CHAPTER 6

Patterns of Productivity Change by Industry Groupings

THE economy productivity measures are, in effect, weighted averages of productivity indexes for the component industries. Just as it was necessary to look at the aggregates for the macroeconomic analysis contained in Part II, so it is informative to disaggregate and look at the diverse productivity movements in the various industries. Not only do the industry productivity indexes reveal the sources of national productivity advance by industry of origin, but relative changes in productivity by industry can be related to relative changes in other variables in order to increase our understanding of causal factors and of the impact of productivity changes on the economic structure (treated in Chapter 7).

This chapter is primarily a summary description of productivity movements in the various industrial groupings of the private domestic economy between 1899 and 1953 and in the six component subperiods. Estimates of total factor productivity and the partial productivity ratios are available for five major segments of the economy and for thirty-three industrial groups within the five segments. Output per manhour measures are also available for three other major segments, for many Standard Industrial Classification 4-digit industries within the twenty manufacturing groups, for twelve groups within the farm segment, and for additional transportation industries.

As the analyst leaves the measures of productivity for the total economy and examines those for the industrial groupings, he is struck first by the considerable diversity of productivity movement. The industry rates of productivity change, while tending to cluster about their mean, show a considerable range of dispersion. The dispersion is markedly greater in the subperiods than it is over the long period, 1899–1953, and it is somewhat greater for the two partial productivity ratios than it is for total factor productivity. As would be expected, dispersion becomes greater the finer the industry detail that is subjected to analysis.

Consistent with these observations, variations in movements of the productivity ratios over the subperiods are greater for the industry groupings than for the economy as a whole; and variability tends to increase the more detailed the industrial classifications. The total factor productivity measures, however, tend to show less variability than the

partial productivity ratios. This indicates a positive correlation between relative changes in output per unit of labor input and in capital per unit of labor input.

Yet, despite the diversity of industry productivity movements, one is impressed by the strength and breadth of the underlying forces promoting productivity advance. Over the long period, no segment or group and very few individual industries experienced productivity declines. Even in the subperiods, productivity gains predominated heavily. Nevertheless, the difference in rates of productivity change is an intriguing topic for further investigation. Although we do not attempt a full-scale statistical explanation of industry differentials, in the concluding section of the chapter we speculate about some possible causal forces with reference to exploratory statistical studies.

Total Factor Productivity

SECULAR RATES OF CHANGE

Rates of change in total factor productivity are contained in Table 34. Over the long period, 1899–1953, the average annual rates of increase in the major segments range from 1.1 per cent in farming (on a net output basis) to 3.6 per cent in communications and public utilities. Mining and manufacturing each show about a 2 per cent yearly rate of advance, as does the covered sector as a whole, while transportation registers about 3 per cent (see Chart 12). Analysis of the interrelationships between relative changes in productivity and associated variables is deferred until the concluding section, but it may be helpful to mention here that there is a significant positive correlation between productivity and output changes. The ranking of the segments with respect to productivity change roughly corresponds to their ranking with respect to the growth of output.

Direct estimates of outputs and total factor inputs are available only for these five segments and their components; these accounted for 54 per cent of private domestic income in 1953. Since productivity estimates are available for the total private domestic economy, however, implicit estimates for the uncovered sector may be derived. Over the fifty-four-year period, total factor productivity grew at an average annual rate of 2.1 per cent in the covered sector compared with 1.7 per cent in the private domestic economy. This implies a 1.3 per cent rate of growth in the uncovered sector, which consists mainly of trade, finance, services, and construction. The estimate is necessarily crude, for reasons given in Appendix A; but the lower rate of growth in the residual area is consistent with direct estimates of real product per manhour for the component segments.

CHART 12

Private Domestic Economy: Total Factor Productivity, by Segment, Key Years, 1889–1953 (1929=100)

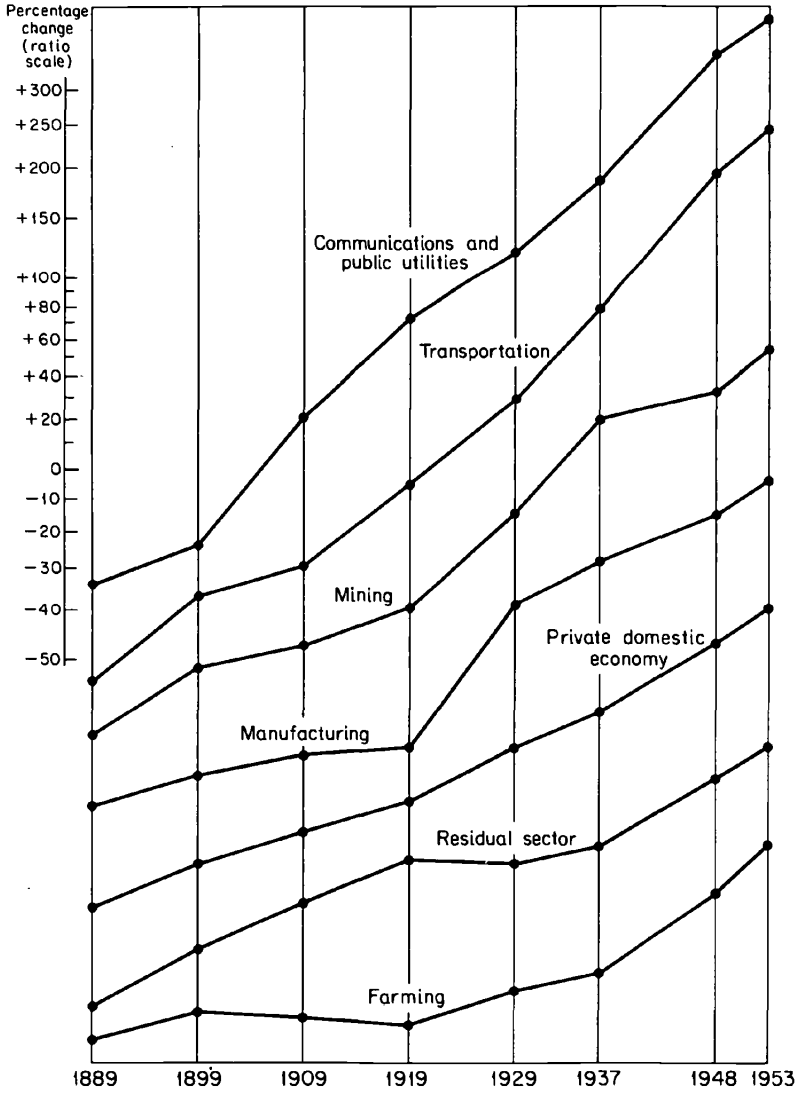


TABLE 34

Private Domestic Economy: Average Annual Rates of Change in Total Factor Productivity, by Segment and by Group, with Measures of Dispersion, Subperiods, 1899–1953
(per cent)

	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Farming	0.9	−0.2	−0.3	1.2	0.8	2.7	3.7	1.1	1.1
Mining	1.4	0.8	1.4	3.5	4.3	1.0	2.9	2.2	1.3
Metals		1.1	2.2	3.8	4.3	2.3	−2.6	2.2	1.3
Anthracite coal		−0.4	0.5	0.0	4.3	0.6	−0.3	0.7	1.0
Bituminous coal		1.2	1.8	2.4	1.0	0.3	3.9	1.6	0.8
Oil and gas		1.3	0.9	5.5	8.1	0.5	3.8	3.0	2.5
Nonmetals		1.6	0.4	5.9	0.7	4.4	1.2	2.6	2.0
Manufacturing	1.4	0.7	0.3	5.3	1.9	1.6	2.5	2.0	1.3
Foods		0.3	−0.4	5.3	1.5	1.5	2.2	1.7	1.5
Beverages		0.9	−5.6	−0.2	15.2	1.7	0.9	1.6	4.0
Tobacco		1.2	4.9	4.4	6.3	2.8	0.7	3.5	1.7
Textiles		1.1	0.9	2.9	4.6	2.5	2.6	2.4	1.0
Apparel		0.7	2.7	4.0	2.5	−0.7	1.3	1.7	1.4
Lumber products		−0.4	−1.2	2.5	0.4	2.2	3.8	1.0	1.5
Furniture		−0.8	−0.5	4.2	0.5	3.2	1.7	1.4	1.8
Paper		2.4	0.3	4.7	4.3	1.0	1.6	2.3	1.5
Printing, publishing		3.9	3.0	3.7	2.6	0.6	1.5	2.6	1.0
Chemicals		0.7	−0.7	7.4	3.0	3.7	4.1	2.9	2.2
Petroleum, coal products		0.7	−1.0	8.6	2.7	1.0	3.0	2.4	2.5
Rubber products		2.3	7.4	7.7	4.0	0.7	2.1	4.1	2.5
Leather products		0.1	0.5	2.9	3.6	0.4	0.0	1.2	1.3
Stone, clay, glass		2.2	0.7	5.7	2.3	2.0	2.4	2.6	1.2
Primary metals		2.7	−0.5	5.5	−1.3	3.2	0.5	1.9	2.1
Fabricated metals		2.3	1.8	4.6	1.0	1.6	5.1	2.6	1.2
Machinery, nonelectric		1.0	0.7	2.9	2.3	1.2	2.6	1.7	0.8
Electric machinery		0.6	0.3	3.5	3.2	2.1	5.0	2.2	1.3
Transportation equipment		1.1	7.0	8.4	−0.4	0.9	3.7	3.5	3.1
Miscellaneous		0.8	−0.6	4.6	2.9	2.0	3.0	2.0	1.4
Transportation	3.3	0.9	3.2	3.1	4.1	4.7	3.3	3.2	0.9
Railroads		1.8	3.4	1.9	1.7	3.6	2.7	2.6	0.8
Local transit		1.1	2.7	4.1	2.5	5.2	−4.3	2.5	1.8
Residual transport		−1.2	1.5	7.4	8.8	3.9	5.5	4.0	2.9

(continued)

TABLE 34 (concluded)

	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Communications and public utilities	1.2	4.6	3.7	2.5	3.3	4.3	2.7	3.6	0.7
Telephone		4.8	1.9	1.6	2.4	0.9	0.5	2.0	1.1
Telegraph		1.5	−1.2	4.3	2.1	2.1	2.4	1.8	1.2
Electric utilities		5.2	8.2	2.5	5.0	6.6	5.0	5.5	1.4
Manufactured gas		4.1	5.0	3.2	1.6	6.7	8.8	4.7	1.7
Natural gas		0.0	1.1	0.2	3.7	5.5	1.6	2.0	1.9
Residual sector	0.8	1.7	1.5	−0.1	0.8	2.2	2.3	1.3	0.7
Private domestic economy	1.2	1.2	1.1	2.0	1.6	2.3	2.7	1.7	0.5
Aggregate of 5 covered segments	1.6	0.7	0.8	3.7	2.3	2.4	2.9	2.1	1.0
Mean deviation from sector rates:									
5 segments	0.5	0.5	1.1	1.6	0.9	1.0	0.4	0.5	
33 groups		1.0	1.6	1.8	1.3	1.0	1.1	0.6	

Turning to the thirty-three industry groups for which total factor productivity estimates are available, we find a greater dispersion of trends. Over the long period, the average annual rates of productivity advance range from 0.7 per cent in anthracite coal mining to 5.5 per cent in electric utilities.

Within each of the four segments from which the group detail presented in Table 34 is drawn, the degree of dispersion is also pronounced (see Table 46 for statistical measures of dispersion). Within mining, average annual rates of advance range from less than 1 per cent for anthracite coal to 3 per cent for crude petroleum and natural gas. In manufacturing, the range is from 1 per cent for lumber products to 4 per cent for rubber products. Within transportation, both railroads and local-transit lines average a gain of about 2.5 per cent a year; but residual transportation, which includes motor transport, waterways, airlines, and pipe lines, averages 4 per cent a year. In the public utility segment, the range of the annual increase is from 1.8 per cent in the telegraph industry to 5.5 per cent for electric utilities.

A more graphic picture of the dispersion in the average annual rates of productivity change is given by the frequency distribution in Table 35

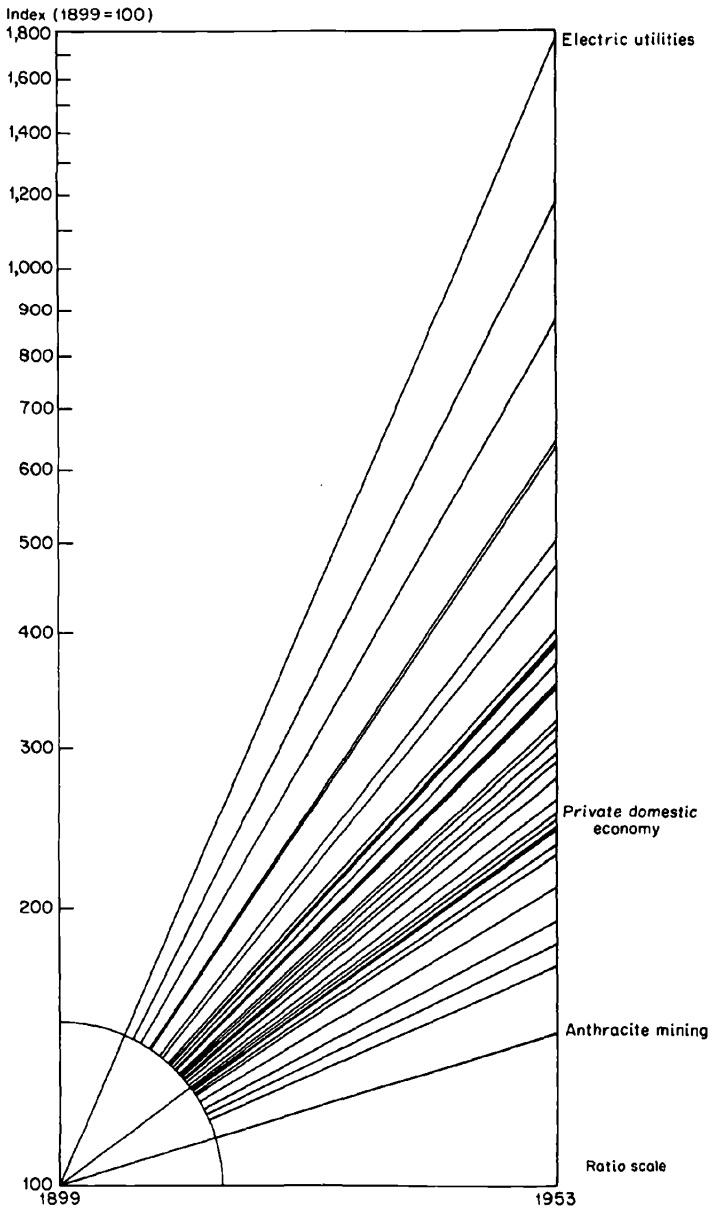
TABLE 35

Thirty-three Industry Groups: Frequency Distributions of Average Annual Rates of Change in Productivity Ratios, Subperiods, 1899–1953

Class Interval (per cent)	*Total Factor Productivity*							*Output per Unit of Labor Input*							*Output per Unit of Capital Input*						
	1899–1953	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953
Under −5.0			1							1						1					4
−5.0 to −4.0							1							1			1				1
−4.0 to −3.0																1					1
−3.0 to −2.0							1			1						7	5	1	3	1	2
−2.0 to −1.0			3		1					1						7	7	2	1		5
−1.0 to 0		5	6	2	1	1	1		3	5		3	1		4	5	5	3	2	2	3
.0 to 1.0	1	8	9	1	6	10	5	1	4	8	2	6	9	4	5	5	4	2	1	4	3
1.0 to 2.0	12	11	4	3	3	4	6	10	15	4	3	2	7	5	17	2	4	2	4	8	6
2.0 to 3.0	14	5	3	6	9	9	7	14	5	5	8	9	7	8	4		1	6	5	6	3
3.0 to 4.0	3	1	2	5	4	4	7	4	5	3	5	3	4	6	1	2	3	6	6	1	1
4.0 to 5.0	2	2	1	7	5	1	1	2			1	5	1	2	2	2	2	5	3	2	1
5.0 to 6.0	1	1	1	5	1	2	3	1		1	6	1	2	3		1		4	4	3	2
6.0 to 7.0					1	2		1		1	2	2	2	2				1	2	4	
7.0 to 8.0			2	2					1	2	2	1		1							1
8.0 to 9.0			1	2	1		1			1	3						1	1		2	
9.0 and over					1						1	1		1					2		

CHART 13

Thirty-three Industry Groups: Divergence of Total Factor Productivity, 1953 Relative to 1899



(first column) and Chart 13. The average annual rates are concentrated in the 1.0 to 3.0 per cent class intervals, but the distribution is somewhat skewed to the right. No group experienced secular declines in productivity, and six groups had gains that averaged more than 3 per cent a year over the long period.

PATTERNS OF PRODUCTIVITY MOVEMENT

Although we have been speaking of average annual rates of change, the course of productivity advance is not a smooth one. Between key years, rates of productivity change differ in each of the segments to a considerably greater extent than in the economy as a whole, and variability is even greater in the industry groups. Nevertheless, the major segment indexes show no actual declines in any of the subperiods except for a slight sag in farming prior to 1919. Among the groups, almost half show declines in one, or occasionally two, of the six subperiods.

As would be expected, annual changes in productivity exhibit still greater variability than average rates of change in the subperiods; and declines are more frequent on an annual basis, especially in periods of business recession. Due to the small number of total productivity series available on a yearly basis, annual fluctuations of all three productivity ratios are treated together in a later section of this chapter.

Each industry segment and group has had a unique pattern of productivity movement over the long period. The different group rates of change in the subperiods have tended to be offsetting in their effect on productivity change in the economy as a whole. The marked acceleration of productivity advance in the economy after 1919, for example, was not the result of acceleration in all groups at the same time, but rather a matter of "rolling acceleration" relative to pre-1919 rates of growth.

Thus, in terms of the segments shown in Chart 12, manufacturing and mining showed pronounced acceleration of productivity advance after 1919; but this lasted for only a decade in manufacturing and until 1937 in mining. Beginning around 1937, productivity advance accelerated in farming and in the residual service area, offsetting lower rates of advance elsewhere. Productivity gains in transportation were strong throughout the entire period after 1909, and especially so in the World War II subperiod. Persistently strong advance was already evident around 1899 in the communications and public utilities segment.

Productivity movements have not been graphed for the thirty-three groups, but to give a little more of the flavor of the industry patterns, we shall give a short summary of how they conform to or depart from the broader segment patterns. Variability in productivity changes over the subperiods was a little greater for the thirty-three industry groups, on the average, than for the five segments, as shown in Table 34. A few groups

showed even steadier rates of gain than the segments of which they are a part; examples include bituminous coal, nonelectric machinery, and the steam railroads. But, in general, group variability was somewhat higher and the greater stability in segment rates of advance was due to offsetting changes in rates of advance of the component groups.

In the mineral industries, the 1919–37 acceleration was widespread. Deceleration after 1937 was most marked in the metals group, which showed an absolute drop in total productivity in the 1948–53 subperiod. Only in bituminous coal was the rate of efficiency gain higher in the last subperiod than in any preceding. Yet it is too early to say that the tendency towards diminishing returns in the mineral industries is drawing ahead in the race with technological progress.

About half of the manufacturing groups followed the segment pattern of a slow rate of productivity advance between 1899 and 1919, marked acceleration in the 1920's, and a more moderate upward trend since 1929. In printing and publishing, however, a high rate of productivity advance was already evident in the first subperiod, 1899–1909; it continued through 1929, with some deceleration thereafter. Acceleration began in the 1909–19 subperiod for tobacco manufactures, apparel, rubber products, and transportation equipment. In the case of the latter two groups, this obviously reflected the dynamic early phase of the automobile era; productivity in both groups showed marked deceleration after 1929, although there was an improved rate of advance after 1948. The tobacco and apparel groups continued with higher-than-average productivity advance through 1937, but with deceleration thereafter. Some groups have shown their most rapid productivity growth since World War II, notably electric machinery, chemicals, and lumber products—influenced, no doubt, by high investment demand.

Within the transportation segment, which experienced a rather consistent upward trend, steam railroads showed accelerated average rates of productivity advance averaging around 3.5 per cent a year in each of the World War subperiods. Since 1948, the average annual rate of gain has been 2.7 per cent, close to the secular rate. The local transit group, consisting of electric railways and bus lines, showed almost as large a long-run rate of growth as steam railroads; but following acceleration during the World War II subperiod, there was an actual decline in both productivity and output after 1948. The residual transportation group has shown rapid productivity gains since World War I, as motor transportation, pipe lines, and finally airlines have become of increasing importance relative to waterways and the vanishing horse-drawn vehicle. Although rates of gain in this group are now below the 8 per cent annual average in the interwar period, the 5.5 per cent average rate between 1948 and 1953 keeps it one of the most technologically dynamic areas in the economy.

In the public utility segment, the smallest temporal variations in productivity advance relative to trend were in the electric utility group. Advances were consistently well above the economy average, although a very high rate of advance between 1909 and 1919 was succeeded by considerable deceleration in the following decade. Variations were also relatively small in the manufactured gas group, which showed advances in excess of the economy average in all subperiods after 1899. There was some deceleration in the 1929–37 subperiod, coincident with a drop in output. But in the 1948–53 subperiod, when output again declined, productivity showed its most rapid advance—averaging 8.8 per cent a year. The greatest relative variability in the segment was shown by the natural gas group. Production increased sharply after 1899, but productivity showed small gains prior to 1929. Large productivity increases between 1929 and 1948 were followed by more modest gains.

In the telephone industry, the largest productivity advances came in the early decades, and the smallest advances have been experienced since 1937—although this may be due partly to incomplete measurement of output (see Appendix H). Productivity advance in the telegraph industry has been steadily but moderately upwards since 1889, with the exception of a drop in the 1909–19 subperiod that was compensated for in the following decade.

MEASURES OF VARIABILITY AND DISPERSION

If one wishes to pin down the variability of subperiod rates of change in productivity, it is possible to measure the mean deviation of these rates from the long-term rate for each group or segment. These measures are shown in the last column of Table 34 and are summarized in Table 47. It can be seen that the mean deviation of subperiod rates so defined is 0.5 per cent for the private domestic economy as a whole and 1.0 for the five-segment aggregate, and averages 1.4 for the groups.

Variability in a few groups, as measured by the mean deviation of subperiod rates of change from the secular rate, was as high or higher than the secular rate itself. This was the case in anthracite coal mining, lumber products, products of petroleum and coal, primary metals, and beverages. In the case of beverages, however, variability was largely the result of the depressing effect of prohibition on productivity followed by the temporary stimulation of repeal. There is a tendency for the coefficients of variation to be inversely correlated with the secular mean rates of productivity change in the groups and segments.

That variability of productivity advance has not been uniform among the various groups, but has tended to be offsetting, suggests a larger dispersion of segment and group rates of change in the subperiods than over the period as a whole. In fact, as shown in Tables 34 and 46, the

mean deviation of segment and group productivity changes in the subperiods from their average are approximately twice as great as the mean deviations from secular rates of change. Mean deviations of group rates of change relative to rates of change for the segment to which the groups belong are also approximately twice as great in the subperiods, on the average, as for the long period. The greater dispersion of subperiod rates of change is roughly what one would expect from the law of averages.

A graphic picture of dispersion in the subperiods compared with the period as a whole can be seen in the frequency distributions in the first panel of Table 35. It is apparent that there are more extreme rates of change in the subperiods than over the long period. Subperiod rates range from negative values to values exceeding 8 per cent a year. There is much less concentration of rates of change in the 1.0 to 3.0 per cent class intervals than is the case with the secular rates of change.

The question naturally arises as to whether the degree of dispersion of group rates of change from their mean has tended to lessen over the subperiods. If so, this would be some indication of a more rapid rate of diffusion of innovations from one group to others, or of more similar rates of innovation arising within the several groups, or both. The answer seems clear-cut with respect to the mean deviations of the segments or groups as percentages of the rates of change in the covered sector, i.e., the coefficients of variation. For convenience, the coefficients of variation, based on the data underlying Table 34, are given in Table 36. By the last two subperiods, 1937–53, the coefficients had fallen sharply from their values for the first two subperiods, 1899–1919. The decline was relatively

TABLE 36

Trends in Relative Dispersion (Coefficient of Variation[a]) of Changes in Total Factor Productivity, Subperiods, 1899–1953
(per cent)

	Covered Sector		*Groups by Segment*			
	Segments	Groups	Manufacturing	Mining	Transportation	Communications and Public Utilities
1899–1909	0.66	1.39	1.26	0.34	1.05	0.38
1909–19	1.31	2.02	6.07	0.45	0.21	0.51
1919–29	0.42	0.48	0.28	0.42	0.60	0.50
1929–37	0.41	0.59	0.76	0.60	0.56	0.16
1937–48	0.42	0.42	0.56	0.89	0.06	0.38
1948–53	0.15	0.39	0.42	0.69	0.46	0.63

[a] Coefficients show mean deviations of segment and group rates of productivity change from sector rates of change as ratios to the latter.

TABLE 37

Thirty-three Industry Groups: Deviations of Ranks of Rates of Change in Productivity Ratios in Six Subperiods from Mean Ranks, by Group, 1899–1953

	Total Factor Productivity			*Output per Unit of Labor Input*			*Output per Unit of Capital Input*		
	Mean Rank	Mean Deviation	Mean Deviation as Per Cent of Mean	Mean Rank	Mean Deviation	Mean Deviation as Per Cent of Mean	Mean Rank	Mean Deviation	Mean Deviation as Per Cent of Mean
Farming	11.8	7.8	66	13.7	10.2	74	11.2	4.6	41
Mining									
Metals	17.7	6.3	36	17.2	6.1	35	19.0	7.7	41
Anthracite coal	8.7	7.6	87	7.5	7.0	93	13.3	8.0	60
Bituminous coal	14.2	8.8	62	12.7	7.9	62	10.5	4.3	41
Oil and gas	21.2	6.8	32	20.5	6.3	31	18.0	11.0	61
Nonmetals	18.0	9.0	50	18.8	6.5	35	18.2	6.2	34
Manufacturing									
Foods	13.2	4.9	37	12.7	4.7	37	16.7	5.8	35
Beverages	11.8	8.5	72	12.7	7.7	61	15.3	9.7	63
Tobacco	22.0	6.0	27	24.0	8.3	35	12.5	8.5	68
Textiles	20.0	4.0	20	18.7	4.7	25	19.0	6.7	35
Apparel	13.7	6.3	46	12.3	6.8	55	13.0	8.3	64
Lumber products	10.7	8.6	80	11.2	8.5	76	10.7	8.0	75
Furniture	11.8	7.5	64	10.5	7.3	70	14.3	6.0	42
Paper	19.2	7.5	39	18.3	6.3	34	16.3	1.6	10
Printing, publishing	18.0	7.3	41	16.8	8.1	48	20.3	6.7	33

(continued)

TABLE 37 (concluded)

Manufacturing (continued)									
Chemicals	20.3	8.9	44	21.2	8.2	39	20.2	4.8	24
Petroleum, coal products	16.5	8.2	50	23.0	8.0	35	15.0	9.3	62
Rubber products	22.7	7.8	34	22.2	7.1	32	21.3	6.7	31
Leather products	10.3	6.0	58	10.2	5.9	58	13.7	9.2	67
Stone, clay, glass	19.3	4.8	25	18.7	5.7	30	16.5	5.2	32
Primary metals	16.0	11.3	71	16.2	10.2	63	13.5	8.2	61
Fabricated metals	20.8	6.6	32	19.3	5.9	31	18.8	4.5	24
Machinery, nonelectric	14.3	2.4	17	14.3	2.7	19	15.0	6.0	40
Electric machinery	17.3	6.3	36	17.7	4.7	27	17.2	8.5	49
Transportation equipment	19.0	10.3	54	17.5	10.2	58	23.2	8.2	35
Miscellaneous	16.7	5.1	31	14.8	6.2	42	17.8	6.1	34
Transportation									
Railroads	19.3	7.2	37	19.0	6.7	35	16.8	11.2	45
Local transit	18.0	6.3	35	16.3	7.1	44	22.0	10.0	67
Communications and Public Utilities									
Telephone	14.8	8.8	59	14.5	9.0	62	15.8	11.2	71
Telegraph	15.2	5.4	36	14.8	4.3	29	22.0	7.3	33
Electric utilities	27.5	6.2	23	27.8	7.6	27	26.0	5.0	19
Manufactured gas	25.2	9.1	36	25.2	7.4	29	25.5	7.7	30
Natural gas	15.8	9.2	58	20.8	6.2	30	12.3	7.7	63
Average	17.0	7.2	42	17.0	7.0	41	17.0	7.3	43

small between the midperiod, 1919–37, and the last two subperiods. The tendency towards less dispersion has been marked in the manufacturing segment; but the reverse tendency has prevailed in mining, possibly due to a differential impact of the tendency towards diminishing returns. Perhaps improvement of data has had some influence.

The foregoing discussion implies that the relative positions, or ranks, of the various groups have fluctuated over the subperiods. Variations in rank were indeed marked, as shown in Table 37. The groups were first ranked with respect to rates of change in the subperiods, number 1 being the group with the smallest rate of advance, and number 33, with the largest. The averages of ranks in the subperiods are, of course, higher for the low industries and lower for the high industries than the ranks over the long period due to the fluctuations in rank. On the average, the mean deviations of the subperiod ranks from the average rank for the subperiods was 7.2, or about 42 per cent of the average rank for the subperiods.

Further analysis suggests that there has been a tendency for the groups with low average ranks to improve their position over the subperiods, while the high-ranking groups have tended to slip in the scale. Table 38

TABLE 38

Average Ranks of Quartiles and Halves of Thirty-three Industry Groups Classified with Respect to Secular Rates of Change in Total Factor Productivity, Subperiods, 1899–1953

Thirty-three Industry Groups	1899–1953	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953
First quartile	4.0	6.9	10.2	9.6	13.9	13.2	15.5
Second quartile	12.5	19.1	15.2	15.9	13.9	16.8	11.8
Third quartile	21.0	18.8	16.9	20.0	18.9	19.8	18.4
Fourth quartile	29.5	23.0	25.6	22.1	21.1	17.9	22.1
Lower half	8.5	13.0	12.8	12.8	13.9	15.0	13.6
Upper half	25.0	20.8	21.0	21.0	19.9	18.9	20.2

shows that the most striking trend was the improvement over the subperiods in the average rank of the first quartile, so designated with respect to average rank over all subperiods. The second quartile tended to drop in average rank, but not enough to prevent the groups in the lower half from rising in average rank. Both of the upper quartiles, and the higher half as a whole, showed some decline in average rank over the period. This tendency is to be expected between two periods, and has been called the "regression effect";[1] but when it persists it represents a real change. The

[1] Milton Friedman and Simon Kuznets, *Income from Independent Professional Practice*, New York (NBER), 1945, pp. 331–332n.

analysis of ranks was made of the groups excluding residual transportation. This group had one of the lowest ranks prior to 1919, but since then it has had one of the highest. If it had been included, the trends noted above would have been accentuated.

Changes in the Partial Productivity Ratios

STATISTICAL INTERRELATIONSHIPS AMONG THE PRODUCTIVITY RATIOS

Rates of change in output per unit of labor input have averaged around 13 per cent higher than the corresponding rates of change in total factor productivity in the industry groups of the private economy over the long period, and the ranks of the industry groups with respect to both ratios have been quite similar. These similarities are the outcome of two forces. In the first place, the relative weight accorded labor in the calculation of total factor input has averaged about three times the weight of capital over the period as a whole; so the movements of total productivity are much closer to the movements of output per unit of labor input than to the movements of the output-capital ratio in almost all industries. Secondly, capital has risen in relation to manhours in almost all industries; so output per manhour in most industry groups, and output per unit of labor input (weighted manhours) in all the segments and the private economy as a whole, have risen more than total factor productivity. The differences between the proportionate changes in the two ratios in the various industry groups and segments are largely a function of differences in proportionate changes in real capital input per unit of labor input in each. That is, the differences between the output-labor and total factor productivity ratios reflects the substitution of capital for labor, obtained directly as the quotient of total input and labor input, or as the proportionate change in capital per unit of labor input multiplied by the percentage weight of capital.

To illustrate the relationship, take the average annual percentage rates of change (plus 100.0) for the total private domestic economy, 1899–1953. The proportionate increase in output per unit of labor input (101.95) divided by that in total factor productivity (101.72) is 100.2. The 100.2 indicates the degree of substitution of capital for labor and is obviously the quotient of the proportionate increases in total factor input and labor input (101.57) and (101.34). Since total factor input is the weighted average of the two factor inputs, the substitution of capital for labor can also be obtained by weighting the proportionate rate of increase in capital per unit of labor input by the relative weight of capital ($0.8 \times 0.25 = 0.2$).

Output per unit of capital input in the various industry groups has risen by less than output per unit of labor input to the degree that capital has risen in relation to labor input. This can be illustrated with reference

to link relatives for the private domestic economy. The average proportionate increase in output per unit of capital input (101.16) is the quotient of the proportionate increases in output per unit of labor input (101.95) and in capital per unit of labor input (100.78). Since capital per unit of labor input is the strategic variable in explaining the relationships among the productivity ratios, we shall first review briefly the movement of this ratio for the covered segments and groups.

TABLE 39

Private Domestic Economy: Average Annual Rates of Change in Capital per Unit of Labor Input, by Segment and by Group, with Measures of Dispersion, Subperiods, 1899–1953
(per cent)

	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Farming	0.6	0.8	0.7	0.0	0.0	3.4	7.8	1.7	1.8
Mining	4.3	1.1	1.3	2.6	−2.3	0.6	5.1	1.2	1.3
Metals		1.5	0.4	2.6	−3.3	−0.6	8.7	1.0	2.2
Anthracite coal		−0.6	1.0	0.9	3.0	−3.8	8.9	0.7	2.4
Bituminous coal		3.6	3.7	−0.9	−1.2	−1.5	14.4	1.9	3.5
Oil and gas		4.1	4.3	1.6	−3.3	2.4	−4.3	1.4	2.4
Nonmetals		0.8	0.6	4.9	−1.0	−2.1	4.5	1.0	2.1
Manufacturing	3.5	2.8	2.8	1.3	−0.6	−0.7	2.2	1.2	1.3
Foods		1.5	2.6	0.3	−2.4	0.0	1.3	0.6	1.2
Beverages		0.9	−1.9	1.8	−1.8	−0.6	3.3	0.0	1.6
Tobacco		4.1	6.0	8.7	2.5	6.4	0.6	5.2	2.1
Textiles		1.8	4.3	−2.4	−0.9	−0.4	5.4	0.9	2.4
Apparel		2.5	6.2	0.0	−3.4	2.2	3.6	1.8	2.3
Lumber products		3.3	1.8	4.0	−4.0	0.9	3.1	1.5	1.9
Furniture		2.2	1.5	1.6	−2.2	−3.7	1.7	0.1	2.2
Paper		4.1	1.2	2.0	0.7	−1.0	2.7	1.5	1.4
Printing, publishing		0.7	1.5	0.1	0.3	−0.5	−0.6	0.3	0.6
Chemicals		2.2	1.5	2.1	0.0	0.5	4.8	1.6	1.0
Petroleum, coal products		4.8	4.5	0.5	4.4	−1.2	2.8	2.5	2.2
Rubber products		3.5	4.0	4.4	−2.8	0.3	1.0	1.9	2.2
Leather products		3.2	2.7	−2.1	−2.7	−0.5	3.0	0.5	2.3
Stone, clay, glass		5.2	2.1	3.1	−2.5	−2.7	4.2	1.3	2.8
Primary metals		6.0	0.6	1.0	1.5	−2.7	6.2	1.6	2.5
Fabricated metals		4.0	1.3	2.4	−2.0	−0.6	1.0	1.1	1.6
Machinery, nonelectric		3.6	−0.3	0.4	−1.3	0.6	1.6	0.8	1.2
Electric machinery		3.7	−1.5	2.3	−1.8	0.9	2.1	0.9	1.7
Transportation equipment		1.3	3.4	3.0	0.7	−1.5	−2.7	1.0	1.8
Miscellaneous		2.3	0.0	5.0	−2.9	0.1	0.4	1.0	2.0

(continued)

TABLE 39 (concluded)

	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Transportation	−1.4	−1.3	1.4	2.0	4.1	−2.5	3.9	0.8	2.1
Railroads		−3.1	0.9	2.9	5.2	−2.1	6.1	1.0	2.9
Local transit		0.7	−1.4	−1.9	1.5	−3.3	−0.3	−1.0	1.5
Residual transport		2.1	7.8	0.5	3.4	−2.2	4.1	2.3	2.7
Communications and public utilities	1.1	−1.0	−0.3	−0.2	4.5	−1.6	6.2	0.6	2.2
Telephone		−2.1	−4.0	0.9	6.8	−1.4	7.5	0.4	3.3
Telegraph		0.6	−4.0	−1.7	4.1	−4.0	2.2	−1.0	2.6
Electric utilities		4.0	0.3	−1.1	2.9	−0.3	5.1	1.4	2.1
Manfactured gas		−1.3	2.1	−1.0	2.8	−1.8	1.4	0.1	1.7
Natural gas		7.6	3.6	4.7	2.3	−2.3	3.9	3.1	2.5
Residual sector	−0.9	−0.3	0.5	0.0	1.9	−2.4	2.4	0.2	1.2
Private domestic economy	0.8	0.5	1.1	0.8	0.9	−0.5	3.3	0.8	0.6
Aggregate of 5 covered segments	2.2	1.3	1.7	1.4	0.5	0.6	4.1	1.3	0.6
Mean deviation from sector rates:									
5 segments	1.9	1.4	0.9	0.6	1.7	1.6	1.9	0.2	
33 groups		1.8	1.4	1.5	2.0	2.0	3.0	0.5	

CAPITAL PER UNIT OF LABOR INPUT

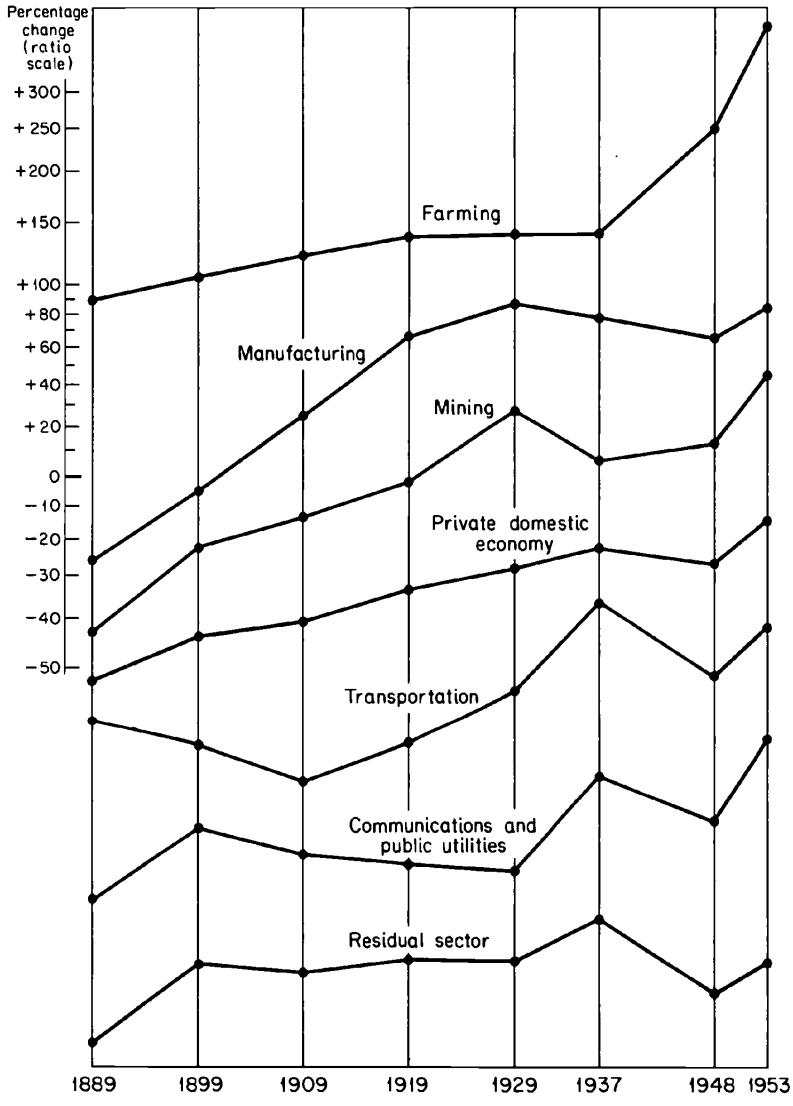
In the covered sector as a whole, capital per unit of labor input rose at an average rate of 1.3 per cent a year over the period 1899–1953. This rate compares with an average increase of 0.8 per cent a year in the total private domestic economy. The comparison implies that capital per unit of labor input in the uncovered sector rose at an annual rate of about 0.2 per cent—less than the increase in any of the covered segments.

Over the long period, there was relatively little dispersion of the segment rates of change from their weighted mean (see Table 39 and Chart 14). Mining and manufacturing each showed average increases of 1.2 per cent a year; the increase in farming was greater, while the increases in the transportation and the public utility segments were somewhat under 1 per cent a year.

The dispersion of group rates of change in capital per unit of labor input was considerably greater than the dispersion of segment rates, but was less than the dispersion of group rates of change in total factor productivity.

CHART 14

Private Domestic Economy: Capital per Unit of Labor Input, by Segment, Key Years, 1889–1953 (1929=100)



All but two of the thirty-three groups showed positive secular increases in capital per unit of labor input. Most of the group rates of increase clustered within the sector rate of increase of 1.3 per cent ±0.6.

Significantly larger rates of increase in capital relative to labor input were shown by tobacco manufactures, natural gas utilities, and products of petroleum and coal. Very small rates of increase in the capital-labor ratio were evident in beverages, furniture, and manufactured gas utilities. The local transit and the telegraph groups each showed average declines of 1.0 per cent a year.

As would be expected, the subperiod rates of change in capital per unit of labor input fluctuated considerably in each of the groups. It will be recalled that in the private economy as a whole the rate of increase was fairly steady over the subperiods up to 1937; the subperiod 1937–48 was marked by a drop in the capital-labor ratio, while the years 1948 to 1953 saw an accelerated rate of advance. The pattern differs somewhat by industry groups. Declines in the capital-labor ratio characterized railway transportation from 1870 to 1909, and some of the communications and public utility groups in selected subperiods from 1899 to 1929, due to a prior build-up of plant and equipment beyond near-term requirements for output and labor input.

In the subperiod 1929–37, capital per unit of labor input dropped in the mining and manufacturing segments and in most of the component groups, although this was more than offset by increases in other segments. Apparently, the shorter life of equipment in these areas compared with transportation and public utilities made possible a quicker adjustment of capital stock to the decline in labor requirements experienced in this subperiod.

Between 1937 and 1948 declines in the capital-labor ratio were quite widespread as a result of wartime restrictions on civilian industry capital investment. A notable exception was farming, in which substitution of capital for labor was required to meet essential food and fiber needs because of the wartime farm labor shortage. A significant increase in capital per manhour in oil and gas production was also a major exception to the general tendency. In the 1948–53 subperiod, a substantial increase in capital per unit of labor input was quite general, only four groups showing declines.

Consistent with the large variability in subperiod movements, the dispersion of segment and group rates of change from the sector rate was much larger in the subperiods than over the period as a whole (see Table 46).

OUTPUT PER UNIT OF LABOR INPUT

Estimates of output per unit of labor input are available not only for the five covered segments and thirty-three groups, but also for three additional segments, a dozen groupings within farming, and eighty or more individual

manufacturing industries. The behavior of labor productivity in the additional industries will be described, following a brief review of the covered area.

Covered segments and groups. There is no need to detail the movements of output per unit of labor input in the covered area, since they are quite similar to the patterns of change in total factor productivity, after allowing for the divergent movements of capital and labor inputs. Thus, with

TABLE 40

Private Domestic Economy: Average Annual Rates of Change in Output per Unit of Labor Input, by Segment and by Group, with Measures of Dispersion, Subperiods, 1899–1953
(per cent)

	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Farming	1.1	0.0	0.0	1.2	0.8	3.8	6.2	1.7	1.7
Mining	2.0	1.0	1.7	4.2	3.5	1.2	4.8	2.5	1.4
Metals		1.9	2.4	5.3	2.3	2.0	0.4	2.6	1.0
Anthracite coal		−0.4	0.5	0.0	4.3	0.1	0.5	0.7	1.1
Bituminous coal		1.2	2.0	2.4	0.9	0.0	5.7	1.7	1.1
Oil and gas		2.3	2.3	6.1	6.3	1.9	1.2	3.4	1.8
Nonmetals		1.9	0.6	7.8	0.4	3.5	2.9	2.9	2.0
Manufacturing	1.7	1.1	0.8	5.6	1.8	1.4	3.0	2.2	1.4
Foods		0.6	0.0	5.4	0.9	1.5	2.5	1.8	1.3
Beverages		1.3	−6.4	0.5	14.4	1.5	2.2	1.6	3.8
Tobacco		1.8	6.1	7.2	7.6	5.7	1.0	5.1	2.0
Textiles		1.4	1.7	2.4	4.4	2.3	3.9	2.5	0.8
Apparel		0.9	3.3	4.0	2.1	−0.5	1.7	1.9	1.4
Lumber products		−0.2	−1.0	3.0	−0.2	2.4	4.4	1.2	1.7
Furniture		−0.7	−0.4	4.3	0.3	2.6	1.9	1.3	1.7
Paper		3.0	0.5	5.1	4.5	0.7	2.5	2.6	1.6
Printing, publishing		4.0	3.3	3.7	2.7	0.5	1.4	2.7	1.1
Chemicals		1.3	−0.3	8.2	3.1	3.9	6.0	3.5	2.4
Petroleum, coal products		3.1	1.8	9.0	5.6	0.2	4.7	3.8	2.6
Rubber products		2.5	7.8	8.4	3.5	0.8	2.3	4.3	2.8
Leather products		0.5	0.9	2.5	3.2	0.3	0.5	1.3	1.0
Stone, clay, glass		2.8	1.0	6.3	1.7	1.3	3.3	2.7	1.5
Primary metals		3.8	−0.4	5.8	−0.9	2.5	2.1	2.3	2.0
Fabricated metals		2.9	2.0	5.1	0.5	1.6	5.2	2.7	1.4
Machinery, nonelectric		1.8	0.7	3.0	1.9	1.3	2.9	1.8	0.6
Electric machinery		1.3	0.0	4.0	2.9	2.3	5.5	2.4	1.3
Transportation equipment		1.3	7.7	9.1	−0.2	0.6	3.1	3.7	3.5
Miscellaneous		1.1	−0.6	5.5	2.2	2.0	3.1	2.1	1.4

(continued)

TABLE 40 (concluded)

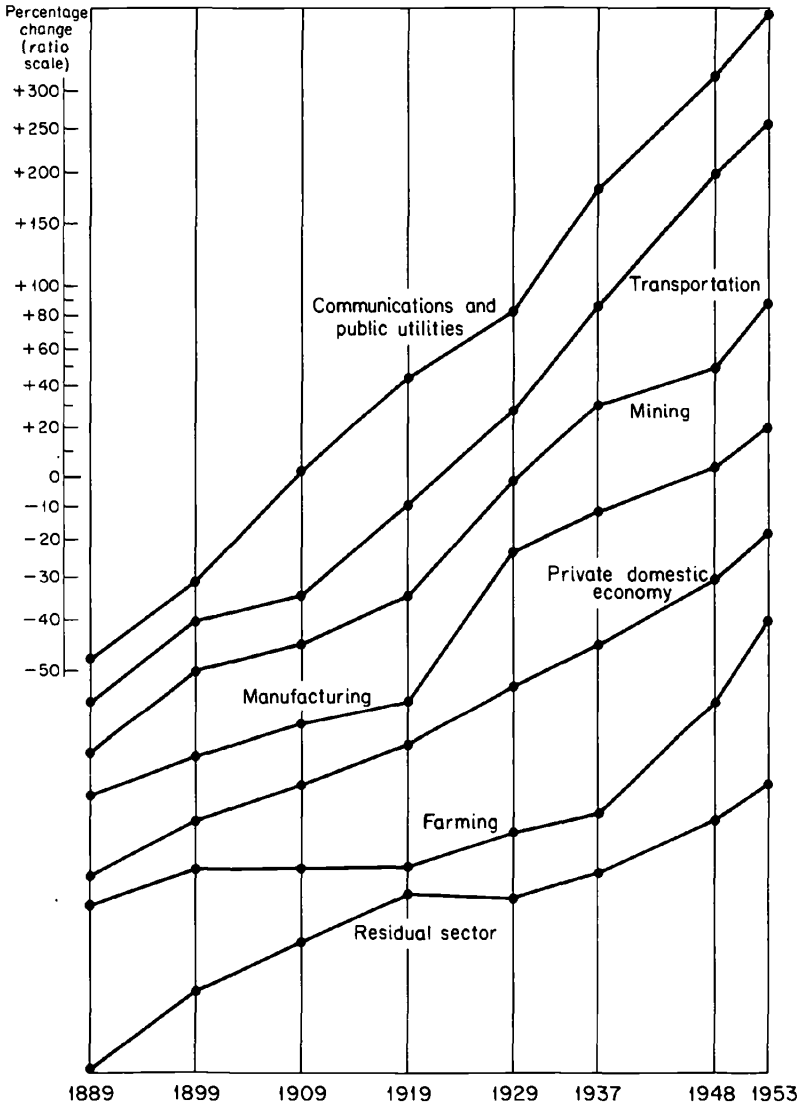
	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Transportation	3.0	0.9	3.3	3.5	4.9	4.3	3.7	3.4	0.9
Railroads		1.1	3.6	2.6	2.9	3.2	3.7	2.8	0.7
Local transit		1.3	2.4	3.7	2.7	5.0	−4.4	2.4	1.7
Residual transport		−1.1	2.0	7.4	9.2	3.7	5.9	4.1	3.0
Communications and public utilities	1.7	4.1	3.5	2.4	5.5	3.7	4.6	3.8	0.7
Telephone		3.7	0.4	1.8	4.4	0.6	1.5	2.0	1.3
Telegraph		1.8	−2.4	3.9	2.8	1.9	2.5	1.6	1.5
Electric utilities		7.1	8.3	1.9	6.5	6.5	7.7	6.2	1.6
Manufactured gas		3.5	5.7	3.0	2.6	6.2	9.2	4.7	1.8
Natural gas		1.6	2.3	2.0	4.8	4.3	3.4	3.0	1.1
Residual sector	0.9	1.8	1.7	−0.1	1.1	1.8	2.7	1.4	0.8
Construction	1.5	4.3	−1.0	1.0	−0.5	0.5	3.6	1.1	1.6
Trade	0.6	1.5	0.4	1.1	1.6	2.2	1.8	1.4	0.5
Finance and services	1.8	2.0	1.6	−0.8	−0.9	3.0	2.6	1.2	1.4
Private domestic economy	1.4	1.3	1.5	2.2	1.8	2.2	3.4	2.0	0.5
Mean deviation of 8 segment rates from economy rate	0.5	0.7	0.8	2.2	1.3	1.0	1.0	0.6	
Aggregate of 5 covered segments	1.8	1.0	1.2	4.1	2.5	2.5	4.0	2.4	1.0
Mean deviation from sector rates:									
5 segments	0.4	0.4	0.9	1.5	1.3	1.3	1.2	0.5	
33 groups		1.0	1.8	1.8	1.4	1.2	1.6	0.6	

respect to the major segments, the differences between the long-period average rates of increase in total factor productivity and in output per unit of labor input were either 0.2 or 0.3 percentage points (compare Table 40 with Table 34, and Chart 15 with Chart 12). The larger difference, evident in farming, was not due to a higher rate of increase in capital per unit of labor input, but rather to a relatively larger weight accorded to capital because of the effect of net rents.

Among the thirty-three groups, differences between average annual rates of change in the output-labor ratio and total factor productivity were concentrated, for the most part, between 0.1 and 0.4 percentage points. In the local transit and the telegraph industries, output per unit of labor input rose slightly less than total factor productivity, since capital

CHART 15

Private Domestic Economy: Output per Unit of Labor Input, by Segment, Key Years, 1889–1953 (1929=100)



per manhour fell, as noted in the preceding section. In a few other groups, rates of change in both variables rounded out to the same amount due to small rates of increase in capital per manhour, or the small relative weight of capital, or both factors. On the other hand, several industries showed much larger average annual increases in output per unit of labor input than in total factor productivity. The largest percentage-point differences were 1.6 in tobacco manufactures, 1.4 in petroleum and coal products, and 1.0 in natural gas utilities. These are, of course, the groups in which capital per manhour rose most strongly.

Thus, the dispersion of group rates of change in output per unit of labor input was somewhat greater than that in total factor productivity, as measured in Table 46 and depicted in the frequency distributions of Table 35. The secular average annual rates of change in labor productivity ranged from 0.7 per cent for anthracite coal mining to 6.2 per cent for the electric utilities.

Despite different rates of change in the output-labor ratio and in total productivity, the ranking of the thirty-three groups was quite similar with respect to each. Several industries had significantly higher ranks with respect to labor productivity than with respect to total factor productivity because of relatively high rates of substitution of capital for labor. These include farming, natural gas utilities, petroleum and coal products, and tobacco manufactures. On the other hand, some groups stood lower with respect to output per unit of labor than to productivity, because of relatively low or negative rates of capital substitution; the telegraph and telephone, local transit, and printing and publishing groups are in this category. Electric utilities maintained top place in both rankings, although capital substitution was less than in some other groups. Anthracite coal mining stood at the bottom of both rankings, although capital substitution was positive.

Correlation of the ranks of the thirty-three groups with respect to both productivity ratios is highly positive ($r = +.94$, significant at the 1 per cent level). Thus, analyses of productivity change based on output-per-manhour measures should give results comparable to analyses based on total factor productivity. If available, measures of total productivity and the two partial productivity measures are, of course, preferable for analytical purposes, since they yield more information than output per manhour alone.

The movements of output per unit of labor input in the segments and groups are as described for total productivity, adjusted for movements in capital per unit of labor input appropriately weighted. The adjustment results in several major differences. In the first three subperiods, 1899–1929, labor productivity increased at rates that were generally higher than the rates of increase in total productivity, with the major exceptions found

in transportation and in communications and public utilities, where the capital-labor ratio fell in one or more subperiods.

In the 1929–37 subperiod, labor productivity rose less than total productivity in most of the manufacturing and mining groups, because of a drop in the capital-labor ratio, and in the 1937–48 subperiod the smaller rise in labor productivity was widespread among all groups. In contrast, labor productivity rose substantially more than total productivity after 1948 in most groups because of large increases in the capital-labor ratio. With reference to the rates of advance recorded for total productivity after 1948 compared with the preceding period, acceleration, rather than deceleration, of gains in output per unit of labor occurred in the communications and public utility segment; deceleration was less marked in transportation; and acceleration was more marked in manufacturing, mining, farming, and the residual segments. In general, variability in the segment and group rates of change in output per unit of labor input over the subperiods was somewhat higher than that in total productivity. Subperiod dispersion was also greater, of course, as can be seen in the frequency distribution of Table 35, and in Table 46.

Residual segments. It will be recalled that total factor productivity of construction, trade, and finance and services as a whole could be estimated by a residual method. It is possible directly to estimate real product per manhour for each of the residual segments separately. The estimates, as shown in Table 40, indicate that real product per unit of labor input in each of the uncovered groups, as well as in the area as a whole, increased at a significantly lower rate than labor productivity in the private economy. According to our rough measures, the average annual rates of increase ranged from 1.1 per cent in construction to 1.4 per cent in trade.

In trade the rate of increase in output per unit of labor input over the subperiods was even steadier than in the covered segments. In contrast, variability was much greater in contract construction. Here, subperiod variations in rates of change in real product per manhour have been associated to some extent with the building cycle. There appears to have been little net gain in labor productivity in construction over much of the period, but the output estimates are undoubtedly subject to some downward bias (see Appendix E). Output per unit of labor input in the finance and services segment increased in all subperiods except those from 1919 to 1937.

It will be noted that there were larger-than-secular rates of advance in trade, finance, and services after 1937, and in construction after 1948. This acceleration of productivity advance in previously lagging segments of the economy is encouraging, if true. It must be stressed, however, that the real-product estimates for these segments are subject to a large margin of error, since they are derived from private real-product estimates, which are likewise somewhat unsatisfactory in this area due to inadequate price deflators.

Farm groups and regions. Although we have index numbers of total factor productivity only for the farm segment as a whole, index numbers of production per manhour have been prepared by the Department of Agriculture for the period from 1910 forward for twelve major groups of farm enterprises. These index numbers, based on gross production measures, show an average annual rate of increase per manhour between 1910 and 1953 of 2.3 per cent for the segment, contrasted with a 2.1 per cent rate of growth in our measures of net output per manhour.

Among the farm groups, the average annual rates of increase range from about 0.5 per cent for livestock and tobacco to 3.7 per cent for food grains and oil crops. In general, output per manhour has increased twice as fast for crops as for livestock and products (Table 41). The dispersion of the

TABLE 41

Farm Segment: Average Annual Rates of Change in Production per Manhour, by Groups of Enterprises, with Measures of Dispersion, Subperiods, 1910–53
(per cent)

	1910–1919	1919–1929	1929–1937	1937–1948	1948–1953	1910–1953	Mean Deviation of Subperiod Rates from Secular Rate
Livestock and products	0.3	0.5	−0.3	2.6	3.0	1.1	1.2
Meat animals	0.3	0.7	−0.4	1.2	1.2	0.6	0.5
Milk cows	0.5	1.1	−0.5	2.9	2.9	1.4	1.2
Poultry	0.0	0.7	0.7	2.1	5.4	1.4	1.2
Crops	0.7	0.8	2.0	4.9	3.2	2.3	1.5
Feed grains	0.6	0.9	1.8	7.0	7.1	3.3	2.8
Hay and forage	−0.2	0.7	1.3	4.3	4.4	2.0	1.8
Food grains	0.8	3.9	1.1	7.2	5.1	3.7	2.1
Vegetables	0.0	1.5	0.7	2.5	1.5	1.3	0.7
Fruits and nuts	2.8	1.5	2.3	0.8	2.4	1.8	0.7
Sugar crops	−1.0	2.2	1.1	2.6	7.7	2.1	1.7
Cotton	0.2	0.8	4.4	3.1	5.3	2.5	1.7
Tobacco	−0.5	−0.3	0.6	2.1	−0.2	0.4	0.9
Oil crops	−1.1	2.4	2.1	7.7	9.3	3.7	3.3
Total farm production per manhour	0.5	1.2	2.1	4.5	3.4	2.3	1.4
Mean deviation from total farm sector	0.7	0.8	0.9	2.0	2.3	0.9	

SOURCE: *Changes in Farm Production and Efficiency: A Summary Report*, Dept. of Agriculture, Statistical Bulletin No. 233, August 1958, Table 15. A revised edition was published in September 1959, too late to incorporate the revisions into this volume. Presented here, for comparison, are the revised rates of change for total farm production per manhour: 1910–19, 0.5; 1919–29, 1.5; 1929–37, 1.7; 1937–48, 4.8; 1948–53, 4.7; and for the long period (1910–53), 2.5.

group rates of change over the long period from their weighted average in farming is not much greater than in the nonfarm economy; the average deviation of group rates of change from their mean (2.3 per cent) is 0.9 per cent.

It will be seen in Table 41 that there was a definite acceleration in rates of advance over the subperiods from 1910 to 1948 in all groups except fruits and nuts. Tobacco was the only group in which there were declines in production per manhour in more than one of the subperiods. Whereas production per manhour in several major groups and the total showed a somewhat smaller advance in the 1948–53 subperiod than in the preceding subperiod, further acceleration was marked in poultry raising, sugar crops, cotton, oil crops, and fruits and nuts.

Variability of productivity changes in the farm segment was not significantly greater than in the other segments. The mean deviation of subperiod average annual rates of change from the secular rates was 1.4 per cent for the segment and 1.5 per cent, on the average, for the groups—almost precisely the same figures that apply in manufacturing. Apparently the weather and other relatively uncontrollable factors do not cause wider variations of productivity advance in farming than in other segments over intervals as long as the subperiods used in this study.

Farming is the only segment for which regional productivity indexes are readily available (Table 42). The dispersion of rates of change in production

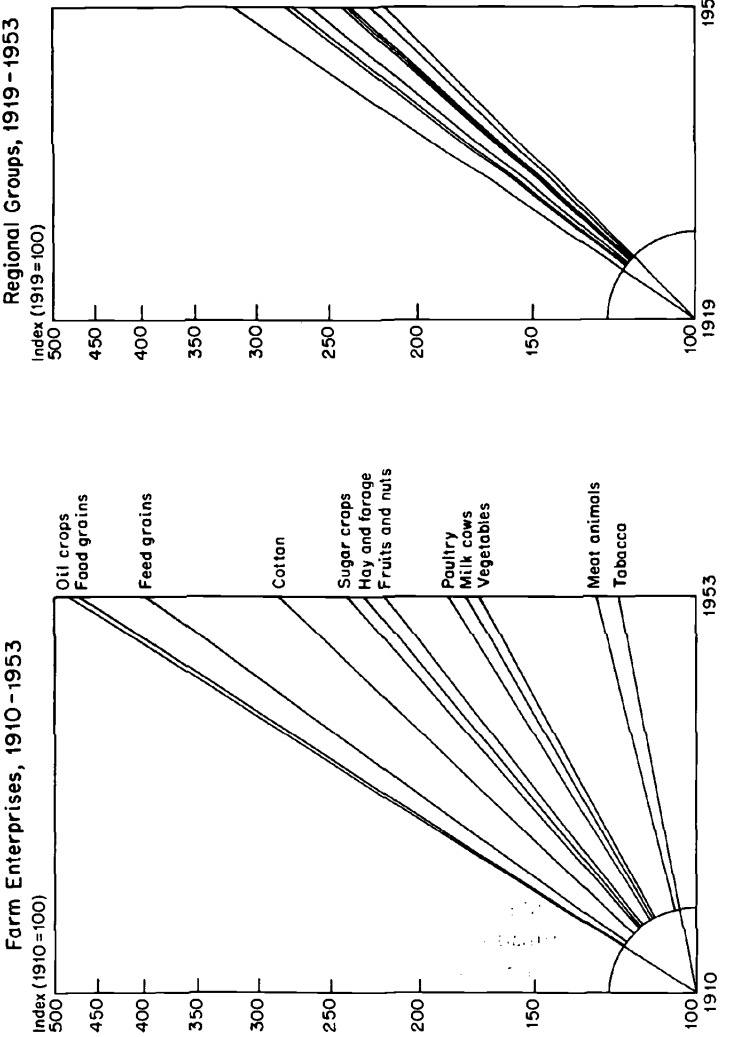
TABLE 42

Farm Segment: Average Annual Rates of Change in Production per Manhour, by Geographical Division, with Measures of Dispersion, Subperiods, 1919–53
(per cent)

	1919–1929	1929–1937	1937–1948	1948–1953	1919–1953	Mean Deviation of Subperiod Rates from Secular Rate
New England	1.9	1.0	4.2	3.0	2.6	1.2
Middle Atlantic	1.3	2.2	3.7	3.7	2.6	1.0
East North Central	1.2	2.4	4.7	4.1	2.8	1.4
West North Central	1.9	0.7	6.2	2.3	3.0	2.1
South Atlantic	1.6	1.9	3.2	3.3	2.4	0.8
East South Central	1.2	2.6	3.1	2.5	2.3	0.6
West South Central	0.0	3.8	4.3	4.3	2.9	1.7
Mountain	3.1	1.1	5.3	4.0	3.5	1.3
Pacific	1.6	1.8	3.5	3.5	2.5	0.9
United States	1.2	2.1	4.5	3.4	2.8	1.3
Mean Deviation from Total Farm Sector	0.5	0.7	0.8	0.6	0.3	

CHART 16

Farm Segment: Divergence of Gross Production per Manhour



per manhour between 1919 and 1953 among the nine regions shown is only about one-third as great as the dispersion of group rates of change (see Chart 16). This is not surprising since most regions participate to some extent in most types of farming, although in different proportions.

Variability of productivity changes in the nine regional groupings was no greater than that for farming in the country as a whole from 1919 to 1953 (Table 42). The several divisions of the Central Region were the only ones to show above-average variability, which is undoubtedly associated with the above-average variability of productivity changes in food and feed grains.

Manufacturing industries. Output per manhour measures beginning in 1899 are available for eighty manufacturing industries, as defined by SIC 4-digit classifications or combinations thereof[2] (see Appendix Tables D-V and D-VI). The simple mean of the average annual rates of change in the eighty industries between 1899 and 1954 is 2.2 per cent, the same increase as in the manufacturing segment as a whole. The changes range from a few small negatives to a high of 5.8 per cent a year for cigars and cigarettes (see Table 43).

A frequency distribution of the average annual rates is shown in the first column of Table 44. It is similar to the frequency distribution of the group rates of change (see Table 35). About 70 per cent of the industries had rates of change between 1.0 and 3.0 per cent a year. The distribution is also somewhat skewed to the right, reflecting the greater tendency for industries to have high rates of productivity advance than to experience declines.

As measured by mean deviations, the dispersion of rates of change in output per manhour in the eighty industries is 50 per cent greater than the dispersion of the manufacturing-group rates of change. This confirms the impression that the greater the degree of industry detail in terms of which the productivity ratios are constructed, the greater the degree of dispersion —and also of variability.

The majority of the eighty manufacturing industries followed the segment pattern of movement. There was, generally, a slow rate of productivity advance from 1899 to 1919, and even some declines. This was followed by a period of relatively rapid advance in the 1920's. After 1929, however, most industries saw a rate of advance which was less than that of the 1920's but above the pre-1919 rate.

In a few industries, the higher rate of advance achieved in the 1920's persisted thereafter, as in fertilizers, paints, and cigars and cigarettes. In at least a dozen industries, the rate of advance in output per manhour was fairly steadily upward from 1899 on—as in canning of fruits and vegetables,

[2] In several instances, the measures of output per manhour for groups are used if no component-industry measure is available.

TABLE 43

Output per Manhour in Manufacturing Industries: Average Deviations of Subperiod Rates of Growth and Ranks from Subperiod Averages, 1899–1954

Industry	EIGHTY MANUFACTURING INDUSTRIES			
	Average Annual Rate of Change, 1899–1954	*Average Deviation of Subperiod Rates*	*Subperiod Ranks*	
			Average	Average Deviation
Cigars and cigarettes	5.8%	2.4%	63.0	18.3
Motor vehicles and equipment	5.0	5.8	41.0	26.0
Silk and rayon goods	4.6	2.2	61.3	17.6
Rubber products group	4.4	2.7	55.5	15.5
Chemicals, n.e.c., rayon, gases	4.3	2.1	62.2	12.4
Beet sugar	4.1	3.5	50.8	20.8
Canning, fruits and vegetables	4.1	0.8	63.5	8.7
Glass products	3.6	1.6	56.2	14.1
Blast furnace products	3.5	3.7	43.0	26.0
Knitting mills	3.5	0.9	54.7	17.0
Petroleum refining	3.5	3.4	49.8	26.9
Coke oven products	3.4	2.7	48.7	22.4
Fertilizers	3.3	1.8	54.2	16.8
Primary nonferrous metals	3.3	2.4	53.7	18.1
Chewing and smoking tobacco	3.2	1.6	52.7	20.3
Cement, lime, concrete	3.1	1.9	49.5	15.8
Heating and cooking apparatus	3.0	0.9	51.0	17.7
Converted paper products	2.9	1.2	47.8	13.8
Raw cane sugar	2.8	3.7	48.8	26.9
Dairy products	2.8	1.0	48.2	10.5
Tanning and dyeing materials	2.8	2.8	46.7	20.7
Printing and publishing group	2.7	1.1	44.8	18.8
Bolts, nuts, screw machine products	2.7	2.6	44.8	23.5
Sheet metal work	2.6	2.1	44.5	22.2
Pianos	2.6	1.3	45.5	22.7
Carbon black	2.6	3.0	43.0	26.7
Manufactured ice	2.5	1.3	43.8	14.9
Nonferrous metal products, n.e.c.	2.5	1.4	46.0	17.0
Paper and pulp mills	2.4	2.0	42.8	17.6
Electric machinery group	2.4	1.4	43.2	11.8
Wirework, n.e.c.	2.3	3.0	36.7	25.2
Cotton goods	2.3	0.9	44.2	15.1
Rice cleaning	2.2	2.5	40.0	18.7
Steel mill products	2.2	1.9	39.7	20.0
Hats, wool felt	2.1	3.3	42.2	25.4
Glue and gelatin	2.1	1.5	39.7	12.1
Misc. mfg. incl. instruments	2.1	1.7	39.7	12.1
Salt	2.1	1.2	39.7	10.0
Soap and glycerine	2.1	1.9	39.5	14.5
Carpets and rugs, wool	2.0	0.5	40.7	17.3
Agricultural machinery	2.0	1.2	40.3	12.3
Jute and linen goods	2.0	0.8	41.2	11.8

n.e.c. = not elsewhere classified.

(continued)

TABLE 43 (concluded)

Industry	EIGHTY MANUFACTURING INDUSTRIES			
	Average Annual Rate of Change, 1899–1954	*Average Deviation of Subperiod Rates*	*Subperiod Ranks* Average	Average Deviation
Cottonseed oil mills	2.0	3.2	41.0	23.7
Woolen and worsted goods	2.0	0.9	41.5	11.8
Leather tanning and finishing	2.0	1.1	37.3	15.7
Explosives	1.9	4.0	39.8	27.8
Apparel group	1.9	1.3	33.5	15.8
Paints and allied products	1.9	1.2	36.2	16.2
Linseed oil mills	1.9	3.8	39.2	30.5
Corn products	1.8	1.6	35.2	18.2
Office and store machines	1.8	2.2	37.0	17.7
Foundry and machine shop products	1.8	0.6	37.2	7.2
Wood distillation	1.8	1.7	38.8	10.6
Cane-sugar refining	1.8	2.7	38.2	19.8
Structural steel products	1.8	2.1	35.0	19.3
Leather gloves and mittens	1.8	1.1	37.2	17.5
Grease and tallow	1.7	3.6	38.2	23.2
Cutlery and edge tools	1.7	2.2	38.8	19.2
Beverages group	1.7	3.7	32.3	20.3
Carriages, wagons, sleighs	1.6	1.5	34.0	21.0
Bakery products	1.6	0.9	34.5	19.2
Furniture group	1.6	1.9	37.0	15.3
Cordage and twine	1.6	1.4	32.3	12.3
Clay and pottery products	1.5	0.9	33.0	10.0
Vinegar and cider	1.5	1.4	33.7	12.8
Hand tools	1.5	1.8	30.0	15.3
Nails and spikes	1.5	1.3	31.7	13.3
Canning, fish	1.4	1.6	33.2	20.9
Flour and meal	1.4	1.9	34.3	14.0
Hats, fur felt	1.4	1.1	33.8	19.8
Footwear, leather	1.3	1.1	30.3	18.4
Leather belting	1.2	1.8	32.0	13.3
Liquors, distilled	1.1	12.1	21.2	24.9
Lumber mills	1.1	1.9	32.0	17.3
Gum naval stores	0.7	1.6	29.2	25.2
Meat packing	0.5	1.5	18.7	8.3
Ships and boats	0.3	1.4	22.7	15.9
Saddlery, harness	−0.2	2.3	21.2	17.6
Locomotives and parts	−0.5	3.1	26.0	23.7
Railroad and street cars	−0.7	1.9	19.0	22.0
Average of 80 covered industries	2.2	2.1[a]	40.5	17.9

[a] 2.1 is the unweighted average of the industry subperiod deviations. The average deviation of subperiod rates taken about the average change for the average of all covered industries is 1.0.

knitting mills, glass, converted paper products, industrial chemicals, and nonferrous metal products. In others, there was a straight-line trend, but with some subperiod irregularity, as in foundry and machine shop products,

agricultural machinery, and clay and pottery products. These industries were usually the technologically older ones, in which acceleration in productivity advance had occurred prior to 1899.

Some industries advanced rapidly in the early decades and then experienced retardation or decline—for example, cement, lime, and concrete, the sugar industries, and leather gloves and mittens. On the other hand, some industries showed renewed acceleration of productivity advance after World War II, particularly in the stone, clay, and glass and the machinery groups.

TABLE 44

Manufacturing Industries:[a] Frequency Distributions of Average Annual Rates of Change in Output per Manhour, Subperiods, 1899–1954

Class Interval (per cent)	*1899–1954*	*1899–1909*		*1909–19*		*1919–29*		*1929–37*		*1937–47*		*1947–54*	
	A	A	B	A	B	A	B	A	B	A	B	A	B
Under −2.0		4	4	9	11	2	2	7	11	2	6	2	6
−2.0 to −1.0		6	7	4	5	1	1	4	10	1	11		4
−1.0 to −0.0	3	5	6	15	18	2	3	13	20	11	21	5	12
0.0 to 1.0	3	7	7	18	17	3	5	11	28	16	31	7	29
1.0 to 2.0	29	22	21	10	18	7	10	6	17	20	31	9	43
2.0 to 3.0	28	12	14	9	10	7	11	12	16	17	31	17	50
3.0 to 4.0	10	13	15	10	13	10	16	14	22	6	15	14	38
4.0 to 5.0	6	5	5	2	3	13	18	5	13	4	12	5	29
5.0 to 6.0	1	2	2		1	15	18	1	6	1	3	12	28
6.0 to 7.0		2	5			5	9	2	6	2	3	4	22
7.0 to 8.0		1	1	2	2	4	7	1	3		1	3	10
8.0 to 9.0		1	1			7	9	1				0	11
9.0 to 10.0						1	3	1	1		1	2	13
10.0 and over				1	1	3	4	2	5				12
Total number of industries	80	80	88	80	99	80	116	80	158	80	166	80	307

[a] The "A" distributions refer to a constant sample of eighty industries; the "B" distributions refer to a varying number of industries, the progressive increase in number of industries in successive subperiods stemming from finer breakdowns of the preceding industry classification and from the introduction of estimates for additional industries.

Finally, a few industries have been stagnant or have actually experienced irregularly declining output per manhour in this century: meat packing, saddlery and harness, ships and boats, and railroad equipment. In the latter two industries, however, the apparent decline in output per manhour may be due to the use of broad quantity measures that do not reflect shifts in production to higher value-added types of the product groupings; output per manhour indexes based on deflated value-of-product measures show slight increases.

Just as there was generally greater variability in productivity changes between key years in the twenty manufacturing groups than in the segment, so there is still greater average variability in industry movements. The mean deviations of subperiod rates of change in output per manhour from the secular rate in the eighty industries average 2.1 per cent com-

pared with 1.6 per cent for the groups and 1.4 per cent for the manufacturing segment as a whole. It is clear that variations in productivity changes in components tend to be offsetting; hence productivity movements of aggregates are less variable than those of the components. Also, as in the groups, there were large fluctuations in the rank of the manufacturing industries with respect to changes in output per manhour. The coefficient of variation of ranks in the subperiods from average rank was more than 40 per cent (see Table 43).

Dispersion of the rates of change in the eighty manufacturing industries in the subperiods is pictured in the frequency distributions of Table 44. The greater range of change and the lesser degree of central tendency in the subperiods than in the long period and for the individual industries compared with the manufacturing and other groups (see Table 35) stand out clearly. There is even greater dispersion when a larger, variable sample of manufacturing industries is used, comprising up to 307 industries in the last subperiod (the "B" columns of Table 44).

Other industries. Estimates of output per manhour are available for five of the industries that constitute the residual transportation group. As shown in Table 40, the average annual rate of increase for the residual was 4.1 per cent between 1899 and 1953 compared with 3.4 per cent for transportation as a whole. Within the residual, output per manhour for waterways, which showed the smallest increase (approximately 3 per cent a year), was still above the economy average. Much larger rates of increase were shown by the newer forms of transportation. Between 1919 and 1953, output per manhour for pipe lines increased at an average annual rate of 7.5 per cent. This was also approximately the average rate of advance for intercity motor transport; trucking advanced somewhat more and passenger buses somewhat less. Between 1929 and 1953, the airlines experienced a better-than-9-per-cent average annual gain in output per manhour.

A few scattered series are available for other industries. Rough estimates for fisheries (see Appendix B) show an average annual rate of advance of 0.9 per cent a year in output per worker between 1899 and 1953. In the government-enterprise segment, estimates are available for the postal service. Here, output per manhour rose at an average rate of 1.8 per cent a year over the long period (see Appendix J), which compares favorably with private-industry experience.

OUTPUT PER UNIT OF CAPITAL INPUT

Despite the substitution of capital for labor over most of the period under review, substantial savings in capital per unit of output[3] were realized in

[3] The "capital coefficient," which is the reciprocal of "capital productivity" (i.e., output per unit of capital input), fell over the period.

the economy and its major segments between 1899 and 1953. Output per unit of capital input increased at an average annual rate of 1.2 per cent in the private domestic economy, and 1.0 per cent in the covered sector, implying an average rate of increase of 1.3 per cent a year in the uncovered sector.

Among the segments, the average annual rates of advance in the output-capital ratio range from practically no change in farming to 2.5 and 3.2 per cent in transportation and communications, respectively, with near-average changes in mining and manufacturing (see Table 45 and Chart 17). The differences in rates of advance are associated not only with the technological characteristics of the several industries, but also with the dates, which differed considerably, at which relatively full mechanization was achieved.

Although the segment rates of change in output per unit of capital input over the long period run lower than those in total factor productivity, the dispersion is virtually the same in absolute terms (see Table 46). This is also true of average rates of change in the group output-capital ratios, which range from a small negative in lumber products to 4.7 per cent a year in electric utilities. A frequency distribution of changes in output per unit of capital input in the groups (Table 35, last panel) shows that the modal class is between 1 and 2 per cent a year, instead of between 2 and 3 per cent, as in the case of changes in total productivity and the output-labor ratio. The peaking of the distribution is sharper, and the distribution has a more normal shape.

The time sequence differs, but there is a typical pattern of movement of output per unit of capital input in the various segments and groups. The first phase is characterized by a rapid build-up of capital as mechanized processes are substituted for hand processes or as plant is constructed in anticipation of gradually increasing demand and rates of utilization. During this phase, output per unit of capital input generally declines. Then, once production processes have been made as capital-using as current technology and relative factor prices warrant, resources are devoted primarily to refining equipment and production processes. Capital-saving innovations are more numerous in this phase since possibilities of cutting costs along these lines are greater because of the larger relative quantity of capital, and output per unit of capital input begins to rise.

The timing of the early shift in output per unit of capital input from a downward to an upward direction varied widely among the segments. The low points of the ratio (in terms of our key years) were 1919 in manufacturing, 1909 in mining, and 1879 in communications and public utilities. In the last case, there was little net change in the ratio between 1869 and 1899, as increases in the older groups tended to be offset by

declines in the burgeoning groups. The period of "capital deepening" in transportation, dominated by the railroads, had apparently ended before the beginning of our estimates in 1870. This was also true in farming, but the farm output-capital ratio showed a renewed decline during the build-up of the second technological revolution in the early twentieth century.

Within each segment, the pattern varied somewhat by group. In mining, the low point of output per unit of capital input for anthracite coal came

TABLE 45

Private Domestic Economy: Average Annual Rates of Change in Output per Unit of Capital Input, by Segment and by Group, with Measures of Dispersion, Subperiods, 1899–1953
(per cent)

	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Farming	0.5	−0.7	−0.7	1.2	0.8	0.4	−1.5	0.0	0.8
Mining	−2.2	−0.1	0.4	1.5	6.0	0.6	−0.3	1.3	1.5
Metals		0.3	2.0	2.7	5.9	2.6	−7.6	1.6	2.2
Anthracite coal		0.2	−0.4	−0.9	1.3	4.1	−7.7	0.0	2.0
Bituminous coal		−2.3	−1.7	3.3	2.2	1.6	−7.5	−0.2	2.7
Oil and gas		−1.8	−1.9	4.5	9.9	−0.5	5.8	2.0	3.9
Nonmetals		1.1	0.0	2.7	1.4	5.8	−1.5	1.9	1.8
Manufacturing	−1.8	−1.6	−1.9	4.3	2.4	2.1	0.8	1.0	2.1
Foods		−0.9	−2.5	5.1	3.4	1.5	1.2	1.2	2.2
Beverages		0.4	−4.6	−1.2	16.6	2.0	−1.1	1.6	4.4
Tobacco		−2.2	0.0	−1.3	4.9	−0.7	0.0	0.0	1.6
Textiles		−0.3	−2.5	4.9	5.4	2.8	−1.4	1.6	2.8
Apparel		−1.6	−2.6	4.0	5.7	−2.6	−1.9	0.0	3.1
Lumber products		−3.4	−2.8	−1.0	3.9	1.5	1.2	−0.4	2.3
Furniture		−2.9	−1.9	2.7	2.5	6.6	0.2	1.3	3.0
Paper		−1.0	−0.7	2.9	3.8	1.7	−0.2	1.1	1.7
Printing, publishing		3.2	1.8	3.7	2.4	1.0	2.0	2.3	0.8
Chemicals		−0.9	−1.7	6.0	3.0	3.4	1.2	1.8	2.5
Petroleum, coal products		−1.6	−2.6	8.4	1.2	1.4	1.8	1.3	2.7
Rubber products		−0.9	3.7	3.8	6.4	0.5	1.3	2.4	2.2
Leather products		−2.6	−1.8	4.7	6.1	0.9	−2.4	0.9	2.9
Stone, clay, glass		−2.3	−1.0	3.1	4.4	4.2	−0.8	1.4	2.6
Primary metals		−2.1	−0.9	4.8	−2.4	5.4	−3.9	0.6	3.4
Fabricated metals		−1.1	0.7	2.6	2.6	2.2	4.2	1.6	1.3
Machinery, nonelectric		−1.8	1.0	2.5	3.3	0.7	1.3	1.1	1.2
Electric machinery		−2.3	1.5	1.6	4.8	1.4	3.3	1.4	1.4
Transportation equipment		0.0	4.1	5.9	−0.9	2.2	5.9	2.7	2.3
Miscellaneous		−1.2	−0.7	0.4	5.3	2.0	2.7	1.1	1.8

(continued)

TABLE 45 (concluded)

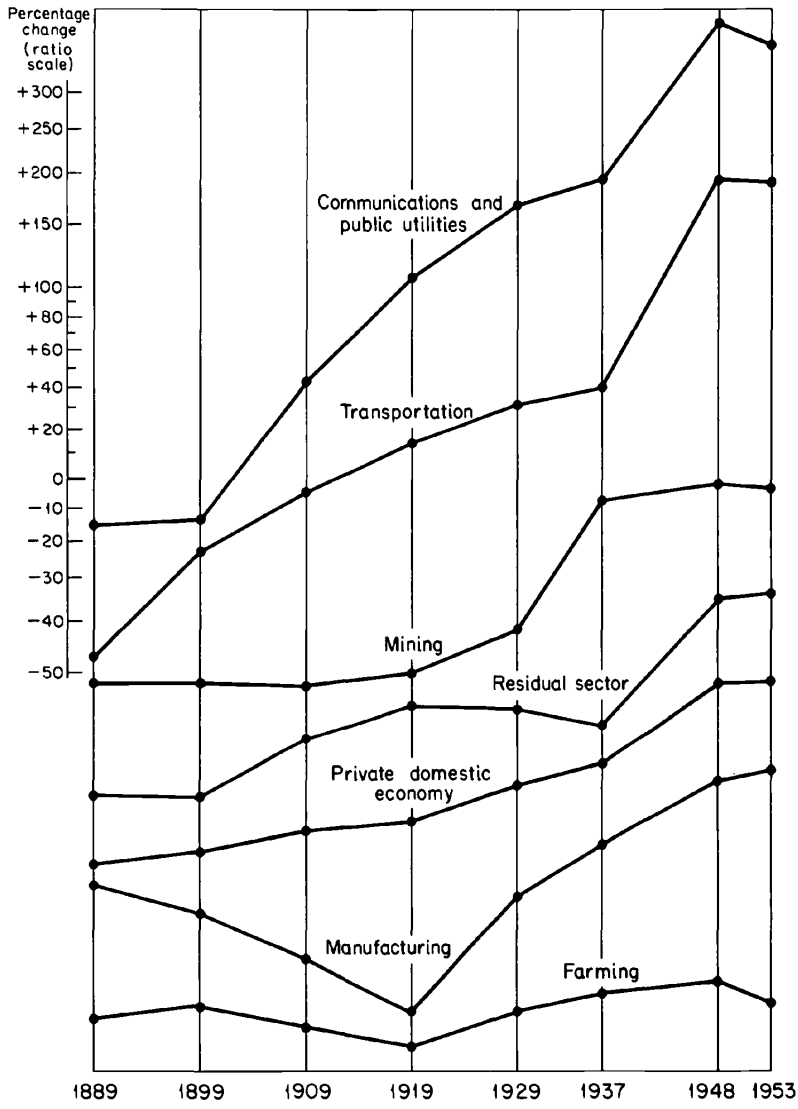
	Pre-1899	1899–1909	1909–1919	1919–1929	1929–1937	1937–1948	1948–1953	1899–1953	Mean Deviation of Subperiod Rates from Secular Rate
Transportation	4.5	2.2	1.8	1.5	0.8	6.9	−0.1	2.5	1.8
Railroads		4.3	2.7	−0.3	−2.1	5.4	−2.2	1.8	2.7
Local transit		0.5	3.8	5.7	1.2	8.7	−4.1	3.4	3.1
Residual transport		−3.2	−5.4	6.9	5.6	6.0	1.8	1.8	4.6
Communications and public utilities	0.5	5.1	3.8	2.7	1.0	5.3	−1.5	3.2	1.8
Telephone		5.9	4.6	0.9	−2.2	2.0	−5.5	1.6	2.8
Telegraph		1.2	1.6	5.7	−1.2	6.1	0.4	2.6	2.5
Electric utilities		3.0	8.1	3.1	3.5	6.8	2.4	4.7	2.0
Manufactured gas		4.9	3.5	3.9	−0.2	8.1	7.6	4.6	2.1
Natural gas		−5.7	−1.2	−2.6	2.4	6.8	−0.5	−0.1	3.5
Residual sector	1.8	2.1	1.2	−0.1	−0.8	4.3	0.3	1.3	1.4
Private domestic economy	0.6	0.8	0.3	1.4	0.9	2.7	0.1	1.2	0.7
Aggregate of 5 covered segments	−0.3	−0.3	−0.5	2.7	2.0	1.9	0.0	1.0	1.3
Mean deviations from sector rates:									
5 segments	1.5	1.4	1.3	1.4	1.1	1.1	0.9	0.6	
33 groups		1.5	1.7	1.9	2.4	1.5	2.6	0.8	

in 1879, although the ratio showed little trend in subsequent decades. In metal and nonmetal mining and quarrying, the low point was reached in 1889. In bituminous coal and in crude petroleum and natural gas production, the output-capital ratios did not reach bottom until 1919.

In manufacturing, the majority of groups followed the segment pattern of declines up to 1919, followed by increases (at a decreasing rate) in the succeeding subperiods. All groups but printing and publishing and beverages showed declines in output per unit of capital input in the 1899–1909 subperiod. Between 1909 and 1919, six of the twenty groups registered increases in advance of the segment as a whole. Although there were relatively few drops in output per unit of capital input in the three subperiods between 1919 and 1948, seven groups registered declines in the last subperiod reviewed here, 1948–53. It will be interesting to see if this increasing dispersion foreshadows a reversal of movement, as was the case in the 1909–19 subperiod.

CHART 17

Private Domestic Economy: Output per Unit of Capital Input, by Segment, Key Years, 1889–1953 (1929=100)



In the transportation segment, output per unit of capital input for the railroads was already advancing sharply in the first decade for which we have estimates, 1869–79. The big build-up of roadbed and, to a lesser degree, equipment had already occurred. The turning point in the output-capital ratio for local transit came in 1899. In the residual transportation segment, the turn appears to have come nearest the key year 1919, influenced by the early phase of capital-building in pipe lines and in motor transport.

In the utilities segment, low points in the output-capital ratios were reached in 1889 in the telephone industry, 1899 in electric utilities and manufactured gas, and not until 1929 in natural gas. In the telegraph industry, the early phase of plant expansion relative to output apparently took place prior to the first decade for which data are available (1879–89).

Once begun, the rise in output per unit of capital input continued in most areas, but with major irregularities in the last two subperiods as a result of World War II. Due to wartime restrictions and early-postwar capital shortages, the growth of capital stocks was retarded and the rise in the output-capital ratio was accelerated in the economy. Conversely, between 1948 and 1953 capital was expanded about as rapidly as was output in the covered sector and in the economy. In all segments, output per unit of capital input either fell or showed only small increase. Taking 1937–53 as a whole, the rate of increase was in line with past experience. Whether the pattern since 1948 has merely been a "catching-up" with the trend, to be followed by further substantial increases in the output-capital ratio, or whether part of it represents a new period of deepening of capital, is not clear. It seems reasonable to assume that output per unit of capital input will resume some advance in the economy as a whole. Despite the fact that a catching-up was undoubtedly involved in the capital expansion from 1948 to 1953, the ratio remained fairly stable. On the other hand, some of the major postwar technological developments suggest that the intermediate-term trend in output per unit of capital may be less steep than the 1899–1953 trend, particularly so long as high-level employment, income, and investment are maintained.

As this review suggests, variability in rates of change of output per unit of capital input in the segments and groups between key years was considerably greater, on the average, than was variability in rates of change in output per unit of labor input (see Table 47). Among the segments, variability in rates of change of the output-capital ratio relative to the output-labor ratio was particularly large in transportation and in communications and public utilities. This would seem to indicate even less flexibility in these segments than in manufacturing in adjusting capital to changes in output over subperiods as compared with adjusting labor to output. Variability in rates of change in the output-capital ratio was

considerably higher in the groups than in the segments of which they are components; so the group variations must have been partially offsetting.

Dispersion of rates of change in output per unit of capital input in the segments was about twice as great in the subperiods as for the period as a whole, and greater still with respect to the thirty-three group measures. If anything, the degree of dispersion has tended to increase with time.

COMPARISON OF DISPERSION AND VARIABILITY IN THE PRODUCTIVITY AND INPUT RATIOS

Dispersion. If there were no systematic relationship between changes in the two partial productivity ratios, we could expect that the mean deviation of the segment or group rates of change in total factor productivity from their mean would approximate a weighted average of the mean deviations of rates of change in the two partial productivity measures from their means. But the measures of dispersion of rates of change in total factor productivity generally fall below the average dispersion of rates of change in the two partial productivity ratios, whether measured over the long period or subperiods (see Table 46).

This indicates that the deviations of segment and group rates of change in the two partial productivity ratios from their means must be inversely correlated. Looked at differently, segment and group rates of change in capital per unit of labor input and output per unit of labor input must be positively correlated. Rank correlation of the latter two variables for the thirty-three groups over the long period yields a coefficient of +.40, significant at the 5 per cent level. Actually, total input per unit of labor input, which gives capital its appropriate weight, is more closely correlated with output per unit of labor input; the Spearman coefficient of rank correlation between these variables for the thirty-three groups is +.60, significant at the 1 per cent level.

Inspection of Table 46 makes it clear that, on the average, the dispersion of rates of change in total productivity is more decisively below the average dispersion in rates of change in the two partial productivity ratios in the subperiods than over the long period. The lesser dispersion is also more pronounced with reference to changes in the thirty-three group rates than in those of the five segments. Dispersion differs somewhat within each segment, as shown in the table.

The fact that there is less difference between group rates of change in total factor productivity than in labor productivity suggests that the same result may obtain in international comparisons. That is, difference in rates of change, and in levels, of productivity among nations might well be less if capital as well as labor input were used in the denominators of productivity ratios. Sufficient information with respect to capital input

TABLE 46

Private Domestic Economy: Comparison of Dispersion in Rates of Change in Productivity Ratios, by Segment, 1899–1953
(per cent)

	MEAN DEVIATIONS OF COMPONENT RATES OF CHANGE FROM RATES OF CHANGE IN THE AGGREGATE							
	Long Period, 1899–1953				*Subperiod Averages*			
	Total Factor Productivity	Output per Unit of Labor Input	Output per Unit of Capital Input	Capital per Unit of Labor Input	Total Factor Productivity	Output per Unit of Labor Input	Output per Unit of Capital Input	Capital per Unit of Labor Input
Covered sector								
5 segments	0.5	0.5	0.6	0.2	1.0	1.1	1.2	1.3
33 groups	0.6	0.6	0.8	0.5	1.3	1.4	1.8	1.8
Segments								
Mining								
5 groups	0.7	0.8	0.4	0.4	1.2	1.3	1.9	1.9
Manufacturing								
20 groups	0.5	0.6	0.5	0.5	1.3	1.3	1.6	1.4
Transportation								
3 groups	0.6	0.6	0.2	0.6	1.2	1.1	1.4	1.5
Communications and public utilities								
5 groups	0.8	1.2	0.8	0.7	1.4	1.5	2.2	1.7

in other countries has not been compiled to make possible a test of this hypothesis.

It can also be seen in Table 46 that dispersion in group rates of change over the long period in capital per unit of labor input is somewhat less than in capital or labor in relation to output. In other words, trends in requirements by industry group for either input provide a better guide to trends in requirements for the other input than do secular changes in output.

Subperiod variability. Variability in rates of change in total factor productivity over the subperiods is generally distinctly less than average variability in subperiod rates of change in the two partial productivity ratios. In fact, variability in subperiod rates of change in total productivity is below the corresponding measure of variability in output per unit of labor input in the segment and group measures, on the average, and in some of the groups as combined by segment (Table 47). The reason behind the greater stability of rates of change in total productivity compared with the partial productivity ratios must be that there is, generally, an inverse correlation between the deviations of the subperiod rates of change in the two partial ratios from their secular rates of change. Or, subperiod rates of change in output per unit of labor input and capital (or total input) per unit of labor input must be positively correlated.[4] To put it differently, in those subperiods in which capital per unit of labor input shows greater-than-average increases, output per unit of labor input often rises by more than the average, while output per unit of capital input tends to show less-than-average increases.

It will also be noted that over the subperiods, movements of capital are generally more closely related to movements of labor input than to movements of output. This is indicated by the lesser variability in subperiod rates of change in capital per unit of labor input than in output per unit of capital input. The greater stability of rates of change in the capital-labor ratio is particularly pronounced in the measure for the covered sector of the economy, but is also significant in the group measures, on the average, and in the manufacturing groups in particular.

The reader who is interested in intermediate- or long-range economic projections will note certain relevant implications of the comparisons of our variability measures. For example, the lesser variability of total factor productivity than of output per unit of labor input suggests that the composite measure would be a better vehicle for projection. Likewise, the capital-labor ratio is a better means of projection than the capital-output ratio, since it shows less than half as much variability in the private

[4] As we noted above, the coefficient of rank correlation is +.40 when changes in the output-labor and the capital-labor ratios are used, and +.60 when changes in the output-labor and total input-labor ratios are used.

TABLE 47

Private Domestic Economy: Comparison of Variability in Subperiod Rates of Change in Productivity Ratios, by Segment, 1899–1953
(per cent)

	MEAN DEVIATIONS OF SUBPERIOD RATES OF CHANGE FROM SECULAR RATE							
	Aggregate Measures				*Component Averages*			
	Total Factor Productivity	Output per Unit of Labor Input	Output per Unit of Capital Input	Capital per Unit of Labor Input	Total Factor Productivity	Output per Unit of Labor Input	Output per Unit of Capital Input	Capital per Unit of Labor Input
Covered sector	1.0	1.0	1.3	0.6				
5 segments					1.2	1.3	1.7	1.6
33 groups					1.4	1.0	2.1	2.0
Segments								
Mining	1.3	1.4	1.5	1.3				
5 groups					1.6	1.3	3.2	2.8
Manufacturing	1.3	1.4	2.1	1.3				
20 groups					1.6	1.6	2.3	1.8
Transportation	0.9	0.9	1.8	2.1				
3 groups					1.4	1.5	3.0	2.7
Communications and public utilities	0.7	0.7	1.8	2.2				
5 groups					1.3	1.5	2.8	2.7

domestic economy as a whole. Also, the lesser variability of all measures for the economy than for the segments or groups means that a projection of an aggregate as a whole is likely to be more accurate than an average of projections of the constituent elements, although the latter would be necessary to forecasts of economic structure.

Annual variability. In the several segments or groups for which annual estimates are available, the mean deviations of annual percentage changes in the productivity ratios from the secular rates are much larger than the subperiod mean deviations. They are generally well above the secular rates of advance themselves. This is also true of the mean deviations of the annual percentage changes in the productivity ratios for the private domestic economy as a whole, but weighted averages of the group mean annual deviations are somewhat larger than those in the aggregate measure (Table 48).

TABLE 48

Private Domestic Economy: Mean Deviations of Annual Rates of Change in the Productivity Ratios from Average Annual Secular Rates of Change, 1899–1953
(per cent)

	Total Factor Productivity	*Output per Unit of* Labor Input	Capital Input
Private domestic economy			
Secular rate of change	1.8	2.0	1.4
Mean deviation of:			
Subperiod rates	0.5	0.5	0.7
Annual rates	3.0	2.9	5.3
Covered groups[a]			
Secular rate of change	1.8	2.3 (2.4)[b]	0.9
Mean deviation of:			
Subperiod rates	1.1	1.4 (1.4)[b]	1.4
Annual rates	4.6	4.1 (4.3)[b]	5.9

[a] Weighted measures for farming, railroads, local transit, electric utilities, telephone communications, and natural gas utilities.

[b] The figures in parentheses include, in addition, mining, manufacturing, and manufactured gas utilities, for which annual estimates of output per unit of labor input alone are available.

It is possibly somewhat surprising that the mean annual percentage deviations of the group and economy total productivity measures lie below the average mean annual percentage deviations of the corresponding partial productivity ratios. As was true in the subperiods, this indicates that annual changes in capital per unit of labor input are positively

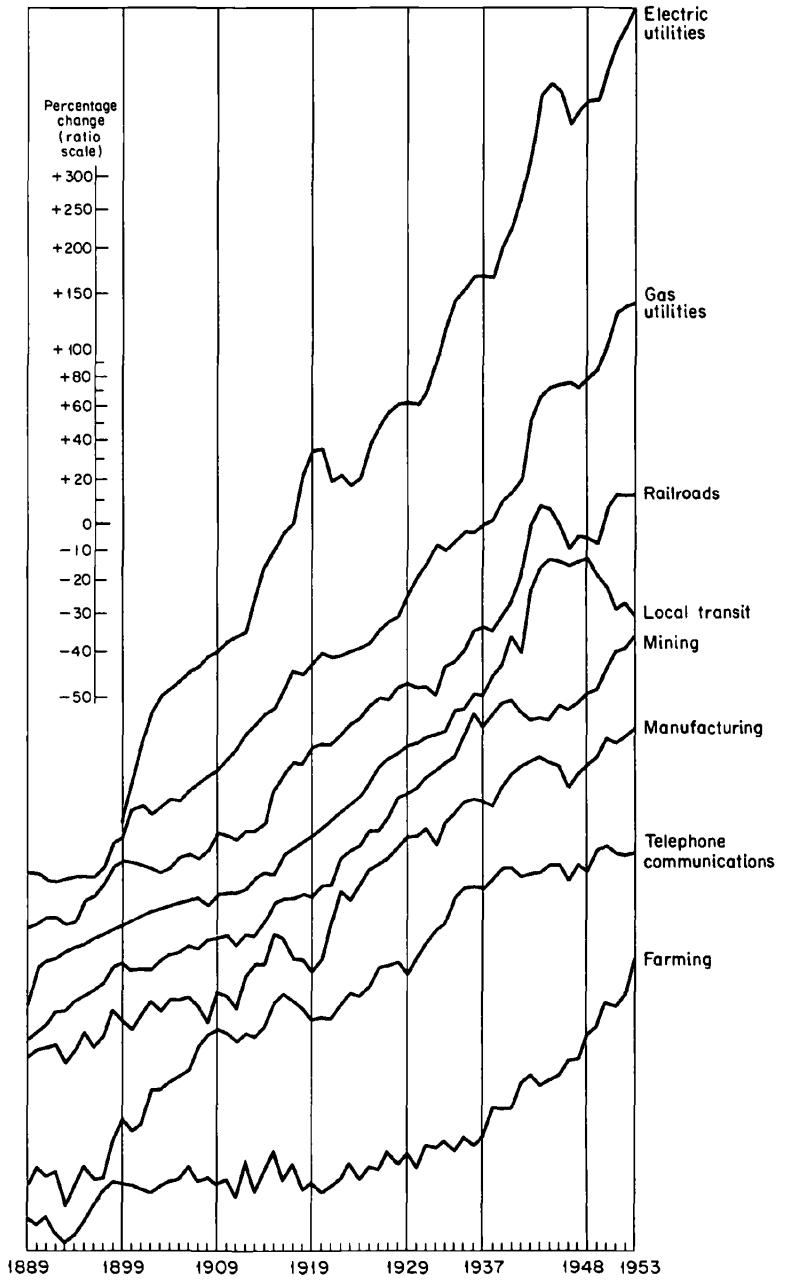
TABLE 49

Private Domestic Economy: Average Annual Percentage Changes in Productivity, Expansions versus Contractions, by Major Segment and by Selected Groups, 1899–1953

	Total Factor Productivity	*Output per Unit of* Labor Input	Capital Input
Private domestic economy			
Expansions	2.7	2.2	4.1
Contractions	−0.3	1.6	−5.2
Farming			
Expansions	1.3	1.5	0.4
Contractions	1.4	3.0	−0.2
Private domestic nonfarm economy			
Expansions	3.0	2.5	4.6
Contractions	−0.5	1.5	−6.2
Mining			
Expansions		2.7	
Contractions		2.2	
Manufacturing			
Expansions		3.4	
Contractions		−0.1	
Railroads			
Expansions	5.1	4.4	7.9
Contractions	−2.8	−0.6	−10.2
Local transit			
Expansions	3.3	3.0	5.4
Contractions	1.0	1.2	−0.3
Electric utilities			
Expansions	7.6	7.9	7.2
Contractions	1.1	3.0	−0.4
Telephone communications			
Expansions	2.8	2.3	3.3
Contractions	0.7	1.6	−1.5
Manufactured gas utilities			
Expansions		5.0	
Contractions		4.6	
Natural gas utilities			
Expansions	3.1	3.3	2.4
Contractions	−0.2	2.8	−5.2

CHART 18

Private Domestic Economy: Output per Unit of Labor Input, by Selected Industry Group, 1889–1953 (1929=100)



correlated with annual changes in output per unit of labor input. Apparently, the tendency for these variables to vary together is strong enough to overcome the tendency in years of recession for capital per unit of labor input to rise (since capital stocks are relatively inflexible), while output per unit of labor input shows less-than-average increases or actual declines.

The importance of the cycle in explaining differences in annual changes in the group or segment productivity ratios is brought out in Table 49 and Chart 18 (see the discussion with respect to the influence of the cycle on economy annual changes in Chapter 3). The tendency for productivity to rise more in expansions than in contractions prevails in all groups for which we have annual measures except farming.

The smaller productivity increases, or actual declines, in nonfarm industries are due principally to a drop in capital productivity as measured; but even output per unit of labor input rises only half as much in contractions as in expansions. In the farm economy, to the contrary, total factor productivity has actually risen somewhat more in general business contractions than in expansions—1.4 per cent compared with 1.3 per cent, on the average. Although farm output is influenced primarily by weather, political controls, and other factors outside the general business cycle, it appears that the squeeze on net farm income that results from the sensitivity of farm prices to the business cycle tends to spur efficiency gains. This may also be true in nonfarm industries, but the adverse effect of falling rates of utilization of capacity more than offsets the tightening up of operations induced by falling profit margins.

Some Forces Underlying Industry Changes

The forces underlying the pervasive productivity advance by industry are highly complex. They comprise the cultural values that affect the motivations of individuals and direct their energies; the socio-economic organization or "institutional" framework that enables or promotes the pursuit of efficiency; and, more directly, the changes in technology that affect the organization, processes, and instruments of production in the individual enterprises of the economy. A discussion of these matters must, of necessity, be somewhat speculative, although reference will be made to some quantitative analyses by ourselves and by another investigator, who used our measures of total factor productivity for the manufacturing industry groups.[5]

Although the quantitative analysis is fragmentary and at best could not be conclusive in the face of the complex interrelationships involved, it is

[5] See Nestor E. Terleckyj, "Factors Underlying Productivity: Some Empirical Observations," *Journal of the American Statistical Association*, June 1958, p. 593; also, his unpublished doctoral dissertation for Columbia University, *Sources of Productivity Change. A Pilot Study Based on the Experience of American Manufacturing Industries, 1899–1953*, 1959.

important to try to explain the causal forces. In order to project changes in relative prices and other structural aspects of the economy, it is necessary to project productivity by industry, a task that requires knowledge of the underlying forces. More important, if we wish to take action to affect productivity advance, we must have knowledge of its causes. This section is but an introduction to the subject, and it is hoped that our productivity indexes will be useful to others who wish to carry the analysis further.

PERVASIVE FORCES

During our review of industry productivity trends, we remarked that despite differences in rates of change, all industry groups advanced over the long period, and practically all smaller component industries did likewise. Indeed, average rates of increase were heavily concentrated at between 1.0 and 3.0 per cent a year. This indicates that there are certain broad, pervasive forces that promote productive efficiency throughout the economy. Before taking up reasons for differences among industries, we shall consider some factors that have a fairly even incidence on all industries.

The social factors alluded to above are usually taken for granted by the inhabitants of a nation and often overlooked in explaining economic developments. Yet the values of a people and the institutions through which they work are fundamental, although the actions taken to alter the productive mechanism are more apparent and immediately related to productivity change. The prevalence of similar values and institutions throughout our society is a major reason for the breadth of productivity advance. We shall discuss several of the more important social factors briefly; they are not generally susceptible to quantification.

A prerequisite for productivity increase is the *desire* for material advance on the part of the people of a society—not for fixed goals, the attainment of which removes incentive for further advance, but for standards of living that continually stay ahead of attained levels. A rising standard of living has been characteristic of the United States, and it has been strengthened by the crafts of advertising. The desire for material advance has not been directed solely toward rising consumption levels, however; it has embraced the goals of providing increased capital for future generations and a broader material base for national security.

Another basic social value, which is in line with our liberal heritage, is the belief in maintaining maximum economic as well as political freedom consistent with the general welfare. Our concepts of the proper role for government activity have changed as the economy has evolved; but in general, public opinion has favored retention of the maximum possible role for individual initiative. This has helped foster a creative and dynamic economy.

When coupled with the institutions of private property, the profit motive, and competition, economic freedom has been a powerful means of promoting the material welfare of the community as well as of the individual. This tenet of economic liberalism is based on the premise that each person, seeking to maximize his income, will employ his labor and capital in their most productive uses. Further, in order to increase their profits, entrepreneurs develop and introduce new products or cost-reducing methods of producing existing products. Under the spur of competition, other firms of an industry must imitate the management of firms that have pioneered the innovations, or else their profit margins disappear, and they go into bankruptcy. Thus, prospective profit is the carrot and competition the stick that motivate progress. Other systems of rewards and penalties are possible, but it has yet to be demonstrated that they are as effective in achieving productivity advance; and, certainly, they do not allow as much scope for individual freedom, which many people value even more than material progress.

The reports of many European productivity teams that have visited the United States stress the importance of a relatively high degree of competition in spurring technological progress. Some writers, to the contrary, have maintained that a degree of market control is conducive to progress, since the greater financial strength and stability of sheltered firms make possible the large-scale research and development work necessary for continuous innovation.

In an attempt to test these hypotheses, Nestor Terleckyj correlated rates of total productivity advance in manufacturing industry groups with each of two measures of phenomena related to the extent of competition in the several industries. One is a measure of rates of entry, based on the number of births of new firms relative to the size of the industry groups as measured by value added. The other is a measure of concentration, representing weighted averages of the proportions of sales accounted for by the four largest firms in the 4-digit industries constituting the manufacturing-industry groups (see Table 50).

There is no significant correlation between productivity changes and levels of these two measures. It would seem either that there is a sufficient degree of competition throughout American industry to provide a fairly uniform stimulus to productivity advance and, therefore, interindustry differentials are due to other factors, or that the negative aspects of competition, if any, approximately offset the positive effects on productivity change. This conclusion is tentative, since the two measures used are not ideal indexes of the extent of competition.

Besides institutional factors, there are forces that directly affect technology across a broad industrial front. Most industries benefit from the growth of the whole economy: As markets become more concentrated,

TABLE 50

Entry of New Firms, Entry Rates, and Concentration Ratios, by Industry Group, 1947 and 1948

	New Firms, 1948	Firms in Operation at Beginning of 1948	Entry Rate, 1948[a]	Concentration Index 1947[b]
	(number in thousands)			
All industries	393.3	3872.9	102	
Manufacturing	34.6	315.4	110	
Foods incl. beverages	3.5	39.0	90	35.9[c]
Textile mills	0.7	9.2	76	21.9
Apparel	4.1	39.7	103	11.1
Lumber, basic products	10.9	49.7	219	20.6
Furniture	1.4	12.3	114	20.3
Paper and products	0.3	3.7	81	22.0
Printing, publishing	2.3	39.8	58	19.7
Chemicals	0.9	11.5	78	45.8
Petroleum, coal products	0.1	0.9	111	39.6
Rubber products	0.1	1.0	100	77.2
Leather and products	0.5	6.9	72	26.2
Stone, clay, glass products	1.3	13.8	94	44.3
Primary metals	0.4	5.7	70	42.1
Fabricated metals	2.2	20.7	106	28.4
Machinery, nonelectric	2.2	22.8	96	37.5
Electric machinery	0.5	4.8	104	62.2
Transportation equipment	0.5	5.3	94	86.3
Miscellaneous incl. tobacco	2.7	28.6	94	31.6[d]
Mining and quarrying	5.3	36.3	146	
Contract construction	65.0	310.3	209	
Trade	275.6	1984.7	139	
Transportation, communications and public utilities	23.9	175.9	136	
Finance, insurance, real estate	16.0	322.4	50	
Services	72.9	728.0	100	

SOURCE: Betty C. Churchill, "Recent Business Population Movements," *Survey of Current Business*, Dept. of Commerce, January 1954, pp. 15 and 16; and Nestor E. Terleckyj, *Sources of Productivity Change. A Pilot Study Based on the Experience of American Manufacturing Industries, 1899–1953*, unpublished doctoral dissertation, New York, Columbia University, 1959, based on *Report of the Federal Trade Commission on Changes in Concentration in Manufacturing, 1935 to 1937 and 1954*, 1954. The entry rate shown here is not the same as the one used by Terleckyj.

[a] Number of new entries per 1,000 firms in operation.

[b] Weighted averages of the proportions of sales accounted for by the four largest firms in the Standard Industrial Classification 4-digit industries constituting the manufacturing industry groups.

[c] Excluding beverages, for which the index is 33.5.

[d] Excluding tobacco, for which the index is 76.4.

greater specialization is made possible, and the average education and training of the labor force is increased. Progress in certain strategic industries benefits all. For example, as transportation and communication facilities have improved, it has been possible for industry to reduce inventory-sales ratios and thus increase total productivity. Certain types of new products developed by the machinery and other producer industries have broad applications across industry lines. Examples include office equipment, furnishings, and supplies; materials handling equipment; and heating, lighting, and power equipment. Innovations made in more specialized industries may also have applications across industry lines. Such "linked" innovations probably spread with some lag, as is suggested by the variability of industry ranks over the subperiods that we noted earlier in the chapter. But linked innovations are a cause of widespread productivity advance over longer periods.

So far, the factors discussed are ones believed to affect most, if not all, industries. Even these pervasive forces may have a somewhat different impact by industry. But the main forces explaining relative industry changes in productivity are the ones that directly affect the technology of the individual industries.

FORCES WITH DIFFERENTIAL IMPACT

Terleckyj has done a rather elaborate quantitative study of the relationship between changes in our estimates of total productivity and ten explanatory variables for twenty 2-digit and up to twenty-five 3-digit manufacturing industry groups for one or more of our subperiods or combinations of subperiods between 1899 and 1953. On the basis of simple rank correlations, multiple regressions, and graphic techniques, he concluded that three of the explanatory variables were significantly related to relative industry rates of change in productivity: rates of change in output, amplitudes of cyclical fluctuations, and ratios of research and development outlays to sales or of research and development personnel to total manhours worked. The reader who wants the technical details of the Terleckyj study may refer to the sources noted. We observe here only that neither the simple nor the multiple correlation coefficients were very high; they varied considerably from one period to another, as between subperiods and longer periods, and also as between the analysis based on the 2-digit and that based on the 3-digit industry groups. Yet, the findings are suggestive.

In the light of our a priori discussion of causal forces in Chapters 1 and 4, it is not surprising that the three variables named above turned out to be significant in explaining relative changes in productivity. On the other hand, in view of the deficiencies of the measures and the complexity of the underlying forces, it is also not surprising that the unexplained variance in

both the simple and multiple correlations remained relatively large. We turn briefly to a discussion of the reasons why each of the three explanatory variables may be significant, and of the limitations of these measures.

Research and development activity. Since technological change is a chief cause of productivity advance, measures of innovational activity in the various industries should be significantly correlated with relative productivity changes. But even if we could catalogue all the innovations made by the firms of each industry in successive periods, further difficulties would be met in trying to weight each in accordance with its relative importance. At best, only indirect measures of innovational activity, such as the number of patents issued, are possible.

Perhaps the best indirect measure is research and development outlays in relation to sales, of which estimates are available for recent periods (see Table 51). Estimates by industry of research and development

TABLE 51

Research and Development Outlays, Dollar Volume and Ratios to Sales, by Manufacturing Industry Group, 1953

	Research and Development Expenditures	Estimated Sales	Research and Development Expenditures Relative to Sales
	(millions of dollars)		(per cent)
All manufacturing	3,467.8	293,871	1.180
Foods	46.7	40,160	0.116
Beverages	7.5	7,874	0.095
Tobacco	4.0	4,248	0.094
Textiles	25.1	12,927	0.194
Apparel	2.9	11,848	0.024
Lumber products	27.6	7,328	0.377
Furniture	24.7	3,835	0.644
Paper	27.9	8,442	0.330
Printing, publishing	22.4	9,127	0.245
Chemicals	361.1	18,997	1.901
Petroleum, coal products	145.9	25,492	0.572
Rubber products	53.6	5,000	1.072
Leather products	17.8	3,512	0.507
Stone, clay, glass	38.0	6,906	0.550
Primary metals	59.8	23,264	0.257
Fabricated metals	103.3	15,885	0.650
Machinery, nonelectric	318.9	24,170	1.319
Electric machinery	743.3	17,429	4.265
Transportation equipment	1,111.0	36,387	3.053
Miscellaneous	326.3	11,040	2.956

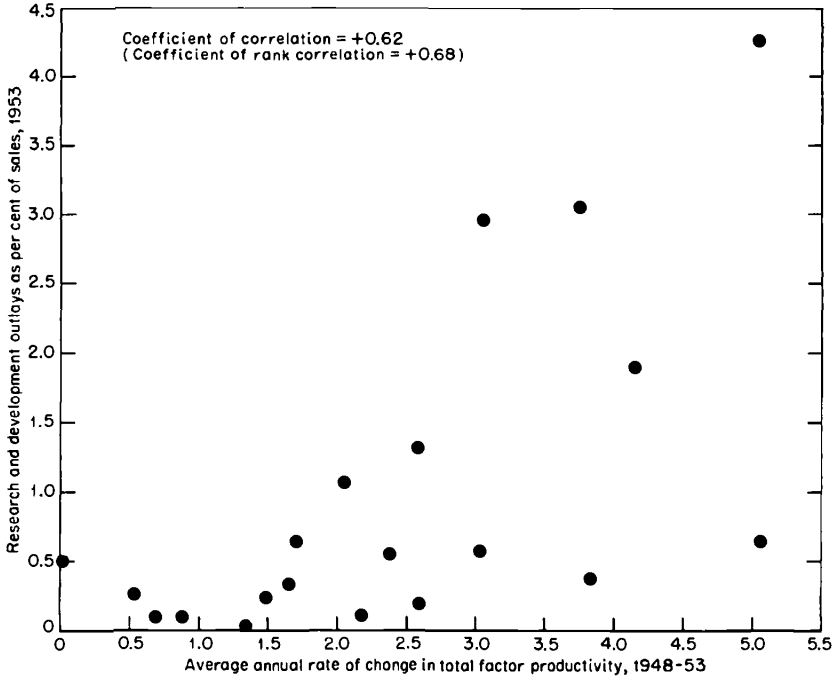
SOURCE: Nester E. Terleckyj, *Sources of Productivity Change.* The research and development expenditures are based on *Science and Engineering in American Industry, Final Report on a 1953–1954 Survey*, National Science Foundation, NSF 56-16, Washington, 1956; sales estimated from *Statistics of Income, 1953*, Internal Revenue Service; and *Census of Manufactures, 1947.*

personnel in relation to total employment or manhours, which Terleckyj also used, have the advantage of being available for prewar years. These measures indicate the relative intensity of investment in activities designed to produce commercially applicable inventions and, thus, eventual innovation.

Despite a relatively good correlation with productivity changes (see Chart 19), the measures of research and development intensity are not

CHART 19

Twenty Manufacturing Groups: Relation between Rates of Change in Total Factor Productivity, 1948–53, and Ratios of Research and Development Outlays to Sales, 1953



ideal indicators of the relative flows of innovation. Some innovation results from unorganized activities, such as changes conceived of by works managers or by production workers and other nonresearch employees (or by proprietors, in the case of noncorporate enterprise). Some of the most important developments affecting the productivity of an industry may originate with equipment manufacturers or suppliers in other industries. Government research is important for certain industries, such as agriculture. Basic scientific research carried on in universities and in

government and nonprofit organizations, as well as in business firms, may have widespread application across industry lines. Further, the volume of commercially applicable inventions resulting from research and development outlays will vary from time to time and from industry to industry, due to chance. There will also be different time-lags between the development of an innovation and its commercial application, although changes in research ratios are probably gradual enough so that use of lagged relationships would not significantly change the relationships of subperiod averages.

It is interesting that Terleckyj's net regression coefficients indicate that rates of productivity advance differ by approximately 0.5 per cent for each tenfold difference in research intensity.[6] Since the logarithms of the research-intensity ratio are related linearly to productivity change, the effect of a given absolute increase in the research and development ratio on productivity advance becomes less the larger the ratio.

A related measure used by Terleckyj is the ratio of numbers of engineers and chemists per 10,000 employees in the several industries. The bulk of the engineers are not engaged primarily in organized research and development work, and the proportion has undoubtedly changed over time. Although the engineer and scientist ratios were significantly related to the research and development ratios, they are not related to productivity changes except in the simple correlations for the last subperiod.

Another indirect approach to the volume of innovational activity is by measures of financial strength in the various industries. Presumably, firms with relatively high rates of return on capital would be more disposed to spend money on research and development (which, in turn, should contribute to earnings) and would be in a better position to borrow funds than firms with less satisfactory earnings. Further, firms with a good financial position would be better able to make the necessary investment to improve efficiency, both from retained earnings and loans—which would be easier to arrange and probably cost less than if profit margins were lower.

As a by-product of our input estimates, we were able to compute rates of return on invested capital for the thirty-three industry groups for 1929–53 and the three component subperiods. The coefficients of rank correlation between the rates of return and the rates of change in total factor productivity turned out to be not significant.

Relative changes in industry output. As shown in the next chapter, there is a significant degree of correlation between relative changes in output and in total productivity for the thirty-three industry groups over the long period and in most subperiods. Terleckyj found the same result with respect to the twenty manufacturing groups. His net regression coefficient

[6] See Terleckyj's dissertation, p. 64.

indicates that for every 3 per cent difference in growth rates among industries, productivity advance differed by about 1 per cent, on the average.[7] This relationship cannot be interpreted as reflecting primarily the effect of relative changes in scale. Index numbers of output provide, at best, a crude measure of the effects of scale. Furthermore, interpretation is complicated because a two-way relationship is involved.

We have already noted that an increase in industry output makes possible increased specialization of production among the plants and firms of an industry and the emergence of new industries providing specialized services, materials, or equipment which further reduce real unit costs. Growth also provides a favorable environment for innovation, whether output is expanded by an increase in the number of firms or by an increase in size of firms as optimum size itself is increased by technological progress. In either case, the planning of new facilities spurs rethinking of production technology. It is also clear that a larger proportion of plant and equipment is of the newest, most efficient type in an expanding industry than in one in which new-equipment purchases are chiefly for replacement.

There are several drawbacks, however, to using relative changes in output as an indicator of the relative impact of economies of scale. Such economies do not occur automatically, and it is unlikely that they bear a linear, or any other regular, relationship to output. External economies may be greater in one phase of industry expansion than in another; by the same token, similar rates of expansion in different industries probably result in different degrees of induced advance in efficiency, with possible lags of differing length.

In the second place, other factors favorable to productivity advance are intercorrelated with rates of growth. Terleckyj's correlations indicate that rapidly growing industries tend to employ more engineers and do more research, are composed of somewhat larger firms and plants, are more concentrated, have slightly greater barriers to entry, and are subject to less frequent business fluctuations. Thus, rates of growth stand for a complex of interconnected factors and cannot indicate external economies alone.

Possibly the most important objection to the growth measure as an explanatory variable is that it is intercorrelated with productivity itself. That is, autonomous innovations may reduce the relative cost and price of the products of an industry; the relative quantity sold will expand as a consequence if demand is price elastic and other demand influences are equal. In this case, the relative expansion of output is a result of the relative rise in productivity. Yet, the increased output, in turn, may be expected to result in economies of scale that will reinforce the productivity

[7] *Ibid.*, p. 62.

advance. Growth of productivity and output not only induces economies of scale, but may also create conditions more favorable to autonomous innovation—such as by strengthening the financial position of the firms involved so that more resources may be devoted to research and development.

In any case, it is clear that the output-productivity relation does not provide an unambiguous measure of scale effects. The picture is complicated further by the possibility that part of the positive association may be spurious (see Chapter 7). Recognizing the mutual influence of relative changes in output and productivity, Terleckyj tried relating productivity changes to the measures of research intensity and cyclical amplitude alone. These two variables jointly explained about 55 per cent of the variability in rates of productivity change for 1919–53, but were less successful for shorter periods.[8]

Cyclical and structural factors. Terleckyj's simple rank correlations reveal a significant degree of correlation between amplitude of cyclical fluctuation and productivity change in 3-digit manufacturing industries in the 1929–37 subperiod. There was a significant but lower coefficient of correlation between frequency of cyclical fluctuation and productivity change in the 2-digit groups in the 1948–53 subperiod. But only the amplitude measure showed up as significant in the multiple regressions. In part, this may occur because frequency of cyclical fluctuation shows a higher and more consistent negative correlation with growth than does the measure of cycle amplitude.

It seems plausible that wide cyclical fluctuations should adversely affect the average productivity of an industry. Some degree of organizational stability is prerequisite to steady improvements in productive efficiency. Frequent or large changes in the size of staff of firms, or cyclical fluctuations in the number of firms in business, would not seem to be conducive to innovation. This factor has often been mentioned as a reason for technological backwardness in the construction industry, for example. The associated lack of financial stability would hardly promote a policy of expenditures for research and development and would have an adverse effect on access to financial markets for investment funds. On the other hand, it could be argued that mild fluctuations provide a spur to efficiency. In Terleckyj's regressions, differences in cyclical amplitude were much less important than differences in research intensity in explaining relative productivity changes.

It might be argued that certain industries, because of various structural features, are more susceptible to innovation than others. Terleckyj introduced several variables of this sort into his correlations: ratios of

[8] *Ibid.*, p. 96.

capital stock to manhours worked; and average sizes of plants and firms in the various industries (as measured by average numbers of employees and average total dollar assets, respectively). None was significantly associated with productivity change in any of the statistical approaches. It is interesting that the average sizes of plants and firms were highly correlated with the measures of concentration and entry that were not correlated with productivity advance, as noted above. We also tried a measure of the ratio of purchased materials to the value of output and found this, too, to be unrelated to relative productivity changes.

CONCLUDING OBSERVATIONS

Although the explanatory variables included in the multiple correlations with relative rates of productivity change by industry reflect what are probably the major factors influencing productivity—innovation, scale, and business cycles—it is not surprising that about half the variance remains unexplained.

In the first place, there are undoubtedly errors in the estimates of the variables. For example, the productivity indexes (except for agriculture) are based on the assumption that gross and net industry output show the same movements, whereas true net output series may have somewhat different movements from gross series.

Secondly, it should be emphasized again that research and development outlays are only an indirect indication of the volume of innovation. Not only are variable lags involved, but identical outlays probably result in different amounts of eventual cost reduction. Results cannot be predicted accurately when the outlay is authorized, and the chance element must be substantial. This is supported by the presence of greater fluctuations in industry ranks with respect to productivity change than with respect to research and development outlays.

Further, research and development expenditures are not the only source of innovations. Although we did not succeed in identifying differences of industry structure that have a bearing on relative productivity change, it does seem reasonable to suppose that some industries are more amenable to cost reduction than others, and more so at one period than another. Also, the rates at which initial innovations spread over the firms of an industry undoubtedly differ from one period to another and from one industry to another. It is likewise probable that the effects on industry organization of proportionate changes in scale, if the scale factor could be isolated, would be found to vary between time periods and industries.

Finally, there are other factors that affect productivity besides changes in industry output and the intensity of investment designed to produce innovation. We have mentioned that the pervasive forces affecting the economy as a whole may have a somewhat different industry impact.

For example, the growth of management consulting services, as the economy has grown, is of greater advantage to the firms of some industries than of others. The rate of innovation may also be affected by additional specific factors, such as availability of financing, average entrepreneurial ability, and so forth, that we could not quantify.

At least, empirical analysis lends modest support to our deductive reasoning as to the forces that are important in explaining productivity advance. It is also significant in appearing to eliminate certain hypotheses, such as those that associate different degrees of competition in various industries with different rates of productivity change.