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Volume Title: Capital in Manufacturing and Mining: Its Formation and Financing

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Volume Publisher: UMI

Volume ISBN: 0-870-14104-X

Volume URL: <http://www.nber.org/books/crea60-1>

Publication Date: 1960

Chapter Title: Some Relationships Bearing on Changes in the Capital-Output Ratios

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Chapter URL: <http://www.nber.org/chapters/c1391>

Chapter pages in book: (p. 93 - 106)

CHAPTER V

Some Relationships Bearing on Changes in the Capital-Output Ratios

Pattern of Change in Capital-Output Ratios in Individual Manufacturing Industries

Is there any pattern underlying the change in the capital-output ratios of individual industries that helps to explain the reversal of trend in the ratio for total manufacturing?

One pattern is clear: Between 1880 and 1919, when the capital-output ratio for all manufacturing was rising, the dispersion of the minor-industry ratios about the all-manufacturing ratio, measured by the coefficient of variation, declined by nearly two-fifths (Table 31).

TABLE 31
Coefficient of Variation of the Capital-Output Ratios in Thirty-seven
Manufacturing Industries, Selected Years, 1880-1948
(based on values in 1929 prices)

<i>Benchmark Years</i>	<i>Coefficient of Variation (Percentage)</i>
1880	63.1
1890	70.3
1900	
Comparable with preceding years	65.5
Comparable with following years	66.9
1904	58.5
1909	49.3
1914	50.5
1919	38.3
1929	33.0
1937	35.6
1948	31.3

Source: Based on data in Appendix Table A-13.

All of the decline occurred after 1900. This must mean that the rate of increase in the capital-output ratio of industries with relatively low ratios in 1880 was typically higher than for industries with relatively high ratios. The continued narrowing of the dispersion of the minor industry ratios after 1919, when the capital-output ratio of all manufacturing was declining, is consistent with only one inference: The

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ratios of industries with relatively high ratios in 1919 generally declined more rapidly than the ratios of industries with relatively low ratios in 1919. This trend toward less dispersion of the capital-output ratios suggests a hypothesis which, however, cannot be tested. During the earlier period, the smaller the importance of capital in 1880, i.e., the lower the capital-output ratio, the greater the scope for additional mechanization of processes; during the later period, the greater the importance of capital in 1919, i.e., the higher the capital-output ratio, the larger the scope for improving the efficiency of capital.¹

The relationship between changes in the capital-output ratios and changes in the rate of growth measured by output in constant prices is not particularly helpful. True, the percentage changes in output and in capital (both in 1929 prices) are highly correlated (the coefficient of correlation between relative changes in output and capital for the 50 or more industries is +0.85 for 1880-1919 and +0.68 for 1919-1948). However, the correlation is high only because, over the long term, output and plant capacity must change in much the same way. Thus, a lower degree of association is expected in the second period when capital-saving innovations have predominated. However, the association between the relative changes in output and in the capital-output ratio is negative and of a low order in both periods (-0.39 for 1880-1919 and -0.37 for 1919-1948).²

Relation between Labor and Capital per Unit of Output and Capital per Man-hour

MANUFACTURING. The reversal in the trend in the capital-output ratios suggests that technological innovations before World War I tended to replace other factor inputs with capital rather than to increase the efficiency of capital, while, more recently, the reverse has been true. This generalization is consistent with the trends in capital (in 1929 prices) per man-hour worked and in man-hours per unit of output.

Man-hours per unit of output (the reciprocal of "labor productivity") are reduced whenever labor is replaced by other factor inputs or whenever other factor inputs operate more efficiently if the efficiency of labor itself remains unchanged. One or the other or both factors have been in continuous operation since 1900, and the index of man-hours per unit of output (in 1929 prices) has declined by substantial amounts from decade to decade during this period (Table 32). Additional

¹ For an analysis of interindustry differences in capital-output ratios as of 1929, see Charles A. Bliss, *The Structure of Manufacturing Production* (National Bureau of Economic Research, 1939, pp. 88-119).

² All coefficients are statistically significant.

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TABLE 32

Indexes of Selected Ratios: Man-hours, Capital, and Output,
All Manufacturing, Selected Years, 1880-1957
(1929=100)

Benchmark Years	Ratios of—				
	Man-hours Worked to Output	Total Capital to Man-hours Worked	Fixed Capital to Man-hours Worked	Total Capital to Output	Fixed Capital to Output
1900 ^a	191.7	46.4	48.0	90.7	96.1
1900 ^b	186.4	48.1	n.a.	89.7	n.a.
1909	172.5	63.8	n.a.	109.8	n.a.
1919	151.7	76.1	n.a.	115.5	n.a.
1929	100.0	100.0	100.0	100.0	100.0
1937	84.2	99.4	94.9	83.7	79.9
1948	73.7	93.4	89.3	68.8	65.8
1953	65.0	103.1	96.3	66.7	62.4
1957	55.7	n.a.	121.0	n.a.	67.4

n.a. = not available.

Note: Capital and output dollar values are in 1929 prices.

^a Including custom and neighborhood shops.

^b Excluding custom and neighborhood shops.

Source: Output and capital estimates from Appendix Tables A-8 to A-10 and A-15. Man-hours worked is the product of (a) average hours worked per week from *Historical Statistics of the United States, 1789-1945*, p. 67. Table I23, for 1900 and 1909; Bureau of Labor Statistics *Handbook of Labor Statistics*, 1950 Edition, pp. 58-59, Table C-1, for 1919-1948; and the *Economic Report of the President, January 1959*, Table D-26, p. 169, for 1953 and 1957; and (b) total employment (active proprietors, salaried personnel and wage earners) from *Census of Manufactures for 1900-1919*; *National Income, 1954 Edition, A Supplement to the Survey of Current Business*, Table 28, pp. 202-203, for 1929-1953; for 1957, from Office of Business Economics, *U.S. Income and Output: A Supplement to the Survey of Current Business* (1959), Table VI-16.

factors have been—to mention a few—the probable increase in the efficiency of labor itself owing to wider public education, the aging of the labor force, and the shorter work-week. During 1900-1929, the reduction in man-hours per unit of output was principally associated with the continuous increase in the amount of capital per man-hour worked. The extraordinary reduction in man-hours per unit of output between 1919 and 1929 was associated with an unusually large increase in capital per man-hour, as well as with a modest increase in capital efficiency (the capital-output ratios declined between 1919 and 1929). Between 1929 and 1948, increased capital efficiency was primarily responsible for the more moderate reductions in man-hours per unit of output, since the amount of capital (total or fixed) per man-hour worked decreased substantially.³ That is, in "real" terms, labor was

³ This discussion assumes that the improved efficiency of labor input *per se* has been a minor factor in the reduction of man-hour requirements.

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equipped with less capital in 1937 and 1948 than in 1929; but because the capital was more efficient, man-hours per unit of output declined by 16 per cent between 1929 and 1937, and by 12.5 per cent between 1937 and 1948. These were matched by increases in capital efficiency, i.e., the capital-output ratio fell by 16 and 18 per cent, respectively.

Over 1948–1953, the reduction in man-hours worked per unit of output was 12 per cent, and between 1953 and 1957, 14 per cent. In contrast to the developments in the preceding two decades, the ratio of fixed capital to labor (man-hours) increased (by 8 and 26 per cent in 1948–1953 and 1953–1957, respectively), and the ratio of fixed capital to output decreased by 5 per cent in the 1948–1953 business cycle but increased by 8 per cent over the 1953–1957 cycle. That is, on balance, capital was moderately more efficient in 1953 than in 1948 but somewhat less efficient in 1957. However, in each year, each man-hour of work was carried out with the use of more capital, both fixed and working.

The relationship between labor per unit of output, capital per employee, and capital per unit of output is more clearly revealed by examining the movements of these ratios by manufacturing industry groups (Table 33).⁴ For each of 20 industry groups, we can prepare the following ratios for selected benchmark years: (1) number employed to output in 1929 prices; (2) capital in 1929 prices to number employed; and (3) capital to output, both in 1929 prices. Each ratio is expressed as an index, with the 1929 ratio taken as 100. We use these data to answer two questions: (1) Is the decrease in the index of labor per unit of output between 1900 and 1929 related to the increase in the index of capital per employee during the same period? (2) Is the decrease in the index of labor per unit of output between 1929 and 1948 related to the decrease in the index of capital per unit of output (i.e., the increase in capital efficiency) during that period?

To answer the first question, we rank the 20 industries by the absolute amount of decline in the index of labor per unit of output between 1900 and 1929, starting with the largest decrease. This ranking is compared with the ranking of the same industries according to the size of the increase in the index of capital to number employed. For the 20 industries, the coefficient of rank correlation, which varies from +1 to -1, is +0.67. If, however, two industries are omitted—motor

⁴ Since we do not have separate indexes of man-hours worked for each industry group, we make no effort to convert number employed to a man-hour basis. Labor per unit of output is measured by the ratio of number employed to output, and we substitute number employed for man-hours to relate labor to capital. Number employed is the total of active proprietors, salaried personnel, and wage earners (monthly average).

TABLE 33
 Indexes of Selected Ratios: Number Employed, Capital, and Output,
 by Major Manufacturing Industries, Selected Years, 1900-1953
 (1929 = 100)^b

Ratio of:	Index of Ratios								
	1900	1909	1919	1929	1937	1948	1953		
Food and kindred products									
1. Labor ^a to output	100.0	111.4	125.3	100.0	94.9	84.3	64.1		
2. Capital to labor ^a	91.1	96.3	86.7	100.0	83.4	74.3	89.5		
3. Capital to output	91.0	107.7	109.2	100.0	78.9	62.7	57.4		
Tobacco products									
1. Labor ^a to output	292.1	259.6	178.1	100.0	65.8	32.9	31.5		
2. Capital to labor ^a	19.3	27.6	47.1	100.0	115.5	179.9	216.9		
3. Capital to output	56.0	71.6	83.6	100.0	76.2	58.8	68.0		
Textile mill products									
1. Labor ^a to output	184.7	167.4	149.5	100.0	92.1	81.6	76.1		
2. Capital to labor ^a	64.1	73.5	87.8	100.0	69.8	71.3	87.3		
3. Capital to output	118.5	123.4	131.3	100.0	64.3	58.3	66.5		
Apparel									
1. Labor ^a to output	154.1	150.7	132.2	100.0	136.6	99.5	79.9		
2. Capital to labor ^a	60.3	71.6	103.6	100.0	60.6	70.6	88.3		
3. Capital to output	92.8	108.0	136.7	100.0	82.7	70.1	70.5		
Leather and leather products									
1. Labor ^a to output	96.7	78.9	100.9	100.0	117.4	94.8	92.1		
2. Capital to labor ^a	83.8	121.2	108.4	100.0	65.7	61.9	64.7		
3. Capital to output	81.3	95.8	109.7	100.0	77.1	58.6	59.7		
Rubber products									
1. Labor ^a to output	658.8	515.0	280.6	100.0	88.1	59.0	53.8		
2. Capital to labor ^a	29.5	38.6	53.2	100.0	82.5	85.4	92.1		
3. Capital to output	194.9	199.2	149.5	100.0	73.0	50.5	49.7		
Lumber and basic timber products									
1. Labor ^a to output	68.4	90.8	104.6	100.0	104.3	1. 84.0	76.6		
2. Capital to labor ^a	54.1	67.0	68.1	100.0	77.7			2. 61.1	72.3
3. Capital to output	37.0	61.0	71.2	100.0	81.1			3. 51.4	55.4
Furniture and finished lumber products									
1. Labor ^a to output	84.3	89.9	106.3	100.0	100.6				
2. Capital to labor ^a	93.6	110.3	105.7	100.0	78.1				
3. Capital to output	79.0	99.4	112.6	100.0	78.8				
Paper and allied products									
1. Labor ^a to output	189.5	147.5	150.0	100.0	109.9	89.5	80.4		
2. Capital to labor ^a	56.5	80.2	82.5	100.0	80.5	66.9	73.5		
3. Capital to output	107.3	118.4	124.2	100.0	88.4	60.1	59.2		
Printing, publishing, and allied industries									
1. Labor ^a to output	140.1	125.7	114.4	100.0	106.9	98.5	103.4		
2. Capital to labor ^a	67.5	71.7	75.4	100.0	93.2	79.8	73.7		
3. Capital to output	94.6	90.3	86.4	100.0	99.5	78.7	76.3		
Petroleum refining									
1. Labor ^a to output	277.8	225.9	300.0	100.0	77.8	69.6	58.5		
2. Capital to labor ^a	31.5	40.4	39.2	100.0	103.5	100.0	101.5		
3. Capital to output	87.6	91.8	117.9	100.0	82.2	69.4	59.3		
Chemicals and allied products									
1. Labor ^a to output	178.7	159.6	185.1	100.0	93.6	85.2	74.5		
2. Capital to labor ^a	59.4	70.9	71.3	100.0	86.8	84.8	113.3		
3. Capital to output	105.6	113.1	131.6	100.0	81.4	72.2	84.7		

(continued)

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TABLE 33 (concluded)

Ratio of:	Index of Ratios						
	1900	1909	1919	1929	1937	1948	1953
Stone, clay, and glass products							
1. Labor ^a to output	210.3	149.0	144.9	100.0	90.9	75.7	59.9
2. Capital to labor ^a	42.6	70.3	75.1	100.0	85.3	62.2	73.1
3. Capital to output	89.7	104.9	109.0	100.0	77.8	47.1	43.8
Iron and steel and their products							
1. Labor ^a to output	181.2	136.9	138.1	100.0	124.4	1. 92.5 2. 88.4 3. 81.9	80.1 105.0 84.2
2. Capital to labor ^a	69.5	113.8	117.2	100.0	93.2		
3. Capital to output	126.0	155.6	162.4	100.0	115.9		
Nonferrous metals and their products							
1. Labor ^a to output	206.4	145.0	145.9	100.0	89.0		
2. Capital to labor ^a	50.1	80.9	78.1	100.0	103.3		
3. Capital to output	102.8	117.0	113.6	100.0	91.3		
Machinery except electrical							
1. Labor ^a to output	171.8	147.0	146.4	100.0	100.0	90.1	76.6
2. Capital to labor ^a	64.1	89.1	77.9	100.0	86.8	73.7	79.7
3. Capital to output	110.1	131.1	114.2	100.0	86.9	66.3	61.2
Electrical machinery							
1. Labor ^a to output	86.3	81.6	93.0	100.0	85.6	50.5	39.1
2. Capital to labor ^a	119.1	160.4	121.5	100.0	83.7	125.3	146.1
3. Capital to output	102.7	130.9	112.8	100.0	71.6	63.2	57.2
Transportation equipment except motor vehicles							
1. Labor ^a to output	130.9	144.7	111.2	100.0	103.3	139.5	111.6
2. Capital to labor ^a	59.0	54.7	71.0	100.0	109.1	59.8	48.6
3. Capital to output	77.3	79.1	79.1	100.0	113.3	83.6	54.5
Motor vehicles							
1. Labor ^a to output	964.9	598.2	162.3	100.0	96.5	82.5	63.9
2. Capital to labor ^a	65.5	58.5	93.6	100.0	95.0	103.3	114.9
3. Capital to output	634.8	351.8	152.3	100.0	92.3	85.7	73.9
Miscellaneous							
1. Labor ^a to output	262.9	233.1	291.9	100.0	137.9	108.1	182.2
2. Capital to labor ^a	31.7	39.3	34.5	100.0	58.2	58.3	30.1
3. Capital to output	83.1	91.3	100.5	100.0	79.9	63.0	54.8

Note: In 1948, we can calculate the following additional indexes:

	Ratios of:		
	Labor ^a to Output	Capital to Labor ^b	Capital to Output
Lumber and basic timber products	143.4	46.2	66.5
Furniture and finished lumber products	42.8	108.9	46.7
Iron and steel and their products	90.6	87.8	79.7
Nonferrous metals and their products	128.4	68.3	87.4

^a "Number employed" or "labor" refers to the total of active proprietors, salaried personnel, and wage earners (monthly average).

^b Capital and output dollar values are in 1929 prices.

Source: Estimates of output and capital from Appendix I, Table A-8, A-10, and A-15. For employment data, see Appendix Table A-16.

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vehicles, with a phenomenal reduction in the index of labor per unit of output (from 965 in 1900 to 100 in 1929), and lumber and basic timber products, with an actual increase in labor per unit of output—the coefficient is +0.91. Thus, for most industries, the reduction in labor per unit of output between 1900 and 1929 is closely associated with the extent of additional capital provided all employed personnel.

We use a similar procedure to answer the second question. The 20 industries are arrayed by order of the decrease in the index of labor per unit of output between 1929 and 1948, and this ranking of industries is compared with their ranking according to the decrease in the index of capital per unit of output. The coefficient of rank correlation is +0.56. That is, the continued decline in labor per unit of output after 1929 was associated, but only to a moderate degree, with the extent of the decline in capital per unit of output (increased efficiency of capital). Omission of the 4 industries with increasing labor per unit of output between 1929 and 1948 does not improve the degree of association. To demonstrate that these correlated movements are important links in a causal chain requires an entirely different set of data and analyses.⁵

MINING. Much the same set of relationships is found in mining as in manufacturing. The increase in the capital-output ratios in all mining industries during the early decades was accompanied by an increase in capital per wage earner and man-hour and a decrease in man-hours to output; the relative increase in capital per unit of labor was greater than the relative decline in the ratio of man-hours to output (Table 34). The downturn in the capital-output ratios was also accompanied by an increase in capital per unit of labor and a decrease in labor per unit of output. But after 1929, capital per unit of labor rose only moderately in some industries and leveled off or declined in others.⁶ Labor per unit of output, however, continued to decrease vigorously throughout the period.

These findings are compatible with the hypothesis that replacement of labor by capital was more common before World War I than after. With one exception, increases in output per unit of labor after World War I resulted primarily from the increased efficiency of equipment, better organizational methods, and greater skill. The decade 1919–1929 was an exception because capital per worker continued to grow at a

⁵ Some of these aspects of productivity are discussed by George J. Stigler, *Trends in Output and Employment* (National Bureau of Economic Research, 1947), and by Frederick C. Mills, *Productivity and Economic Progress*, Occasional Paper 38 (National Bureau of Economic Research, 1952). Other aspects will be discussed by John Kendrick in his monograph now being prepared for the National Bureau.

⁶ See also Chapter II, note 11.

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TABLE 34

Indexes of Selected Ratios: Wage Earners, Man-hours, Capital, and Output,
by Major Mining Industries, Selected Years, 1880-1953
(1929=100)

<i>Ratio of</i>	1880	1890	1909	1919	1929	1939	1948	1953
All mining								
Wage earners to output	387	314	204	168	100	81	58	41
Man-hours to output	393	350	n.a.	165	100	63	53	39
Capital to wage earners	14	20	41	64	100	98	108	142
Capital to man-hours	14	18	n.a.	65	100	125	119	152
Capital to output	54	64	84	107	100	79	62	59
Metals								
Wage earners to output	745	499	198	163	100	99	80	69
Man-hours to output	631	431	n.a.	165	100	84	70	62
Capital to wage earners	18	32	74	78	100	83	73	119
Capital to man-hours	21	37	n.a.	76	100	98	84	131
Capital to output	134	160	146	126	100	82	59	81
Anthracite coal								
Wage earners to output	127	140	109	87	100	83	68	84
Man-hours to output	136	143	108	102	100	65	70	69
Capital to wage earners	60	43	56	73	100	83	77	92
Capital to man-hours	56	42	57	63	100	107	75	112
Capital to output	76	60	61	64	100	69	52	77
Bituminous coal								
Wage earners to output	297	207	153	139	100	109	80	68
Man-hours to output	282	260	157	128	100	83	74	65
Capital to wage earners	22	31	65	85	100	82	105	162
Capital to man-hours	23	25	63	92	100	109	113	169
Capital to output	66	65	99	118	100	90	83	110
Petroleum and natural gas								
Wage earners to output	267	213	161	192	100	65	43	36
Man-hours to output	404	331	211	205	100	52	36	30
Capital to wage earners	22	50	87	85	100	101	115	108
Capital to man-hours	14	32	67	80	100	128	140	128
Capital to output	58	105	141	163	100	66	50	39
Other nonmetals								
Wage earners to output	934	545	282	179	100	89	74	58
Man-hours to output	1,058	608	n.a.	193	100	69	64	51
Capital to wage earners	10	18	39	57	100	97	65	90
Capital to man-hours	8	17	n.a.	53	100	127	75	100
Capital to output	89	99	110	102	100	87	48	52

n.a. = not available.

Note: Capital and output dollar values are in 1929 prices.

Source: Based on data in Appendix Tables B-8, B-11, and B-15. Capital-output ratios for 1939 from worksheets.

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rate generally comparable with that prevailing during the early period.⁷

*Mining: Factors Contributing to Interindustry Differences
in the Rate of Change of the Capital-Output Ratios*

In our search for factors responsible for interindustry differences in the rate of change of capital-output ratios during any given period, we related these changes with (1) the rate of growth of output of the industry and (2) the rate of decrease in workers or man-hours per unit of output.

From 1880 to 1919, increases in the capital-output ratios were

TABLE 35

Total Change in the Capital-Output Ratio, Output, and Wage Earners per Unit
of Output, by Major Mining Industries, 1880-1919 and 1919-1953
(per cent based on values in 1929 prices)

	<i>Metals</i>	<i>Coal</i>		<i>Petroleum and Natural Gas</i>	<i>Other Nonmetals</i>
		<i>Anthracite</i>	<i>Bituminous</i>		
1880-1919:					
Capital-output ratio	-6	-16	+79	+184	+14
Output	+510	+210	+980	+1,520	+660
Wage earners per unit of output	-78	-32	-53	-28	-81
1919-1953:					
Capital-output ratio	-36	+21	-6	-76	-49
Output	+57	-65	0	+636	+259
Wage earners per unit of output	-58	-3	-51	-81	-68

Source: Table 34, and Appendix Table B-8.

⁷ The coexistence, in recent decades, of the above relationships—declining ratio of capital to output and of supplies to output, only slight increases in capital per worker, and continuous and substantial increases in output per worker—is interesting from another aspect. It has been pointed out by several investigators that technological innovations have, so far, successfully struggled against the mounting difficulties of extraction resulting from the depletion of high-grade resources. The net effect of the struggle has been not diminishing returns, but a continuous increase in output extracted per man-hour [see in particular Harold Barger and Sam H. Schurr, *The Mining Industries, 1899-1939: A Study of Output, Employment and Productivity* (National Bureau of Economic Research, 1944)]. Our findings indicate that this struggle has been successful not only in terms of direct labor used in the process of extraction, but also in terms of effort incorporated in the other input factors of plant, equipment, and supplies. That is, improvements in technology have been so considerable that, in spite of increasing difficulties of extraction, output per labor unit has increased during the last two decades without necessitating an increase in the physical volume of capital per worker.

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positively correlated with relatively higher rates of growth of production. The relative increase in the capital-output ratio or rate of growth of output and the decrease in labor per output unit seem to be uncorrelated. Thus, we find the relatively highest increase in the capital-output ratio between 1880 and 1919 to be in the petroleum and natural gas industry, followed, in the order of the size of the percentage change in the capital-output ratio, by the bituminous coal, other nonmetals, metal, and anthracite mining industries (Table 35). The same order holds when one compares the percentage growth in output in these industries between 1880 and 1919.⁸ However, the decrease in wage earners per unit of output was sharpest during that period in other nonmetals mining, followed by metal, bituminous coal, oil, and anthracite mining.

After 1919, other relationships emerge. Industries having the highest relative rates of growth or the lowest relative declines in output, as the case may be, are those in which the worker-output ratio and the capital-output ratio declined the most. In other words, intensive use of capital and of labor is positively correlated with higher rates of growth in production. However, rates of growth during this period were moderate compared with those for earlier decades. Thus, the oil industry had the highest percentage increase in output, followed, in order of percentage increase, by other nonmetals, metal, bituminous coal, and anthracite mining (which actually declined). The same order is found in the percentage decline in wage earners per unit of output and in the percentage decline in the capital-output ratio.⁹

This suggests that the relatively high rates of growth prevailing in the earlier period had a different impact on the declining labor-output ratio and the efficient use of capital (capital-output ratio) than had the relatively lower rates of growth prevailing during the later period. Exceedingly high and exceedingly low rates of growth seem to have

⁸ A similar, although somewhat less pronounced, association with the change in capital-output ratios for the period is found if growth is measured by the change in the number of wage earners employed or man-hours worked. Some might argue that a correlation between the percentage change in the capital-output ratio and that in output is bound to yield spurious results because of the algebraic factor common to the two variables. This objection is overcome if changes in employment are taken as the measure of an industry's growth. On the other hand, changes in employment are bound to be an inferior indicator of an industry's relative growth because of variations in the rate of change of output per labor unit, as well as for other considerations.

⁹ Similar relationships are found when the comparisons are based on shorter time intervals than those used in Table 35. Because of the greater danger of errors in measurement, short time intervals are not well suited to these comparisons. Nonetheless, it is noteworthy that the most pronounced association between growth and an increase in the capital-output ratio occurred during 1890-1909, and the most pronounced association between growth and a decline in the ratio, during the period 1919-1929.

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been associated with less efficient use of the input factors, while more moderate rates of growth have been associated with higher technical efficiency in the use of the input factors. This suggested relationship is reasonable only if the border line between excessively high or low rates of growth and optimal rates is flexible and varies with the given stage of economic and technological development.

Comparison with Manufacturing

We can get some help in forecasting the future growth of capital and output in the mining industry by comparing its past pattern with that in manufacturing. This comparison also permits us to present parameters of changes in some of the raw materials used for a given manufacturing volume. It may also help us determine whether any marked difference in the use of capital per unit of output exists between the two basically different technological processes of manufacturing and mining. Finally, since we assume that the same factors may have contributed to the increase and the subsequent decline in the capital-output ratio in both mining and manufacturing, a comparison of the shape of the curve traced by the two sets of ratios is of some importance.

Though the average value of mining output is only about 5 per cent of that in manufacturing, the capital used in mining averages about 10 per cent of the amount invested in manufacturing (Table 36). The latter percentage would be considerably higher if the value of the mineral resources were included (see note to Table 36). The ratio of mining to manufacturing output, based on values in current prices, varied only slightly during the entire period. Its average for the seven benchmark years is 5.3 per cent; the highest percentage was 6.1 in 1909, and the lowest was 4.3 per cent in 1953. When the ratios are based on values in constant prices, the range is somewhat greater—from 6.2 in 1909 to 3.8 in 1953. Both series show a rise to 1909 and a decline thereafter. Similarly, the ratio of mining to manufacturing capital did not change a great deal. After 1919, the relative importance of mining as a field of investment declined, as indicated by the ratios based on both reported and constant price values. Since, as shown in Chapter I, the factors working for a decline in material requirements are still active, the 1953 ratio of mining to manufacturing output in constant prices (3.8 per cent) could be used, *ceteris paribus*, to project an upper limit for future mining output, and the ratio of mining to manufacturing capital in 1953 (9.3 per cent) could be used as a guide in forecasting future capital investment in mining.

The petroleum industry is largely responsible for the presence of a higher capital-output ratio in mining than in manufacturing. This

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TABLE 36
Comparison of Manufacturing and Mining: Output and Capital, Selected
Years, 1880-1953
(per cent)

	1880	1890	1909	1919	1937	1948	1953
Mining output as a percentage of manufacturing output:							
Based on reported values	5.3	5.4	6.1	5.5	5.5	5.2	4.3
Based on values in 1929 prices	4.3	4.8	6.2	5.6	5.3	4.5	3.8
Mining capital as a percentage of manufacturing capital:							
Based on reported values	8.7	8.6	11.0	10.9	9.8	9.8	9.0
Based on values in 1929 prices	9.2	8.9	11.1	12.3	9.8	10.5	9.3

Note: The capital figures for manufacturing include land; those for mining exclude it. Since land is a negligible proportion of manufacturing capital, the figures may be considered comparable. For 1890, 1937, and 1948, when the data permit us to exclude land from both numerator and denominator, the percentages are 9.5, 10.3, and 10.0, respectively, in terms of reported values, and 9.9, 10.3, and 10.7, respectively, in terms of 1929 price values. For the same years, the inclusion of land in both numerator and denominator increases the series of percentages based on reported values to 20.2, 14.1, and 11.1, respectively.

Source: Manufacturing data from Appendix Tables A-8 and A-10 with adjustments for duplication (Appendix Table B-16); mining data from Appendix Tables B-7 to B-11. Figures for years before 1919 adjusted for comparability. Manufacturing data include shipbuilding in 1953 but not in earlier years.

industry not only uses more capital per unit of output than any other mining industry except precious metals, but also more than any of the major manufacturing industries. Other mining industries are also characterized by relatively high capital-output ratios. This, however, is due to the higher proportion of value added to total value in mining than in manufacturing. Indeed, if we substitute value added for the total value of output (Table 37), the resulting ratios vary considerably from those implicit in the percentages in Table 36.

In 1890, 1909, and 1948, the ratio of capital to value added in total mining did not differ significantly in level from the ratio in total manufacturing. The shape of the curve traced by the two sets of ratios is fairly similar, except that the amplitude of the curve representing the mining ratios is greater. Further examination, however, shows that this difference in amplitude was due entirely to the rapid expansion and subsequent decline in the ratio for the petroleum industry. When we exclude this industry from total mining, the ratio of capital to value added for all remaining mining industries appears to have varied less than that for total manufacturing. Furthermore, the ratio of capital (excluding land) to value added in all mining industries except

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TABLE 37

Comparison of Manufacturing and Mining: Capital and Value Added,
Selected Years, 1880-1948
(based on values in 1929 prices)

<i>Ratio of capital to value added in—</i>	<i>1880</i>	<i>1890</i>	<i>1909</i>	<i>1919</i>	<i>1937</i>	<i>1948</i>
1. Manufacturing ^a	1.51	1.65	2.31	2.56	1.81	1.55
2. Mining ^b	1.24	1.66	2.20	2.89	1.59	1.56
3. Mining excluding petrol- eum and natural gas ^c	1.12	1.27	1.53	1.60	1.25	0.96
4. (3) as percentage of (1)	73.7%	77.0%	66.2%	62.5%	69.1%	61.9%

Note: The capital figures for manufacturing include land; those for mining exclude land. Since land is a negligible proportion of manufacturing capital, the figures may be considered comparable.

^a From Table 11, above.

^b Value added (in 1929 prices) was estimated by applying to the value of output (in 1929 prices) the ratio of value added to value of output (from census reports). The ratio for 1937 was obtained by interpolation between 1929 and 1939. For 1948, the 1939 ratio was used.

^c Value added (in 1929 prices) was estimated as in note b. For 1937 and 1948, the 1939 ratio was used.

petroleum is lower than the ratio for total manufacturing; capital used per dollar of value added in mining varied from about three-fifths to about three-fourths of that in manufacturing.

Summary of Findings

1. Between 1880 and 1919, when the capital-output ratio for all manufacturing was rising, the dispersion of the minor-industry ratios about the all-manufacturing ratio, as measured by the coefficient of variation, declined by nearly two-fifths; and the dispersion continued to decline by nearly one-fifth between 1919 and 1948, when the capital-output ratio was falling. This trend toward less dispersion suggests a hypothesis: During the earlier period, the smaller the importance of capital in 1880, i.e., the lower the capital-output ratio, the greater the scope for additional mechanization of processes; during the later period, the greater the importance of capital in 1919, i.e., the higher the capital-output ratio, the greater the scope for improving the efficiency of capital.

2. During 1900-1929, the reduction in man-hours per unit of output (i.e., the increase in "labor productivity") was principally associated with the continuous increase in the amount of capital per man-hour worked. The more moderate reductions from 1929 to 1948 in man-hours per unit of output are primarily correlated with the increased

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efficiency of capital, since the amount of capital (in 1929 prices) per man-hour worked decreased substantially. Over the next five years, 1948-1953, the reduction per unit of output was 12 per cent and between 1953 and 1957, 14 per cent. In contrast to the developments in the preceding decades, the ratio of total and fixed capital to labor increased—by about 8 per cent and 26 per cent in 1948-1953 and 1953-1957, respectively; the capital-output ratio first declined modestly and then increased modestly. That is, once again, increased labor productivity was associated with the use of more capital per worker.

3. Much the same set of relationships is found in mining as in manufacturing. Increases in the capital-output ratios of individual industries, 1880-1919, were positively correlated with relatively higher rates of growth. However, neither the relative increase in the capital-output ratio nor the rate of growth in output appear to be correlated with the decrease in labor per unit of output. After 1919, other relationships emerge. Industries having the highest relative rates of growth or the lowest relative declines in output, as the case may be, are those in which worker-output and capital-output ratios declined the most. In other words, intensive use of capital and of labor is positively correlated with higher rates of growth in production.

4. A comparison of output and capital in mining and manufacturing reveals that the average value of mining output is only about 5 per cent of that in manufacturing, but the capital used in mining (excluding land) averages about 10 per cent of the amount invested in manufacturing. Although these percentages did not change a great deal over the various benchmark years, the relative importance of mining as a field of investment declined after 1919. The relative constancy of the percentages could be used however, as a guide in forecasting future capital investment in mining, *ceteris paribus*.