such as R&D, or to give them the "wrong" sign. Nevertheless, the final outcome of a stepwise trial using all the independent variables is of interest:[11]

[11] We progressively eliminated variables with the lowest t values, until we were left with variables whose t values were significant at the 0.05 level.

TABLE 6-12

Twenty-one U.S. Manufacturing Industry Groups: Matrix of Simple Correlation Coefficients, Rates of Change in Total Factor Productivity, 1948-66, Versus Nine Independent Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Rate of change in productivity	1.000	0.649[a]	0.248	0.106	0.397	0.397	0.327	0.044	0.112	−0.387
2. Rate of change in output	0.649[a]	1.000	0.801[a]	0.341	0.745[a]	0.762[a]	0.430	0.513[b]	−0.237	0.050
3. Rate of change in real capital	0.248	0.801[a]	1.000	0.311	0.633[a]	0.777[a]	0.270	0.541[b]	−0.075	0.229
4. Variability of output changes	0.106	0.341	0.311	1.000	0.201	0.431	0.125	0.372	0.133	0.249
5. Average education per employee	0.397	0.745[a]	0.633[a]	0.201	1.000	0.571[a]	0.437[b]	0.315	−0.413	0.124
6. Ratio of R&D to sales	0.397	0.762[a]	0.777[a]	0.431	0.571[a]	1.000	0.282	0.510[b]	−0.004	−0.100
7. Average hours worked	0.327	0.430	0.270	0.125	0.437[b]	0.282	1.000	0.292	−0.188	0.103
8. Concentration ratio	0.044	0.513[b]	0.541[b]	0.372	0.315	0.510[b]	0.292	1.000	−0.264	0.425
9. Rate of change in concentration	0.112	−0.237	−0.075	0.133	−0.413	−0.004	−0.188	−0.264	1.000	−0.350
10. Unionization ratio	−0.387	0.050	0.229	0.249	0.124	−0.100	0.103	0.425	−0.350	1.000

Source: Table 6-10.

[a] Significant at .01 level.

[b] Significant at .05 level.

$$\dot{P}iy = 3.179 + 0.305\,\dot{O} - 0.035\,U$$
$$(4.475) \quad (2.810)$$

where $\dot{P}iy$ is the average annual percentage change 1948-66 in total factor productivity; $\dot{O}$ is the average annual percentage rate of change in output over the same period; and U is the percentage of employees of the industries belonging to labor unions in our base period, 1958.

The coefficient of multiple correlation of 0.773 is significant at the 0.01 level. The t value for the rate of change in output is likewise significant at the 0.01 level, while that for the degree of unionization is significant at the 0.05 level (just under the 0.01 value). It must be remembered that, in part, the rate of output change also stands for the R&D ratio and average education per employee, with which it is highly correlated. It should also be borne in mind, in interpreting the regression results, that output change is correlated with the concentration ratio. In the first step of the analysis, concentration did appear with a negative sign, indicating that the less the degree of concentration (as with unionization), the higher the rate of growth of productivity. But the t value for the concentration ratio was only 0.706, and it dropped out in later steps.

When the rate of change in output is dropped from the multiple regressions, for reasons adduced above, the coefficients of multiple correlation are lower, but the equations are interesting. The final result of the stepwise procedure is as follows:

$$\dot{P}iy = 0.568 + 0.407\,Ed - 0.037\,U.$$
$$(2.364) \quad (2.319)$$

The variables are as before, except that average education of employees replaces output change as the significant independent variable in addition to the degree of unionization, which continues to show a negative relationship to the rate of productivity advance. The coefficient of multiple correlation is 0.593, significant at the 0.05 level.

At an earlier stage in the analysis, the R&D ratio and average hours worked (H) also showed up in the multiple regressions with positive signs:

$$\dot{P}iy = -1.084 + 0.254\,Ed + 0.046\,R\&D + 0.002\,H - 0.037\,U.$$
$$(1.102) \quad (0.554) \quad (0.976) \quad (2.156)$$

But the t values for these variables (except for unionization) are not significant at the 0.05 level. However, the coefficient of multiple regression of 0.633 is significant at that level.

The results of the multivariate analyses must be interpreted in the light of

our earlier theoretical discussion. The positive influence of the scale factor as measured by rates of output change is to be expected; but the numerical result is ambiguous because of the reciprocal reaction of productivity change on output change. The positive influence of average education per employee (and the related R&D ratios) is in accord with growth theory. It would have been desirable to include rates of change in average education and R&D ratios, but the data did not permit it. The negative influence of the degree of unionization tells us that apparently the influence of unions with regard to the rate of innovation and changes in economic efficiency has outweighed possible positive union influences mentioned earlier. Even this result is not unambiguous, of course, in view of the possible correlations between unionization ratios and other parameters.

In conclusion, we emphasize again that the results of our cross-sectional analyses are intended to be suggestive, not definitive. It is hoped that eventually more satisfactory estimates can be prepared of the variables included in the theoretical construct for the full range of industry groups. In particular, it would be desirable to compile time series of the several relevant types of real intangible capital stocks on an industry basis, as well as additional estimates relating to institutional forms and practices that affect economic and technological efficiency.

Other analysts, of course, will use somewhat different theoretical approaches than the one we have employed, and will therefore have a somewhat different set of independent variables for empirical implementation. But regardless of the precise theoretical model, the cross-sectional analysis of productivity change will be an important supplement to macroeconomic analysis in the continuing effort to explain the causes of productivity advance. It is hoped that the estimates presented in this volume will make a useful contribution to these studies.