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Volume Title: Employment in Manufacturing, 1899-1939: An Analysis of Its Relation to the Volume of Production

Volume Author/Editor: Solomon Fabricant

Volume Publisher: NBER

Volume ISBN: 0-87014-040-X

Volume URL: <http://www.nber.org/books/fabr42-1>

Publication Date: 1942

Chapter Title: Employment, Output and Related Quantities in Individual Industries

Chapter Author: Solomon Fabricant

Chapter URL: <http://www.nber.org/chapters/c4876>

Chapter pages in book: (p. 83 - 113)

Chapter 4

Employment, Output and Related Quantities in Individual Industries

IN THE preceding chapter, which was devoted to trends in labor per unit, we found that in five out of every six industries covered by our data there was a reduction in the number of workers employed to make a unit of product. In turning now to observe the behavior of employment and of output in individual industries, we shall try to determine how growth in these magnitudes was related to the rate at which their unit labor requirements declined. Once we have established the relationship, we shall consider what factors might have helped to shape it, and in particular whether growth in capital and reductions in costs and prices have played significant roles in its formation.

EMPLOYMENT, OUTPUT AND LABOR PER UNIT

As one might well expect, individual industries varied widely with respect to changes in both employment and output from 1899 to 1937. At the same time there is observable a high degree of correlation between the trends in production and in number of workers within particular industries (Table 6). Employment fell to one twenty-fifth in the industry making carriages, wagons and sleighs and was multiplied 210 times in automobile manufacture; the same industries supply the extremes for changes in output, the former registering a decline to one twentieth and the latter an 1800-

TABLE 6

INDIVIDUAL MANUFACTURING INDUSTRIES

Percentage Changes in Physical Output, Number of Wage Earners, and Wage Earners per Unit of Product, 1899-1937

<i>Industry</i>	<i>Physical Output</i>	<i>Wage Earners</i>	<i>Wage Earners per Unit of Product</i>
	Percentage Change, 1899-1937		
<i>Foods</i>			
Meat packing	66	85	12
Flour	-8	-18	-10
Rice	416	241	-34
Fruits and vegetables, canned	792	213	-65
Butter, cheese and canned milk	460	157	-54
Beet sugar	1,690	375	-73
Cane sugar	86	29	-30
Ice	668	173	-64
<i>Beverages</i>			
Liquors, malt	60	19	-26
Liquors, distilled	315	153	-39
<i>Tobacco products</i>			
Cigars	0.0	-44	-44
Chewing and smoking tobacco	-6	-65	-63
<i>Textile products</i>			
Cotton goods	101	42	-30
Woolen and worsted goods	60	25	-22
Silk and rayon goods	512	79	-71
Knit goods	506	177	-54
Carpets and rugs, wool	52	8	-29
Cordage and twine	38	7	-23
Jute goods	134	45	-38
Linen goods	-44	-43	0.3
Hats, fur-felt	26	-16	-33
Hats, wool-felt	90	92	2
<i>Leather products</i>			
Leather	61	-3	-40
Shoes	87	52	-19
Gloves	29	-3	-25
<i>Rubber products</i>			
Shoes	59	28	-20
<i>Paper products</i>			
Paper and pulp	518	177	-55

<i>Industry</i>	<i>Physical</i>	<i>Wage</i>	<i>Wage Earners</i>
	<i>Output</i>	<i>Earners</i>	
	Percentage Change, 1899-1937		
<i>Printing and publishing</i>			
Total	494	78	-70
<i>Chemical products</i>			
Chemicals, industrial, incl. com- pressed gases and rayon	2,500	693	-70
Cottonseed products	63	51	-8
Wood-distillation products	259	184	-21
Explosives	267	20	-67
Fertilizers	248	80	-48
Paints and varnishes	391	228	-33
Salt	82	-3	-47
Tanning and dye materials	292	71	-56
<i>Petroleum and coal products</i>			
Petroleum refining	1,920	583	-66
Coke-oven products	380	21	-75
<i>Stone, clay and glass products</i>			
Glass	553	50	-77
<i>Forest products</i>			
Lumber-mill products	-32	-20	19
Turpentine and rosin	-32	-22	15
<i>Iron and steel products</i>			
Blast-furnace products	171	-41	-78
Steel-mill products	313	162	-36
<i>Nonferrous-metal products</i>			
Copper	272	28	-66
Lead	51	-51	-68
Zinc	318	132	-45
<i>Transportation equipment</i>			
Automobiles, incl. bodies and parts	180,000	21,300	-88
Carriages, wagons and sleighs	-95	-96	-33
Cars, railroad	-22	9	39
Locomotives	-79	-53	126
Ships and boats	-17	33	61

Source: Appendix F.

fold rise.¹ Though less spectacular than the great increases in the automobile industry, growth in both output and employment was very rapid also in the manufacture of chemicals, in petroleum refining and in fruit and vegetable canning; and at the other end of the scale there was slow growth or even decline in output and employment not only in carriages and wagons but in the industries producing railroad locomotives, lumber-mill products, flour, and chewing and smoking tobacco.

While changes in output and employment were closely related, increases in output tended to be greater than the corresponding rises in employment, as we already know from study of the labor-product ratio. More novel is the finding, plotted in Chart 15, that the breach between growth in output and growth in employment was usually wider among the rapidly growing industries than among the laggard ones. This is shown by the fact that the slopes of the regression lines (the dotted lines) fitted to the points in Chart 15 are both greater than 45 degrees (the slope of the solid line). The difference between rate of growth in output and employment is measured also, of course, by the decline in workers per unit. This decline was greatest in the automobile industry, which is to be credited also with the greatest expansions in output and employment. In industrial chemicals the product increased 2,500 percent and employment 690 percent, but employment per unit fell by 70 percent, a very sharp decline indeed. In lumber mills, on the other hand, output actually fell by 32 percent and employment by 20 percent; the result was a 19 percent *increase* in employment per unit.

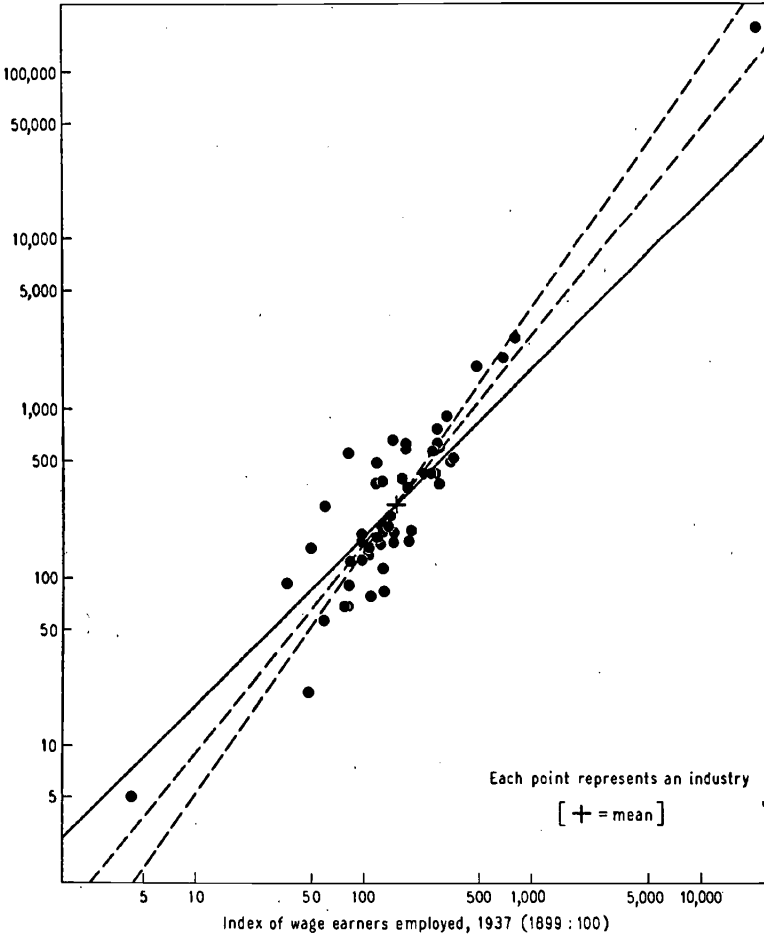
There are some exceptions to the general findings just set forth. In meat packing, for example, the number of workers employed increased 85 percent, almost as much as in total

¹The coefficient of rank correlation between percentage changes, 1899-1937, in output and employment in the 51 industries listed in Table 6 is .86. The coefficient of correlation between logarithms of the original indexes is .93.

Chart 15

RELATION BETWEEN INDEXES OF WAGE-EARNER EMPLOYMENT AND OF PHYSICAL OUTPUT, 1937 (1899 : 100)

Index of physical output, 1937
(1899 : 100)



Based on Table 6

For an explanation of the lines see the accompanying text

Double logarithmic scale

manufacturing, yet employment per unit of product rose 12 percent. A few other industries also fail to conform to the dominant pattern. But by and large there was an inverse relation between change in both output and employment and the movement of labor per unit of product.²

²The coefficient of rank correlation between change in employment and in employment per unit is $-.31$; and between change in output and in employment per unit of output, $-.73$. The former coefficient is so low that it scarcely seems to differ significantly from zero. However, it should be noted that errors of measurement would in themselves tend to cause a *positive* correlation between changes in employment and those in employment per unit, and a *negative* correlation between changes in output and those in employment per unit.

The relations found above may be checked by fitting regression lines to the logarithms of the points in Chart 15. The lines obtained are as follows, with Q representing the index of output (1937 on the 1899 base), N the index of employment, and a and A being constants which need not be specified:

$$\log Q = a + 1.23 \log N, \text{ and}$$

$$\log Q = A + 1.43 \log N.$$

(Exclusion of the extreme point for automobiles or of the extreme points for both automobiles and carriages and wagons does not change the slopes of the regression lines in any important degree.) These equations may be transformed into:

$$\log \frac{N}{Q} = -a - .23 \log N, \text{ and}$$

$$\log \frac{N}{Q} = -A - .43 \log N;$$

or

$$\log \frac{N}{Q} = a' - .19 \log Q, \text{ and}$$

$$\log \frac{N}{Q} = A' - .30 \log Q.$$

According to these results, the relation between $\frac{N}{Q}$ and N is inverse, as is also the relation between $\frac{N}{Q}$ and Q . This confirms the signs of the correlations given in the preceding paragraph.

As noted above, random errors tend to cause employment (or output) and employment per unit of product to be correlated. It is for this reason that we have studied these relations indirectly, through the data on employment and on output. But the employment and output indexes are also subject to error, and to some extent to common errors. Those of the latter type (e.g., variation in degree of coverage by the Census) will cause measurable changes in employment and output to be related. However, these errors affect both indexes to the same relative extent; they therefore tend to cause the slopes of the regression lines to be 45 degrees, not what we find them to be.

The inverse relation noted between the 38-year changes in employment and

These relationships are expressed somewhat differently in Chart 16, in which industries are ranked in descending order of increase in output. The bars representing declines in the employment-output ratios shrink from left to right, just as do the bars that stand for changes in output and employment. (If the industries were to be arranged in descending order of increase in employment, we would find a similar order for output, and an inverse order for employment per unit, though there would be less regularity of relationship.) In the industries that expanded output rapidly, even a substantial cut in the number of men employed per unit was not usually accompanied by a decline in jobs. In those with only a moderate rise in output, a decline in the ratio of men employed to units produced ordinarily meant rather slow growth in employment, and sometimes actually fewer jobs. On the other hand, the few industries that increased the number of workers per unit usually reduced the total number of their employees because they were the ones to suffer declines in output.

The same general conclusions apply to the relations between output, aggregate manhours, and manhours per unit of product. According to the records given in detail below

in employment per unit is absent for shorter periods. Indeed, the measurable correlations appear to be mildly positive, though these may easily be due to chance errors of measurement. For output and employment per unit, on the other hand, the correlations are negative even during the shorter periods; but these results, too, must be qualified because of the possibility of spurious correlation. The coefficients of rank correlation between percentage changes in employment and employment per unit, and output and employment per unit, are as follows:

<i>Period</i>	<i>Coefficient of Rank Correlation between Changes in:</i>	
	<i>Employment and Employment per Unit of Product</i>	<i>Output and Employment per Unit of Product</i>
1899-1909	+ .17	— .46
1909-1919	+ .12	— .25
1919-1929	+ .03	— .57
1929-1937	+ .17	— .54

Percentage change

200,000

20,000

10,000

8,000

6,000

4,000

2,000

1,000

800

600

400

200

100

0

-20

-40

-60

-80

-90

-95

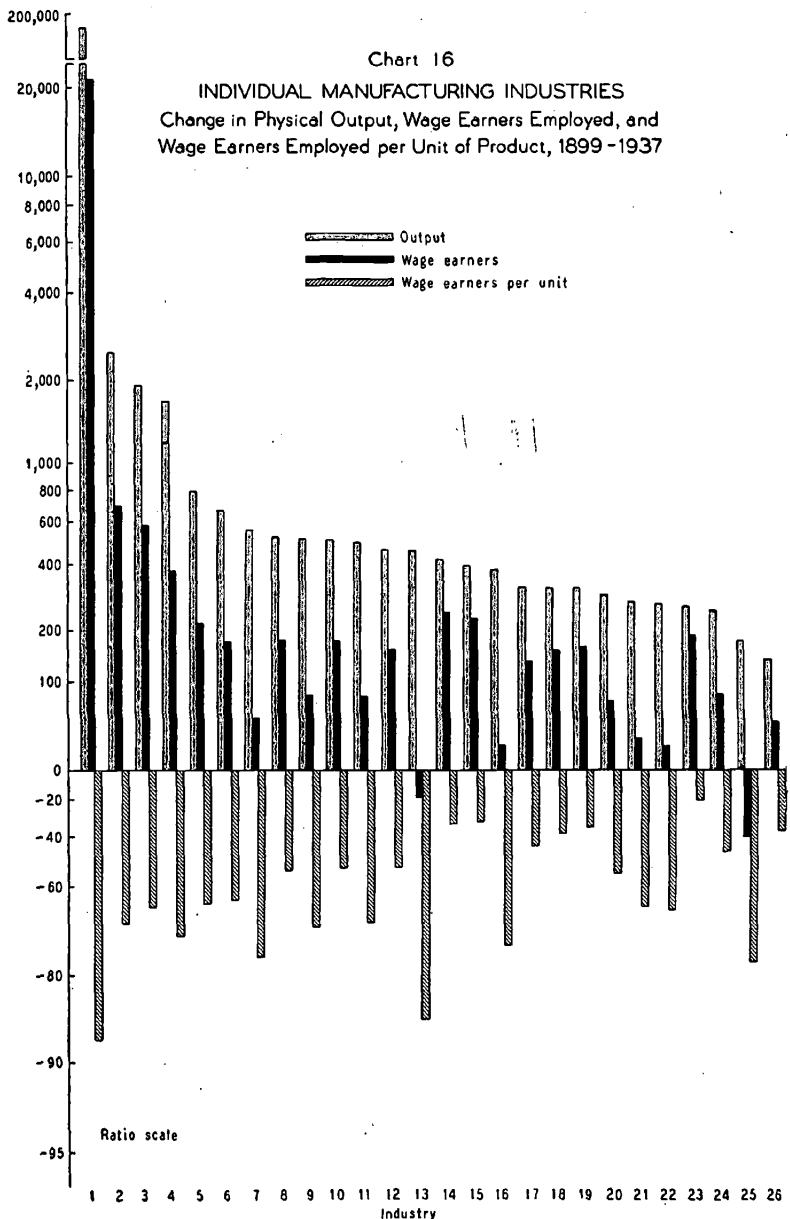
Ratio scale

Chart 16

INDIVIDUAL MANUFACTURING INDUSTRIES
Change in Physical Output, Wage Earners Employed, and
Wage Earners Employed per Unit of Product, 1899-1937

Output
Wage earners
Wage earners per unit

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Industry

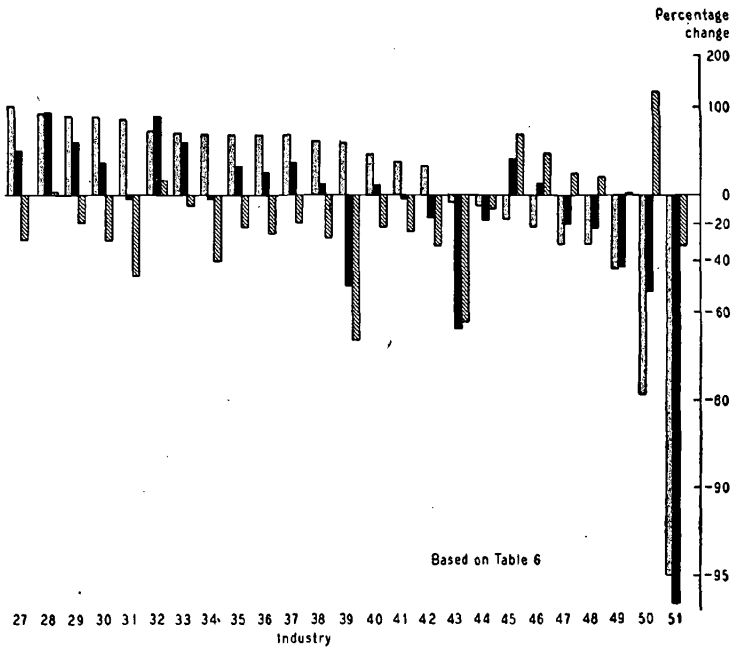


INDUSTRY

- 1 Automobiles, incl. bodies and parts
- 2 Chemicals, industrial, incl. compressed gases and rayon
- 3 Petroleum refining
- 4 Beet sugar
- 5 Fruits and vegetables, canned
- 6 Ice
- 7 Glass
- 8 Paper and pulp
- 9 Silk and rayon goods
- 10 Knit goods
- 11 Printing and publishing, total
- 12 Butter, cheese and canned milk
- 13 Cigars
- 14 Rice
- 15 Paints and varnishes
- 16 Coke-oven products
- 17 Zinc
- 18 Liquors, distilled
- 19 Steel-mill products
- 20 Tanning and dye materials
- 21 Copper
- 22 Explosives
- 23 Wood-distillation products
- 24 Fertilizers
- 25 Blast-furnace products
- 26 Jute goods

INDUSTRY

- 27 Cotton goods
- 28 Hats, wool-felt
- 29 Shoes, leather
- 30 Cane sugar
- 31 Salt
- 32 Meat packing
- 33 Cottonseed products
- 34 Leather
- 35 Woolen and worsted goods
- 36 Liquors, malt
- 37 Shoes, rubber
- 38 Carpets and rugs, wool
- 39 Lead
- 40 Cordage and twine
- 41 Gloves, leather
- 42 Hats, fur-felt
- 43 Chewing and smoking tobacco
- 44 Flour
- 45 Ships and boats
- 46 Cars, railroad
- 47 Lumber-mill products
- 48 Turpentine and rosin
- 49 Linen goods
- 50 Locomotives
- 51 Carriages, wagons and sleighs



(Table 8, pp. 102-04), available only for 1909-37 and for fewer than 51 industries, exceptionally rapid growth in output was associated with above-average increase in total manhours and with unusually drastic cuts in manhours per unit. Slow growth or actual decline in output was accompanied by less-than-average increase in total manhours and by relatively small declines in the manhour-output ratio.³

The interrelations among trends in employment, in output and in labor input per unit of manufactured goods pose a number of problems. They bring into question, for example, the role played by capital investment and other factors of production in growing and declining industries; the connection between unit labor requirements and wage costs; the effect of changes in costs of materials and overhead; the course of selling prices in relation to changes in unit labor requirements. Because of the limited scope of this report and also because data are inadequate, we cannot deal with all these problems, or fully with any of them. In the remainder of this chapter we shall, however, inquire briefly into long-run changes in one kind of capital, namely, that represented by fixed capital assets, and into modifications in hourly earnings of labor, labor costs, value added per unit, and selling

³ There is one important difference between the conclusions concerning change in number of workers and those concerning change in number of manhours. Since hours of labor fell, an above-average increase in manhours frequently meant a rather slight absolute increase in manhours, while an above-average rise in number of workers indicated an unusually large absolute increase in number employed. Similarly, a below-average change usually meant for manhours a rather severe absolute reduction, rather than the slow rate of growth or mild decline that a below-average change indicated for absolute number employed. (The data in Table 8 apply, of course, to the shorter period 1909-37, and exclude the decade of expanding output and employment beginning with 1899. It is partly for this reason that so few increases in manhours appear in the table. But it is hardly likely that extension of the table back to 1899, if this could be done accurately, would materially affect the conclusion stated in the text.) Thus, only 10 of the 19 industries in Table 8 with above-average increase in output and decline in manhours per unit had increases in manhours, while 17 had increases in number of wage earners. Of the other 19 industries, 17 were characterized by declines in manhours, and 5 showed rises in employment.

prices, in an endeavor to determine the relation between these developments and those already noted for output, employment and labor per unit. Since the industrial classification of capital assets varies from that of costs and prices, and because there is no uniformity in the time periods for which data are available, we shall have to treat capital assets apart from the other factors to be reviewed.

CAPITAL ASSETS

A swelling stock of capital goods is only one of the means by which the level of output is raised, and there may be cases of industrial growth in which capital assets have increased only slightly, or not at all. It is conceivable, too, that capital assets, by displacing other factors of production, have grown even in some declining industries. Yet what we can learn of industrial history from the rather crude information at hand bears out the generalization that the expansion of an industry has seldom been accomplished without an influx of capital; and that the aggregate volume of assets in declining industries has, as a rule, contracted. In the automobile industry, for example, total assets rose from less than \$6 million in 1899 to \$1,780 million in 1919. By 1937 automobile manufacturers held over \$3,100 million in assets.⁴ In rayon, another rapidly growing industry, total investment in the principal companies (measured in this case by stockholders' investment plus long-term borrowing) increased from \$8 million in 1915 to \$30 million in 1919, \$228 million in 1929, and \$281 million in 1937.⁵ On the other hand, total

⁴ The figures for 1899 and 1919, which include assets other than fixed assets, are taken from the Census of Manufactures; that for 1937 has been obtained from *Statistics of Income, 1937, Part II*. The last figure covers all assets held by automobile corporations, including investments in business other than motor vehicles.

⁵ Principal rayon companies, covering 99 percent of total production of rayon and yarn and staple fiber in 1920, 94 percent in 1929, and 88 percent in 1937. A Study Submitted by the Federal Trade Commission to the Temporary National Economic Committee, *Part 31* (1941), pp. 17982 and 17988.

assets held by manufacturers of carriages and wagons, including materials and parts, amounted to \$152 million in 1904, \$175 million in 1909, \$177 million in 1914, and—despite the great rise in prices—only \$97 million in 1919. And for marble and stone work, another industry which reached its peak early in the period, the corresponding figures are: \$79 million in 1904; \$115 million in 1909; \$118 million in 1914; and \$113 million in 1919.⁶

Allowance for price changes, revaluations, differences in coverage and other incomparabilities in the statistics would modify the contours of these pronounced trends only slightly. Yet this statement is an admission, too, that available data on capital are difficult to interpret when trends are not so well defined as to obviate the need for precise statistics.⁷ Even from such sparse information as we can command it is possible, however, to make a few observations.

It was noted above that employment rose most rapidly in the industries whose output also rose at record speed. If, in addition, better-than-average increases in output have been associated with a rising volume of capital equipment, as is likely, then growth in capital has coincided with growth in employment more often than with decline in employment. Despite some deficiencies, the available statistics reinforce this inference. In Table 7 we present percentage changes between 1904 and 1937⁸ in book values of net capital assets and other series for groups of manufacturing industries and for two individual industries. The capital data are uncorrected for price changes, their industrial classification is not quite identical with that underlying the employment and output data, and the groupings are often rather heterogeneous. Yet certain conclusions are obvious. The largest in-

⁶ Figures for both declining industries are from the Census of Manufactures. Data for subsequent years are not available.

⁷ See Appendix E.

⁸ Unfortunately, lack of data prevents comparisons over periods consistent in length with those used in other tables in this volume.

TABLE 7

GROUPS OF MANUFACTURING INDUSTRIES

Indexes of Output, Number of Wage Earners, Net Book Value of Capital Assets and Derived Ratios, 1937 relative to 1904

1904: 100

<i>Industrial Group</i>	<i>Physical Output</i>	<i>Number of Wage Earners</i>	<i>Capital Assets^a (net book value)</i>	<i>Wage Earners per Unit of Product</i>	<i>Capital Assets per Wage Earner</i>	<i>Capital Assets per Unit of Product</i>
Foods	281	217	432	77	199	154
Beverages	183	130	188	71	144	102
Tobacco products	313	59	283	19	483	90
Textile products	223	155	230	70	149	103
Leather products	147	125	126	85	101	86
Rubber products	..	294	890	..	303	..
Paper products	467	212	621	45	293	133
Printing and publishing	386	158	292	41	185	76
Petroleum refining	1,660	496	5,450	30	1,100	329
Chemical and coal products	542	218	443	40	203	82
Stone, clay and glass products	..	110	363	..	329	..
Forest products	100	95	308	95	325	309
Iron and steel products	309	198	432	64	218	140
Nonferrous-metal products	..	175	267	..	153	..
Electrical machinery	..	483	781	..	162	..
Machinery, other than electrical	..	188	258	..	138	..
Automobiles, incl. bodies and parts	36,000	3,980	12,300	11	308	34
Transportation equipment, other than automobiles	58	76	308	131	407	534
Miscellaneous products	..	162	773	..	478	..
TOTAL MANUFACTURING	302	166	438	55	264	145

Sources: The indexes of output are from Appendix F, except that for chemical and coal products, which was specially computed for this table, according to our usual procedure. The indexes of wage earners are based on data in Appendix Table B-1; and those of capital assets are constructed on the basis of information collected in Appendix E.

^a Exclusive of land.

creases in employment over the 33-year period 1904-37 occurred in those groups in which fixed capital investment also rose most rapidly. Automobile manufacture, petroleum refining, electrical machinery, chemicals and rubber products stand out in this respect. And among the groups with relatively slight growth in employment are also those with less-than-average increases in capital assets: tobacco, beverages, leather, textiles, forest products, and transportation equipment (other than automobiles). Exceptions exist, of course—one of them is nonelectrical machinery manufacture—but the correlation remains impressive.⁹

Not only has there been a strong bond between employment and capital trends in manufacturing industries, but there has been a tendency for capital assets per worker, as well as for total capital assets, to rise more rapidly in growing than in declining industries.¹⁰ Increase in means of production—machines, tools, structures—has accompanied rise in output and, at the same time, decline in unit labor requirements.

Investment lessens employment per unit of product by increasing the volume of capital assets made available to each worker, and by augmenting the scale of operations and the volume of output. Since capital additions are likely to be improvements over existing equipment, investment helps to reduce labor per unit further than would otherwise be the case. Indeed it provides one of the major channels through which technological advances cut into unit labor input. Many such technological innovations take on concrete form only through changes in the character of new capital goods. Such embodiment of new ideas may occur not only in net additions to capital, but also through the reinvestment of funds freed by capital consumption, such as depreciation, though

⁹ The coefficient of rank correlation is .71.

¹⁰ The coefficient of rank correlation between changes in output and in capital assets per worker is .27. The coefficient of rank correlation between changes in aggregate capital assets and in output is .71.

the speed with which improvements in tools, equipment and structures are put into operation is stepped up when the stock of capital assets is growing and not merely maintained. Even if the stock of capital assets held by an industry rises less rapidly than employment—and even if aggregate assets (deflated for price changes) decline—new investment or replacement can help reduce labor per unit. Although employment fell in relation to output in all groups listed in Table 7, in some of them the rises in book value of capital assets per worker were almost negligible, and in some there were actual declines in capital assets per unit of product.¹¹

The conclusions just stated derive quite simply from the premise that improvements are continually being effected in the capital goods utilized by all industries. If we can assume further that the rate of innovation in techniques has been greater, on the average, in rapidly growing industries than in the mature or stagnant ones—and this is not at all unlikely—then the rate of increase in the average “quality” of capital goods would usually be higher in the growing industries. Thus capital investment would tend still further to cut unit labor requirements in the thriving industries, and to stimulate even greater increases in their output.

UNIT COSTS AND PRICES

In preceding pages we have considered certain aspects of the development of manufacturing industries since 1899. We have found that the most rapidly growing industries were, as a rule, those with better-than-average increases in employment and capital assets as well as output, and with the

¹¹ Even the increases in book value of capital assets per worker shown in Table 7 do not all reflect growth in the physical stock of capital goods per worker. Some part of these increases is attributable to the upward movement of prices. Rises of as much as 50 percent in capital assets per worker or per unit of product might easily be accounted for by the price increases between 1904 and 1937. For all manufacturing combined the most acceptable estimate of the rise in the prices underlying book values of capital assets is around 80 percent. (See Appendix E.)

sharpest reductions in labor per unit. The industries that lagged in pushing up output were also usually backward in raising the number of their workers and the stock of their capital goods; moreover they tended either to cut labor per unit only slightly or actually to raise it. In this section we shall trace the course followed by unit costs and prices in growing and declining industries, and note how costs and prices have behaved in relation to growth in output and employment and to decline in labor per unit. First of all we shall describe briefly the pattern we discover among the changes in the several indexes.

Chart 17 brings together the various quantities for 25 industries: unit wage costs, unit value added (selling price minus unit cost of materials and fuel), and selling price, in addition to manhours, output, and manhours per unit—material already familiar to the reader. By ranking each industry, as we do in the chart, with respect to each of the 6 series,¹² the rather complex picture described by the original indexes (given in Table 8 below), is seen in a clearer light.

Even a casual glance at the chart indicates a tendency toward similarity of ranks. For example, the automobile industry ranks high, while lumber manufacture stands low, in respect of each quantity. Averages of the ranks in each row of Chart 17 differ from one another more widely than one would expect if the variation were a matter merely of chance.¹³

A still simpler picture emerges if the 25 industries in

¹² Unit labor requirements, value added per unit, wage cost per unit, and selling price are ranked in reverse order.

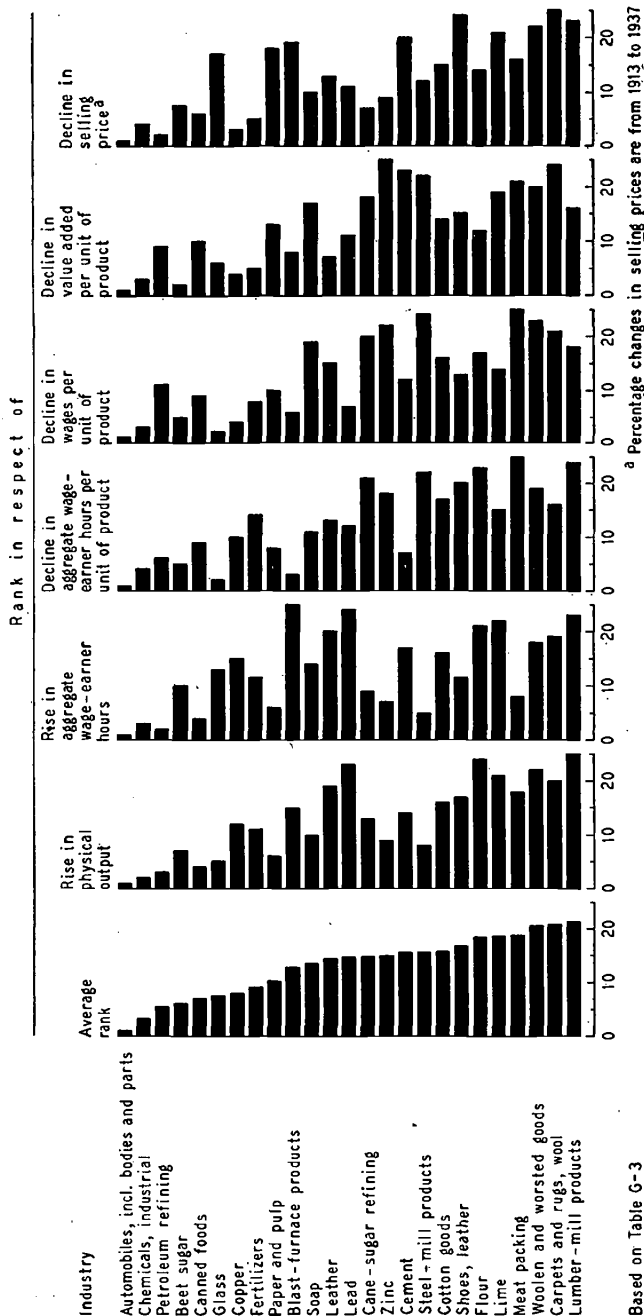
¹³ Milton Friedman's "method of ranks" (*Journal of the American Statistical Association*, Dec. 1937, pp. 675-701) was applied as a test, with the result indicated in the text.

The "coefficient of concordance" for the ranked data in Chart 17 is .57. Since the value of this ratio approaches unity when all ranks in each row become identical, and zero when they are entirely unrelated (see W. Allen Wallis, *Journal of the American Statistical Association*, Sept. 1939, pp. 533-38), there is an appreciable degree of concordance among the ranks of all six series.

Chart 17

INDIVIDUAL MANUFACTURING INDUSTRIES

Ranked According to Change in Unit Costs, Prices and Other Economic Quantities, 1909-37^a



Based on Table G-3

Chart 17 are divided into two groups, the 12 in the upper half with respect to each one of the quantities, and the 13 in the lower half. If the rankings were purely matters of chance, we would expect no pronounced consistency of position. About one third of the industries would be ranked above average in respect of three quantities and below average in respect of the other three; about one half consistently above (or below) average for four quantities and below (or above) for two; about one fifth, consistently above (or below) average for five quantities; and the remainder, less than one twentieth, consistently above (or below) average for all six quantities.¹⁴ In fact, we find almost the reverse frequencies. Ten of the 25 industries are consistently high (or low) for all 6 series; 6, for 5 series; 5, for 4 series; and 4 are divided equally. In other words, five industries—automobiles, petroleum refining, chemicals, beet sugar and canned foods—are above average in increase in output, increase in manhours of employment, decrease in unit labor requirements, decrease in wage cost per unit, decrease in value added per unit, and decrease in selling price of products. Five others—cotton goods, woolen and worsted goods, carpets and rugs, lime, and lumber—are below average in all these respects. Fertilizers and copper are above average in five respects; meat, flour, leather and shoes, below average in five respects.¹⁵

It is clear that a pattern is to be found in the mosaic of changes defined summarily by Chart 17 and in detail by Table 8. Industries with most rapid rates of growth in output and employment and deepest cuts in labor per unit (three concomitant characteristics, as was noted in earlier sections), are also those with lowest increases (or actual decreases) in wage cost per unit, value added per unit, and selling price.

¹⁴ These theoretical frequencies were computed by reference to the coefficients of the terms in the binomial expansion of $(\frac{1}{2} + \frac{1}{2})^6$. A slightly more correct procedure would be based on $(\frac{12}{25} + \frac{13}{25})^6$, but this is hardly worth while.

¹⁵ Some degree of spurious correlation undoubtedly affects these results, but it is impossible to say just how seriously. It is very difficult to believe that the spurious element alone accounts for the relations noted.

And the laggard industries, in which output and employment fell or rose but slightly, are characterized not only by rises or modest cuts in labor per unit but also by greater-than-average increases in unit wage costs, in value added per unit, and in selling price.

So much for a summary of the pattern outlined by Chart 17. A more detailed description of the interrelationships defined by the chart will be obtained if we trace the rather devious connection between changes in labor per unit and changes in volume of output. In the course of this analysis we shall note (1) how reductions in manhours per unit have tended to coincide with reductions in costs; (2) how lowering of costs has been associated with downward revisions of price; and finally, (3) how decline in price has been accompanied by increase in sales. In studying these links in the chain between labor per unit and output we shall cover all the factors included in Table 8 and mention some others in addition.

The first relationship to be described is that between unit costs and unit labor requirements. Here it is necessary to look into changes in wage rates and their bearing on unit wage costs; and then note the possible effects of changes in non-labor costs, as well as wage costs, upon total costs per unit of product.

Now it is true that reductions in manhours per unit were accompanied by increases in wage cost per unit more frequently than by cuts.¹⁶ One reason, of course, is the rise in the general level of wage rates. As the data assembled in Table 8 indicate, wage rates (measured roughly by average hourly earnings)¹⁷ rose in all manufacturing industries between 1909 and 1937, with increases ranging from 87 to 300

¹⁶ Labor per unit may be measured either by workers per unit or by manhours per unit. Workers per unit did not move identically with manhours per unit, but changes in the two are sufficiently proportionate to permit interchangeable citation in the present context. This is true also of aggregate employment and aggregate manhours.

¹⁷ Average hourly earnings should not be regarded as exact measures of wage rates because, among other reasons, they relate to groups of workers inconstant with respect to occupation and skill.

TABLE 8
 INDIVIDUAL MANUFACTURING INDUSTRIES
 Indexes of Unit Costs, Prices and Other Economic Quantities,
 1937 relative to 1909^a
 1909:100

Industry	Physical Output	Aggregate Wage-Earner		Value Added	Wages per Hour	Wages per Wage Earner	Wages per Unit of Product	Value Added per Unit of Product	Selling Price
		Hours	per Unit of Product						
<i>Foods</i>									
Meat packing	130	110	85	244	306	234	260	188	152
Flour	84	53	63	116	268	210	169	138	145
Canned fish, fruits, and vegetables	445	179	40	583	302	205	121	131	104
Beet sugar	264	91	35	184	267	188	92	70	111
Cane-sugar refining	162	94	58	278	303	191	175	171	111
<i>Beverages</i>									
Liquors, distilled	319	106	33	44	382	277	127	14	..
<i>Tobacco products</i>									
Total	270	39	15	376	261	183	38	139	..
<i>Textiles</i>									
Cotton goods	146	74	50	218	328	212	164	148	145
Woolen and worsted goods	111	62	56	199	367	234	203	179	170
Silk and rayon goods	342	78	23	203	307	203	70	59	..
Knit goods	350	116	33	377	383	248	127	108	..
Carpets and rugs, wool	118	58	49	252	357	224	176	213	226
Hats, fur-felt	80	42	53	126	297	196	157	158	..

Industry	Physical Output	Aggregate			Aggregate			Value Added per Unit of Product	Wages per Wage Earner	Wages per Hour	Value Added per Unit of Product	Selling Price
		Wage-Earner Hours	Wages	Value Added	Wage-Earner Hours per Unit of Product	Wages per Hour	Wages per Unit of Product					
<i>Leather products</i>												
Leather	126	57	191	146	46	334	234	152	116	140		
Shoes, leather	143	81	207	214	57	256	178	145	149	193		
<i>Paper products</i>												
Paper and pulp	328	129	430	474	39	334	237	131	144	154		
<i>Printing and publishing</i>												
Total	286	108	314	355	38	290	234	110	124	..		
<i>Chemicals</i>												
Chemicals, industrial, incl.												
rayon and compressed gases	1,370	365	1,210	1,190	27	332	227	88	87	85		
Cottonseed products	113	78	146	165	69	187	151	129	146	..		
Soap	178	80	307	296	45	385	284	173	167	129		
Explosives	151	62	200	196	41	322	233	133	131	..		
Fertilizers	177	81	206	191	46	254	180	116	108	87		
Paints and varnishes	291	176	518	494	61	293	233	178	170	..		
<i>Petroleum and coal products</i>												
Petroleum refining	1,080	392	1,430	1,300	36	365	240	132	120	64		
<i>Stone, clay and glass products</i>												
Cement	158	62	222	334	39	360	225	141	211	160		
Lime	112	52	163	197	46	313	229	145	176	168		
Glass	361	80	258	412	22	323	225	72	114	153		

TABLE 8 (concluded)

Industry	Physical Output	Aggregate				Value Added	Aggregate Wage-Earner Hours per Unit of Product	Wages per Hour	Wages per Wage Earner	Wages per Unit of Product	Value Added per Unit of Product	Selling Price ^a
		Aggregate Wage-Earner Hours	Wages	Value Added	Hours per Unit of Product							
<i>Forest products</i>												
Lumber-mill products	69	47	118	112	68	250	194	171	163	183		
<i>Iron and steel products</i>												
Blast-furnace products	151	39	154	180	25	400	257	102	119	160		
Steel-mill products	224	135	478	457	60	354	239	213	204	138		
Wire	135	92	329	343	68	357	242	245	255	..		
<i>Nonferrous-metal products</i>												
Copper	172	76	156	155	44	205	168	91	90	84		
Lead	92	42	102	127	45	243	188	110	138	137		
Zinc	212	116	398	454	55	344	235	188	215	118		
<i>Transportation equipment</i>												
Automobiles, incl. bodies and parts	5,010	423	1,550	1,280	8.4	368	245	31	26	60		
Cars, railroad	82	65	202	225	79	314	235	246	274	..		
Locomotives	20	47	166	199	242	351	276	854	1,020	..		
Ships and boats	109	110	371	357	101	338	242	341	328	..		

^a The base for the index of selling price is 1913.

Sources: The sources for most of the indexes have been cited in earlier tables. The data on value added and wages were obtained from the Census of Manufactures; and on selling price, from the Bureau of Labor Statistics bulletins on

wholesale prices, together with indexes given in Frederick C. Mills' *Prices in Recession and Recovery* (National Bureau of Economic Research, 1936), Appendix V, extended through 1937 in the present study.

percent. Despite these large advances in wage *rates*, increases in wage cost per unit of product were low in many industries, and in several there were actual declines in wage cost per unit. Furthermore, and this is the significant conclusion, the industries with low increases or actual declines in wage cost per unit were those in which manhours per unit were reduced most, whereas the largest rises in wage cost per unit occurred in industries with the smallest cuts (or actual increases) in manhours per unit. In short, there was an appreciable correlation between changes in wage cost per unit of product and changes in manhours employed per unit.¹⁸ According to Table 8 there were seven industries in which wage cost per unit of product declined between 1909 and 1937, despite the fairly considerable rises in the Bureau of Labor Statistics index of wholesale prices (28 percent, 1909 to 1937) and in its index of cost of living (45 percent from 1913, the first year available, to 1937). And it is in these industries—beet sugar, tobacco products, silk and rayon goods, chemicals, glass, copper, and automobiles—that unit labor requirements fell by exceptionally large percentages.¹⁹

The change in an industry's unit labor requirements may

¹⁸ The coefficient of rank correlation is .87. Because the two series correlated are not independently constructed (they were derived by dividing indexes of wage payments and of manhours, respectively, by indexes of output) there is some danger of spurious correlation.

¹⁹ The coefficient of rank correlation between changes in aggregate manhours and in wages per worker is .30. Dr. Wesley C. Mitchell points out that while changes in wages per worker may not be highly correlated with rates of growth in employment or output, average amounts paid in a given year to workers attached to an industry, whether fully employed or not, may be correlated with rates of growth in employment and output in that year or in the period immediately preceding. For it is likely that workers in declining industries suffer to an exceptional degree from unemployment, part-time, and short hours, which cut down their annual earnings. It seems safe to say, however, that some part of the social gains yielded by reductions in real costs per unit seem to have reached workers in every industry, regardless of the particular gains made in the industry employing them, for the coefficient of correlation between changes in unit labor requirements and in wages per worker is only —.05.

exercise considerable influence on its unit labor cost. But it is total fabrication cost, rather than labor cost alone, that may be expected to affect prices and output. And changes in labor costs and in total costs of manufacture are never in precise one-to-one correspondence, because changes in nonlabor costs usually differ from changes in wage costs, and because the proportion of total factory cost accounted for by payrolls varies from industry to industry.²⁰ Yet there has been a strong correlation between changes in the total cost of fabrication and changes in aggregate manhours employed, as well as between fabrication costs per unit and unit labor requirements (Table 8).²¹ Despite the rise in wholesale prices already mentioned, value added (costs of fabrication, including profits) per unit fell in 6 industries, 5 of these being among those which cut wage cost per unit. Just as unit labor requirements declined most in the industries that grew most rapidly in terms of output, so the value added to each unit fell most (or rose least) in the advancing industries; and in the backward industries, just as unit labor requirements shrank least, so value added per unit also declined least.²² The obvious explanation is that labor cost constitutes an important portion of the total costs of fabrication. It is possible, too, that nonlabor factory costs tend to drop more sharply in rapidly growing, than in stagnant, industries. If this is true, and the data on capital assets previously discussed seem to suggest that

²⁰ See Charles A. Bliss, *The Structure of Manufacturing Production, A Cross-Section View* (National Bureau of Economic Research, 1939), pp. 63 and 70. Dr. Bliss shows in his detailed analysis of the Census data for 1929 that wage costs ranged from less than 5 percent of value of product to slightly more than 55 percent, and from less than 10 percent of value added (value of product less cost of materials and fuel) to a top figure of 65 percent.

²¹ The coefficient of rank correlation between unit labor requirements and fabrication cost per unit (measured by value added, the difference between value of products and cost of materials) is .78.

²² The relation between growth in output and change in value added or value per unit is discussed in more detail in Chapter 5 of *The Output of Manufacturing Industries, 1899-1937* (National Bureau of Economic Research, 1940), pp. 104-20.

it is,²³ then reductions in nonlabor costs per unit would tend to augment, rather than to offset, the effects of reductions in unit labor requirements.

Up to this point we have looked into the relation between labor per unit and costs of fabrication per unit. We have found that the industries in which labor per unit fell drastically are also those in which wage cost per unit of product usually fell or rose less than the average, and that the value added by these industries per unit (i.e., their unit costs of fabrication, including profits) was reduced or pushed up only slightly in comparison to the increase in total value added per unit in all factories. Industries in which reductions in labor per unit lagged were also slow to reduce unit wage costs and costs of fabrication per unit.

The next link in the chain we are tracing between unit labor requirements and output is that between unit costs of fabrication and unit prices. Here the relation is quite naturally affected by the cost of materials per unit of product, by the character of the particular industry, and the prevailing state of competition. The unit cost of materials is a function not only of the price of materials, but also of the amount of materials consumed per unit of product. But changes in prices of materials and savings in materials used per unit are too complex to be dealt with summarily. It is also impossible to remark both briefly and accurately upon the extent of, and the industrial variation in, the degree of monopoly. Aside from the weighty theoretical problem of measuring monopoly power, there are the serious practical difficulties arising not only from the lack of statistical data but from the changing status of individual industries in respect of the control they can exercise over the relation between their unit costs and their prices. Ironically enough, the very fact that an industry may be highly integrated makes it impossible for the Bureau

²³ Though here, too, there is danger of spurious correlation.

of the Census to publish separate data for it without revealing confidential information. For this reason the aluminum industry, among others, has never been shown separately in the Census of Manufactures.²⁴ Despite the paucity of data, there is no doubt that material costs and price controls, as well as changes in costs of fabrication, affect selling prices, and that they do so in varying degree from industry to industry. Here also, therefore, there is loose articulation in the structure of the relationships we are tracing, and considerable room for variation, as is observable from the indexes of selling prices collected in Table 8. Owing to gaps in the data, the indexes of selling prices cover the period 1913-37 rather than 1909-37, but the difference of 4 years is hardly likely to affect the results appreciably. Outweighing by far this slight disadvantage is the fact that the indexes of selling prices were obtained from a non-Census source.²⁵ There is therefore no danger of spurious correlation, so that one does not tend to question the fairly considerable degree of correlation found to exist between changes in value added per unit and in selling prices.²⁶ Between wage cost per unit and selling price, and between unit labor requirements and selling price, too, the correlation is fairly definite.²⁷

So far we have seen that industries at the head of the list with respect to reductions in manhours per unit are also, as a rule, those with greatest reductions in unit costs of fabrication and selling prices. The final link between labor per unit and output is the connection between selling price and output. This relation depends on the nature of the demand for the product, which is conditioned, of course, by the prices

²⁴ Up through 1937 aluminum production was included in "industrial chemicals," and beginning with 1939 in "primary nonferrous metals."

²⁵ Prices could have been derived from Census reports, and for practically all industries for which output data are available, but the advantage of an independent source would have been lost.

²⁶ The coefficient of rank correlation is .57.

²⁷ The coefficients of rank correlation are, respectively, .49 and .39. These measures, too, are free from spurious correlation.

of related commodities, whether competitive or complementary. Thus the demand for gasoline at a specified price depends on such variables as the number of motor cars competing for road space, the price of rubber tires, and so on; and the nature of the demand for lumber is a function of the price of steel, brick, and cement, as well as of wage rates in the construction industry. Since elasticities of demand vary from industry to industry and period to period, no single or rigid relation between the trends we have analyzed is to be expected. Yet the correlation between changes in output and those in selling price is quite definitely negative, and fairly substantial (Table 8).²⁸

Actual cuts in selling price, despite the average rise in wholesale prices, were effected in the industries producing fertilizers, copper, chemicals, petroleum products and automobiles. The last three increased their output far more than the other industries listed in the table. The first two also pushed up production more than the remaining industries for which we have indexes of selling prices. The greater increases in price, on the other hand, apply to those products, notably lumber and flour, which usually either lagged in growth or actually declined.

The foregoing analysis has proceeded from change in unit labor requirements to change in output, in an attempt to trace the connection between them. We have observed that rate of decline in labor per unit has been associated with rate of decline in unit cost of fabrication; that costs of fabrication, in turn, have fallen or risen with selling price; and finally, that selling price has dropped most precipitately in industries in which output has climbed most rapidly. The causal sequence may run in the other direction as well. Growth in output, whatever the initial stimulus, will tend to eventuate in economies of large-scale production, one of which frequently is a reduction in unit labor requirements. Capital

²⁸ The coefficient of rank correlation is $-.66$.

equipment is more readily acquired when output is rising. As we have noted above, there is a fairly strong correlation between trends in output and in capital assets. Organizational changes are more easily introduced in growing industries. Even the rate of improvement and innovation in equipment, methods and organization may be stimulated more in growing than in declining industries. In this concatenation of relationships, also, we find reason to anticipate some degree of correlation (though not a high one) between decline in employment per unit of output and growth in output.

We have now completed a rather sketchy survey of the intricate chain of relationships between changes in unit labor requirements and changes in output. We have said nothing, however, about the character of the equally complex relation between changes in manhours of employment and in unit labor requirements. It will be remembered that these also have been negatively correlated, just as have changes in output and in unit labor requirements.

The basis for an understanding of the inverse relation between labor per unit and manhours is implicit in the evidence already presented in Table 8. We can develop it further by taking explicit note of one aspect, not previously mentioned, of the relation between trends in unit labor requirements and in output, and showing how it illuminates the relation between trends in unit labor requirements and in manhours. The fact to be observed is that movements in labor per unit, in contrast to output movements, were tightly clustered together. The changes in labor per unit ranged, for the industries listed in Table 8, from a decline of 92 percent to a rise of 142 percent, whereas the changes in output varied from a drop of 80 percent to a gain of 4,900 percent. That is, extraordinarily large increases in output, relative to the average change in output, were associated with comparatively moderate decreases in unit labor requirements, also measured in relation to the average movement;

while large declines in output (again compared with the average change in output) were associated with relatively moderate declines in manhours per unit. This relation is not difficult to explain. New uses for a product develop after its unit labor requirement, initially, and its price, eventually, have fallen, and old uses formerly too costly for wide application no longer are impracticable. It is probable, too, that the industries with the most rapid rates of growth are also predominantly those whose products are characterized by demands elastic with respect to income or price or both. Even moderate reductions in labor per unit and thus in selling price would then be accompanied by large increases in output. It is this that explains why trends in unit labor requirements have been negatively correlated with trends in man-hour employment, as well as with trends in output.²⁹

Employment trends, it should be apparent by now, are an important thread in the pattern of industrial development

²⁹ Let us consider the relation that would exist between labor per unit and employment if the degree of variation in labor per unit equaled or exceeded the degree of variation in output (remembering always, of course, that labor per unit and output are negatively correlated). Let us suppose, first, that given percentage changes in output (relative to the average change) were negatively associated with changes of *like* degree in unit labor requirements (also measured by reference to the average). In this case, there would be *no* significant correlation, positive or negative, between trends in unit labor requirements and trends in manhours. This does not mean that manhours would not fall in relation to output, but rather that manhours would not rise *more* rapidly (or less rapidly) in industries drastically cutting unit labor requirements than in those reducing these requirements, only moderately. Now suppose that given percentage changes in output (relative to the average change) were negatively associated with changes of *greater* degree in unit labor requirements (measured against the average). In this case, the correlation between trends in manhours and in unit labor requirements would be *positive* rather than negative. Especially drastic declines in unit labor requirements would then be associated with relative declines in manhours of employment rather than with relative rises; and conversely for especially moderate declines in labor per unit of product. In fact, however, neither of these cases is to be found. The degree of variation among changes in unit labor requirements was neither greater than, nor equal to, the degree of variation among changes in output. The former was less than the latter. As a consequence, then, changes in unit labor requirements were negatively correlated with changes in manhours of employment.

To restate the argument, a negative correlation between trends in unit labor requirements and trends in output is not inconsistent, at least logically,

described in this chapter. Employment shot up most rapidly, as a rule, in manufacturing industries characterized by speed of technological change, by influx of capital at rates in excess of average investment, by particularly sharp cuts in unit labor requirements and unit labor costs, by lowered (or only slightly increased) selling prices and by especially rapid expansion in output. Employment tended to rise slowly or actually to decline in industries where innovation was slow, capital investment was moderate or absent, unit labor requirements and unit wage costs fell only slightly or moved upward, selling prices were raised rather than lowered, and output lagged or declined.

The above analysis of changes during specific periods,³⁰ namely, the three or four decades preceding the present war,

with a positive, negative or zero correlation between trends in manhours and in unit labor requirements. Let

$$\log \frac{N}{Q} = a - b \log Q, \text{ in which } N \text{ is employment (manhours)}$$

and Q is output, while a and b are parameters. If b is positive, then in the derived relation

$$\log \frac{N}{Q} = \frac{a}{1-b} - \frac{b}{1-b} \log N,$$

$\frac{b}{1-b}$ may be either positive or negative, depending on whether b is greater or less than unity. Whether both correlations are negative or not depends, therefore, on the magnitude of the slope of the line of relationship between trends in unit labor requirements and in output. This slope is, in fact, less than unity, as is reasonable on *a priori* economic grounds.

³⁰ It should be stressed that the preceding analysis has merely touched upon certain crucial problems. Further investigation is definitely indicated; in particular, one should tap other sources for independent series of hourly earnings and unit labor requirements (i.e., series not derived from the data on output and employment, but obtained from different sources), expand the number of industries examined, study other periods of time, and seek to include data on costs and quantities of materials and other nonlabor factors of production. It would be desirable, too, to explain more fully the high degree of variation that seems to characterize the relationships noted. Not all industries with rapidly declining unit labor requirements, for example, have expanded output rapidly; nor have all industries with rapidly declining unit labor requirements cut their selling prices more than industries in which unit labor requirements fell only slightly.

suggests a more or less systematic relationship between the level of employment in an individual industry and its stage of growth. Not all industries were in the same phase of development during these years—some were coming into being, some were reaching their prime, some were beginning to fade from the economic scene. The relations between employment and stage of growth are explored in the following chapter.