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Some Relationships Bearing on Changes in the Capital-Product Ratios

Capital and Product per Wage Earner and Man-Hour Worked

The increase in the capital-product ratios in all mining industries during the early decades was accompanied by an increase in both output and capital per wage earner and man-hour, the increase in capital per unit of labor being greater than that in product. The downturn in the ratios was also accompanied by an increase in output and capital per unit of labor. But after 1929, capital per unit of labor rose only moderately in some industries and leveled off or declined in others (Table 13).¹ Output per unit of labor, however, continued to increase vigorously throughout the period.

These findings are compatible with the hypothesis that replacement of labor by capital was more common during the early period than during the later, when increases in output per unit of labor resulted primarily from increased efficiency of equipment, better organizational methods, and greater skill. However, there is one exception, the postwar decade 1919–1929, when capital per worker continued to grow at a rate generally comparable with that prevailing during the early period.²

¹ See footnote 1 of Section 2.

² The coexistence in recent decades of the above relationships — declining ratio of capital to product and of supplies to product, only slight increases in capital per worker, and continuous and substantial increases in product 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 not been diminishing returns but a continuous increase in product 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

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TABLE 13
 CAPITAL AND PRODUCT PER WAGE EARNER AND PER MAN-HOUR, AND CAPITAL-PRODUCT RATIOS, BY MAJOR MINING INDUSTRIES,
 BASED ON VALUES IN 1929 PRICES, SELECTED YEARS, 1870-1948

	1870	1880	1890	1909	1919	1929	1939	1948
Total mining:								
Capital per wage earner (thousands of dollars)	.83	1.23	1.79	3.64	5.60	8.61	8.33	9.07
Product per wage earner (thousands of dollars)	1.14	1.07	1.31	2.03	2.44	4.02	4.89	6.82
Capital per man-hour (dollars)	n.a.	.57	.75	n.c.	2.67	4.04	5.01	4.51
Product per man-hour (dollars)	n.a.	.49	.55	n.c.	1.16	1.88	2.94	3.39
Capital-product ratio	.72	1.16	1.36	1.80	2.30	2.14	1.70	1.33
Metals:								
Capital per wage earner (thousands of dollars)	.94	1.78	3.16	7.27	7.65	9.87	8.20	7.12
Product per wage earner (thousands of dollars)	.73	.77	1.16	2.90	3.54	5.76	5.85	7.06
Capital per man-hour (dollars)	n.a.	.84	1.46	n.c.	3.01	3.95	3.86	n.a.
Product per man-hour (dollars)	n.a.	.37	.54	n.c.	1.40	2.31	2.75	n.a.
Capital-product ratio	1.29	2.30	2.73	2.50	2.16	1.71	1.40	1.01
Anthracite:								
Capital per wage earner (thousands of dollars)	.71	1.33	.95	1.25	1.63	2.23	1.84	1.69
Product per wage earner (thousands of dollars)	1.71	2.12	1.92	2.47	3.09	2.70	3.24	3.98
Capital per man-hour (dollars)	n.a.	.65	.49	.66	.73	1.16	1.24	.85
Product per man-hour (dollars)	n.a.	1.03	.98	1.31	1.38	1.41	2.18	2.01
Capital-product ratio	.41	.63	.50	.51	.53	.83	.57	.43

Bituminous coal:

Capital per wage earner (thousands of dollars)	.76	.49	.70	1.46	1.90	2.24	1.83	2.25
Product per wage earner (thousands of dollars)	.83	.71	1.02	1.38	1.52	2.11	1.93	2.61
Capital per man-hour (dollars)	n.a.	.27	.29	.73	1.06	1.15	1.25	1.25
Product per man-hour (dollars)	n.a.	.38	.42	.69	.85	1.08	1.31	1.45
Capital-product ratio	.91	.70	.69	1.06	1.25	1.06	.95	.86

Petroleum and natural gas:

Capital per wage earner (thousands of dollars)	2.84	5.92	13.21	27.08	28.17	31.29	29.35	33.43
Product per wage earner (thousands of dollars)	1.62	2.87	3.50	5.36	4.81	8.73	12.42	18.80
Capital per man-hour (dollars)	n.a.	1.66	3.65	8.97	11.39	13.56	16.52	n.a.
Product per man-hour (dollars)	n.a.	.80	.97	1.76	1.95	3.78	6.99	n.a.
Capital-product ratio	1.75	2.06	3.78	5.05	5.86	3.58	2.36	1.78

Other nonmetals:^a

Capital per wage earner (thousands of dollars)	.51	.48	.91	1.95	2.86	5.02	4.91	3.23
Product per wage earner (thousands of dollars)	n.a.	.46	.79	1.52	2.41	4.30	4.82	5.76
Capital per man-hour (dollars)	n.a.	.16	.32	n.c.	1.02	1.94	2.47	n.a.
Product per man-hour (dollars)	n.a.	.16	.27	n.c.	.86	1.66	2.42	n.a.
Capital-product ratio	n.a.	1.04	1.16	1.28	1.19	1.17	1.02	.56

^a Because of changes in composition of the group, figures for 1919 and preceding years are not strictly comparable with those for 1929 and succeeding years.

n.a. = not available.

n.c. = not comparable.

Source: Based on Tables 3, A-2, and A-4. Capital-product ratios for 1939 are from work sheets.

Factors Contributing to Differences among Major Branches of Mining in the Rate of Change in their Capital-Product Ratios

In our search for factors that might have determined industry differences in changes of capital-product ratios during any given period, we tested for relationships between these changes and (1) the rate of growth of the industry's output and (2) the rate of increase in product per worker or man-hour.

From 1880 to 1919 increases in the capital-product ratios were positively correlated with relatively higher rates of growth, while there seems to have been no correlation between the relative increase in the capital-product ratio or rate of growth in output and the increase in output per labor unit. Thus, we find the relatively highest increase in the capital-product 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-product ratio, by the bituminous coal, other nonmetal, metal, and anthracite mining industries (Table 14). The same order holds when one compares the percentage growth in output in those industries between 1880 and 1919.³ However, increase in output per wage earner was sharpest during that period in other non-metal mining, followed by metal, bituminous coal, oil, and anthracite mining. Unless these relationships reflect defects in measurement, they raise the question whether the relatively high rates of growth in output during this period were achieved at the price of a relatively greater use of the input factors of capital and to some extent also of labor.⁴

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.

³A similar, although somewhat less pronounced association between the rate of an industry's growth and the change in its capital-product ratio for that period is to be found if growth is measured by the change in number of wage earners employed or man-hours worked. While some might argue that a correlation between the percentage change in the capital-product ratio and the percentage change in product is bound to yield spurious results because of the algebraic factor common to the two variables, this objection will not hold if changes in employment are taken as a 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 differentials in change of output per labor unit as well as for other considerations.

⁴It is conceivable, for instance, that expanding markets called for capital investment and the use of labor in mines that might have appeared below the market margin under circumstances of less rapid growth.

TABLE 14

PERCENTAGE CHANGE IN THE CAPITAL-PRODUCT RATIO, PRODUCT, AND PRODUCT PER WAGE EARNER, BY MAJOR MINING INDUSTRIES, BASED ON VALUES IN 1929 PRICES, 1880-1919 AND 1919-1948

	<i>Metals</i>	<i>Anthra- cite</i>	<i>Bitumi- nous Coal</i>	<i>Petro- leum and Natural Gas</i>	<i>Other Non- metals</i>
Percentage change, 1880-1919, in:					
Capital-product ratio	-6	-16	79	184	14
Product	510	210	980	1,520	660
Product per wage earner	360	46	114	68	424
Percentage change, 1919-1948, in:					
Capital-product ratio	-53	-19	-31	-70	-53
Product	37	-34	29	498	167
Product per wage earner	99	29	72	291	139

Source: Tables 13 and A-2.

Other relationships emerge in the period after 1919. Industries having the highest relative rates of growth or the lowest relative decline in output, as the case may be, are those in which product per worker has increased, and the capital-product ratio declined, the most. In other words, intensive use of capital and of labor is positively correlated with higher rates of growth in product. However, rates of growth during this period were moderate compared with those for earlier decades. Thus, during this period the highest percentage increase in output is registered in the oil industry, followed, in order of percentage increase, by other nonmetal, metal, bituminous coal, and anthracite mining (which actually declined). The same order is found in the percentage increase in output per wage earner and in the percentage decline in the capital-product ratio.⁵

This suggests that the relatively high rates of growth prevailing in the earlier period had a different impact on rising output per labor unit and efficient use of capital (capital-output ratio) than had the rela-

⁵ Similar relationships are found when the comparisons are based on shorter time intervals than those used in Table 14. Because of the greater danger of errors in measurement, short time intervals are not well suited to these comparisons. Nonetheless, it is interesting to note that we find the most pronounced association between growth and increase in the capital-product ratio during the decade 1890-1909, and the most pronounced association between growth and decline in the ratio during the period 1919-1929.

tively lower rates of growth prevailing during the later period. Exceedingly high and exceedingly low rates of growth seem to have been associated with less efficient use of the input factors, while more moderate rates of growth have been associated with higher efficiency in the use of the input factors in a technical sense. This suggested relationship appears reasonable only if the border line between excessively high or low rates of growth and optimal rates is considered flexible and is assumed to vary 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 product in the mining industry by comparing the pattern of the past 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 there is any marked difference in the use of capital per product unit 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-product 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 value of mining output is on the average 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 15). The latter percentage would be considerably higher if the value of the mineral resources were included (see note to Table 15). The ratio of mining to manufacturing product, based on values in current prices, varied only slightly during the entire period. Its average for the six bench-mark years is 5.5 per cent; the highest percentage was 6.1 in 1909 and the lowest was 5.1 per cent in 1948. When the ratios are based on values in constant prices, the range is somewhat greater — from 4.3 in 1880 to 6.2 in 1909. 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 Section 1, the factors working for a decline in material requirements are still active,

TABLE 15
MINING PRODUCT AND CAPITAL AS PERCENTAGES OF MANUFACTURING PRODUCT
AND CAPITAL, SELECTED YEARS, 1880-1948

	1880	1890	1909	1919	1937	1948
Mining product as a percentage of manufacturing product:						
Based on values in current prices	5.3	5.4	6.1	5.5	5.5	5.1
Based on values in 1929 prices	4.3	4.8	6.2	5.6	5.3	4.6
Mining capital as a percentage of manufacturing capital:						
Based on reported values	8.7	8.6	11.0	10.9	9.7	9.3
Based on values in 1929 prices	9.2	8.9	11.1	12.3	9.7	9.4

Note: The capital figures for manufacturing include land, while 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 calculate the percentages excluding land from both numerator and denominator, the percentages are 9.5, 10.2, and 9.5 in terms of reported values, and 9.9, 10.2, and 9.6 in terms of 1929 price values. For the same years including land in both numerator and denominator increases the series of percentages based on reported values to 20.2, 14.0, and 10.5, respectively.

Source: Manufacturing data from Daniel Creamer, *Capital Output Trends in Manufacturing Industries, 1880-1948*, Occasional Paper 41 (National Bureau of Economic Research, 1954), Table 2 and work sheets. Mining data from Tables A-1-A-4 and work sheets. Figures for years before 1919 adjusted for comparability.

the 1948 ratio of mining to manufacturing output in constant prices (4.6 per cent) could be used under a *ceteris paribus* assumption to project an upper limit for future mining output, and the ratio of mining to manufacturing capital in 1948 (9.4 per cent) could be used as a guide in forecasting future capital investment in mining.

The petroleum industry is largely responsible for the fact that there is a higher capital-product ratio in mining than in manufacturing. This industry not only uses more capital per unit of product 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-product ratios. This, however, is due to the higher proportion of value added to total value in mining than in manufacturing. Indeed, if we substitute in the denominator value added for the total value of product (Table 16), the resulting ratios vary considerably from those implicit in the percentages in Table 15.

The ratio of capital to value added in total mining did not differ significantly in level from the ratio in total manufacturing in 1890,

TABLE 16
RATIO OF CAPITAL TO VALUE ADDED IN MANUFACTURING AND MINING,
BASED ON VALUES IN 1929 PRICES, SELECTED YEARS, 1880-1948

	1880	1890	1909	1919	1937	1948
1. Manufacturing ^a	1.51	1.65	2.32	2.56	1.81	1.66
2. Mining ^b	1.24	1.66	2.20	2.89	1.59	1.55
3. Mining excluding petroleum and natural gas ^c	1.12	1.27	1.53	1.60	1.25	.95
4. Ratio (3) as percentage of (1)	73.7	77.0	65.9	62.5	69.1	57.2

^a Taken from Daniel Creamer, *Capital and Output Trends in Manufacturing Industries, 1880-1948*, Occasional Paper 41 (National Bureau of Economic Research, 1954), Table 8.

^b Value added (in 1929 prices) was estimated by applying to the value of product (in 1929 prices) the ratio of value added to value of product 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.

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

1909, and 1948. 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 in 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 (cf. lines 1 and 3 of Table 16). It appears further that the ratio of capital (excluding land) to value added in all mining industries except 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 (line 4).