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Chapter 4

The Relation between Output and Employment

IF WE RELATE a quantity of output to a unit of some particular kind of input, we obtain a measure of what is commonly called the *productivity* of that input. Obviously there exist as many different criteria of productive efficiency, or productivity, as there are factors of production. In the present report we shall regard all labor, regardless of its grade or rate of pay, as a single factor of production. And we shall confine our attention to the measurement of labor productivity. Accordingly, the treatment of output in Chapter 2 and the discussion of employment in Chapter 3 may now be brought together. Our indexes of output, it will be recalled, compare dollar volumes of product at constant prices. If these indexes are divided by comparable indexes of employment, the productivity indexes which result clearly measure changes in the dollar volume of product per worker, or per manday, also at constant prices. Thus our productivity indexes involve a weighting system which depends on money values, just as do our output indexes. However, we may still claim to treat physical quantities, inasmuch as the direct influence of price changes has been eliminated from both types of measure.

The present chapter will furnish a review of productivity changes in mining as a whole. In Part Two (Chapters 5-7) we shall endeavor to supply a background of technological information with which to interpret these changes. More detailed studies of output, employment and productivity, and of associated changes in technology, in individual mining industries, will be undertaken in Part Three (Chapters 8-13).

OUTPUT, EMPLOYMENT AND PRODUCTIVITY

The various industries for which we have comparable output and employment data for the two years 1902 and 1939 are listed in Table 11. Judged by value of products in 1937 these industries

Table 11

INDEXES OF OUTPUT, EMPLOYMENT AND PRODUCTIVITY, 1902 AND 1939[a]

1902:100

	1902	*1939*				
			Employment		Output per	
Industry	All Quantities	Output	Man-days	Man-hours	Man-day	Man-hour
Metal mining, total	100	183	73	62	251	296
Iron ore	100	146	40	33	362	446
Copper	100	216	81	72	268	300
Other metals[b]	100	169	95	81	178	207
Fuels, total[c]	100	332	[f]	83	[f]	398
Pennsylvania anthracite	100[g]	76	60	44	128	172
Bituminous coal	100	151	93	74	163	204
Oil and gas wells	100	1,112	[f]	230	[f]	483
Stone quarrying	100[h]	93	38	[f]	245	[f]
Phosphate rock	100	266	45	35	594	758
Gypsum	100	395	126	100	313	396
Total, Excluding Oil and Gas[d]	100	141	79	64	178	219
Total, Including Oil and Gas[e]	100	283	101	77	280	367

[a] Based on Appendix A, especially Table A-5.

[b] Includes gold, silver, lead, zinc, manganese, tungsten, molybdenum, mercury, bauxite, pyrites, fluorspar (Illinois and Kentucky only), but not placer mining. The classification is on an industry basis: hence the output data exclude gold and silver originating in copper mines. For further explanation, see Appendix B.

[c] The comparison base for Pennsylvania anthracite is 1901. When 1902:100 for anthracite as for other items, the figures for 1939 are as follows: output, 366; man-hours, 92; output per manhour, 399.

[d] For the comparison of 1902 and 1911 the industries included are all those except stone. For comparisons between 1911 and 1939 stone quarrying is also included. The comparison base for Pennsylvania anthracite is 1901. When 1902:100 for anthracite as for other items, the figures for 1939 are as follows: output, 152; mandays, 86; manhours, 70; output per manday, 178; output per manhour, 217.

[e] For the comparison 1902 to 1911 the industries included are all those shown except stone: judged by value of products in 1937 they have a coverage of 89.7 percent of all minerals for which the Bureau of Mines reports value data. For comparisons between 1911 and 1939 stone quarrying is also included, and the coverage is 94.3 percent on the same basis. Mandays for petroleum were included on the assumption that men employed worked 300 days per year. The comparison base for Pennsylvania anthracite is 1901. When 1902:100 for anthracite as for other items, the figures for 1939 are as follows: output, 303; mandays, 101; manhours, 83; output per manday, 299; output per manhour, 366.

[f] Not available.

[g] Applies to 1901; figures for anthracite in 1902 are distorted by the five-month strike in that year. When 1902:100, the figures for 1939 are as follows: output, 124; mandays, 99; manhours, 73; output per manday, 126; output per manhour, 170.

[h] Applies to 1911; no adequate production data are available for stone in 1902.

cover nearly 90 percent of mineral production as a whole.[1] The resulting productivity indexes may therefore be accepted as representative of mining activity. Any reservations we may have relate rather to the comparability between 1902 and 1939 of the employment data for individual industries. These data have been adjusted in various ways, particularly for 1902: the adjustments we felt it necessary to make are described in footnotes to Appendix Table A-3.[2]

For mining as a whole, output nearly tripled; and output per manhour multiplied more than three and a half times (Table 11). This result, to be sure, stems largely from the dramatic expansion in the output and productivity of oil and gas wells. If we exclude the petroleum industry from the comparisons, the changes for the period 1902–39 are much more moderate: a 41 percent rise in output, and a somewhat greater increase in productivity —78 percent in terms of mandays (Chart 28), 119 percent in terms of manhours. For mining as a whole, labor input, measured in manhours, declined between 1902 and 1939, although total employment, in terms of mandays, may have increased slightly (see also

[1] For stone quarrying in 1902 we have employment data but no measure of physical output. In the indexes for mining as a whole in the last line of Table 11, the stone industries are included for comparisons subsequent to 1911. For these comparisons—i.e. for all but the first quarter of the period—the industrial coverage of our output and employment measures exceeds 94 percent.

[2] These adjustments were chiefly (1) to exclude employment at manufacturing or processing plants, (2) to secure 100 percent coverage where the original figures clearly did not provide it, (3) to standardize the basis for averaging employment over the year. The employment figures for recent years, and particularly for 1939, may be accepted as satisfactory. The possibility remains that our employment indexes suffer from an upward bias owing to incomplete coverage in early years. The same possibility exists in regard to our output indexes, but here any upward bias can hardly be significant. The fact that the series we present for employment are much more likely to be subject to upward bias than the series for output, means that any increases we report in productivity are likely to err, if at all, on the side of understatement.

Something should be said of the comparability of 1902 and 1939 in respect to the level of business activity. According to the National Bureau's chronology, 1902 marks the conclusion of a mild recession which started in 1900. 1939 was a more active year than 1938, though not as active as 1937. In terms of general business, 1939 may be considered a "better" year than 1902. Nevertheless the recession of 1900–02 appears scarcely to have affected mining activity, for output tended to expand rather steadily year by year during the first few years of the present century. So far as concerns mining, therefore, both years may be described as fairly active. In the case of Pennsylvania anthracite, comparability is distorted by the five-month strike which occurred in 1902. For this reason in Table 11 we use the years 1901 and 1939 for the comparisons of anthracite productivity.

Table 7 above). Total manhours in petroleum and natural gas production doubled, but this expansion was more than offset by reductions elsewhere.

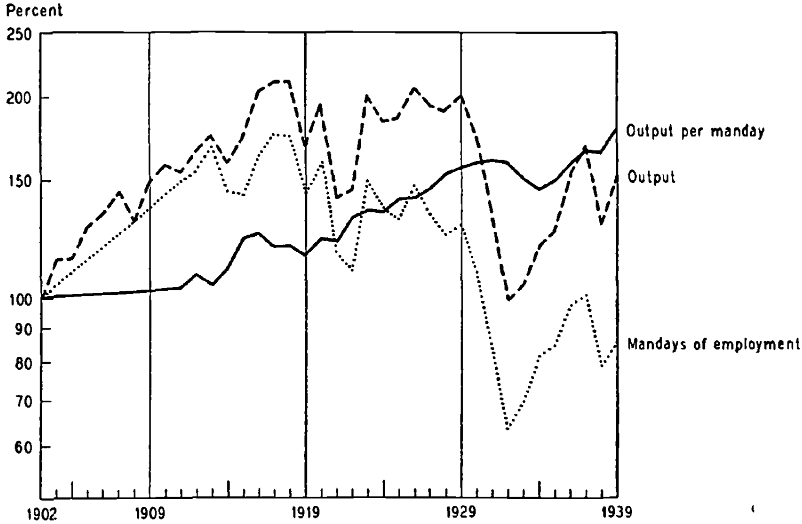
The results shown in Table 11 for the mining industries differ in several respects from comparable measures reported in previous National Bureau studies [3] for manufacturing and for agriculture.

Chart 28

MINING, EXCLUSIVE OF OIL AND GAS WELLS

Output, Employment and Productivity, 1902 – 39

(1902:100)



Ratio scale

For source and notes see Appendix E

As may be seen from Table 12, output tripled in mining and in manufacturing, but rose less than 50 percent in agriculture. However, if once again oil and gas wells are excluded, mining output expanded, like that of agriculture, by less than 50 percent. In terms of workers employed a given number of days a year, labor input was practically unchanged in mining (or declined about 20 percent if petroleum is excluded), rose 50 percent in manufactur-

[3] See Solomon Fabricant, *The Output of Manufacturing Industries, 1899–1937* (1940); the same author's *Employment in Manufacturing, 1899–1939: An Analysis of Its Relation to the Volume of Production* (1942); and Harold Barger and Hans H. Landsberg, *American Agriculture, 1899–1939: A Study of Output, Employment and Productivity* (1942).

TABLE 12

OUTPUT, EMPLOYMENT AND OUTPUT PER WORKER IN MINING, MANUFACTURING AND AGRICULTURE

	Output	*Employment*[d]	*Output per Worker*
Mining, including oil and gas, 1939 (1902:100)[a]	283	101	280
Mining, excluding oil and gas, 1939 (1902:100)[a]	141	79	178
Manufacturing, 1939 (1902:100)[b]	290	149	194
Agriculture, 1937 (1900:100)[c]	145	89	164

[a] See Table 11. The comparison base for Pennsylvania anthracite is 1901 instead of 1902.

[b] Solomon Fabricant, *Employment in Manufacturing, 1899–1939* (National Bureau of Economic Research, 1942), p. 331.

[c] Harold Barger and Hans H. Landsberg, *American Agriculture, 1899–1939* (National Bureau of Economic Research, 1942), p. 251. Comparisons are for five-year averages centered on years indicated.

[d] For mining, comparisons are made in terms of mandays or 300-day workers; for manufacturing, in terms of average wage earners; and for agriculture, in terms of gainfully occupied workers.

ing, and declined slightly in agriculture.[4] Output per worker (or per manday) tripled in mining, doubled in manufacturing, and increased somewhat more than 50 percent in agriculture. In this respect, again, the preeminence of mining results entirely from the inclusion of oil and gas wells: if they are excluded, output per worker rose about 80 percent only, i.e., more than in agriculture, but less than in manufacturing.

The preponderant effect exerted upon our results by the petroleum industry merits further examination. This influence has two aspects. Productivity at oil and gas wells rose more rapidly than elsewhere. In addition, a shift occurred which increased the relative importance of oil and gas wells—an industry in which the absolute level of productivity was higher than elsewhere throughout the period. By productivity in this context we mean of course the dollar value of product per worker (per manday or manhour) measured at constant prices. In this sense output per manhour in the petroleum industry was in 1902 nearly twice, and

[4] Strictly speaking, the comparison in Table 12 is made in terms of manyears containing a definite number of shifts only in the case of mining; in the other industries the comparisons are somewhat vaguer in character. The importance of using a worker employed a definite number of days a year as the unit of labor input is particularly great in mining because of the wide swings in degree of activity characteristic of this industry. In manufacturing wage earners represent the average of 12 monthly counts. In agriculture numbers occupied represent a single count for 1900 and an average of 12 monthly (sample) counts for 1937. For further details, the reader is advised to consult the sources mentioned for these industries.

in 1937 more than twice, the average for mining as a whole (Table 13). These two types of contribution to the productivity change in mining as a whole—which we may impute respectively to changes within industries and to shifts in their relative importance—are segregated for the comparison between 1902 and 1937 in Table 13.[5] It will be seen that about one third of the rise in output per manhour in mining as a whole can be traced to a shift in the relative weight of different industries in the total, and especially to a replacement of other forms of extraction by oil and gas wells.

TABLE 13

OUTPUT PER MANHOUR, BY INDUSTRIES, 1902 AND 1937
At constant prices[a]

Industry	*1902 (dollars)*	*1937 (dollars)*	*Change (dollars)*	*Ratio 1937 to 1902*
Metal mining[b]	.78	2.21	+1.43	2.8
Anthracite	.72	1.08	+.36	1.5
Bituminous coal	.52	1.00	+.48	1.9
Oil and gas wells	1.00	4.11	+3.11	4.1
TOTAL, ABOVE INDUSTRIES	.65	1.95	+1.31	3.0
Part of change associated with:				
Changes within industries[c]	..	..	+.92	..
Shifts between industries[c]	..	..	+.38	..

[a] All money values in this table are expressed, for each industry, in terms of the average of unit values obtaining in 1902 and 1937. Consequently the data are merely a measure of physical output, and take no account of changes in prices between the two dates. Computed from Appendix Tables A-2 and A-5.

[b] Includes gold, silver, copper, lead, zinc, tungsten, molybdenum, mercury, bauxite, iron ore, manganese, pyrites, and fluorspar in Illinois and Kentucky.

[c] Let x represent product per manhour in dollars (in constant prices), y manhours, and suffixes 1902 and 1937 respectively. The part of the change associated with changes within industries may be written $\frac{\Sigma (x_2 - x_1) y_1}{\Sigma y_1}$, and the part associated with shifts between industries $\frac{\Sigma x_2 \left(\frac{y_2}{p} - y_1 \right)}{\Sigma y_1}$, where Σ denotes summation over all industries shown, and $p = \frac{\Sigma y_2}{\Sigma y_1}$.

A further aspect of the shift toward petroleum and natural gas, and away from other types of fuel, is illustrated in Table 14. If

[5] The comparisons in Table 13 are confined to the extraction of metals, coal and petroleum. However, the picture would scarcely be altered if minor industries, for many of which we do not have data, were included. We chose 1937 for the second year of the comparison because data for 1939 were not yet available when this computation was made.

the product of the fuel producing industries is measured in energy units (BTU), we find that output per manhour did not differ greatly among these industries in 1902, but that since then sharp divergence in movement has occurred. Today a worker produces in a given time two or three times as many BTU in the petroleum industry as he does in the coal industry. It should not be assumed from this that we can increase the national product by the simple

TABLE 14

COAL AND PETROLEUM: OUTPUT (IN BTU) PER MANHOUR, 1902 AND 1937[a]

Million BTU per manhour

Industry	*1902*	*1937*	*Change*
Pennsylvania anthracite	6.9	10.4	+3.5
Bituminous coal	9.1	17.5	+8.4
Oil and gas wells	7.0	32.6	+25.6
TOTAL, ABOVE INDUSTRIES	8.5	21.0	+12.5
Part of change associated with:			
Changes within industries[b]	..	..	+9.6
Shifts between industries[b]	..	..	+2.9

[a] Output, Appendix Table A-1; manhours, Appendix Table A-3; BTU from *Minerals Yearbook*, as follows: 27.2 mil. per short ton anthracite, 26.2 mil. per short ton bituminous, 6 mil. per barrel petroleum and natural gasoline, 1,075 per cubic foot of natural gas.

[b] Let x represent BTU per manhour, y manhours, and suffixes 1902 and 1937 respectively. The part of the change associated with changes within industries may be written $\frac{\Sigma (x_2 - x_1) y_1}{\Sigma y_1}$, and the part associated with shifts between industries $\frac{\Sigma x_2 \left(\frac{y_2}{p} - y_1\right)}{\Sigma y_1}$, where Σ denotes summation over all industries shown, and $p = \frac{\Sigma y_2}{\Sigma y_1}$.

expedient of turning coal miners into oil well operatives. Energy content is not the only basis of economic valuation; besides transportation costs and capital investment, depletion prospects should be included in any rational accounting. Nor have we debited petroleum with the labor necessary to refine it, a cost which has no counterpart in the coal industry. Nevertheless, the rising relative efficiency of oil and gas production must have lowered the price of oil in relation to coal, and so stimulated the substitution of oil for coal as fuel which we noted in Chapter 2.[6]

[6] Measured at the point of production, the price of oil rose about 50 percent, the price of coal about 70 percent, between 1902 and 1937 (Appendix Table A-1). Probably the relative cheapening of oil to the ultimate consumer was greater than this, thanks to advances in transportation, processing and combustion techniques.

Measurement of the product in energy units provides us with a useful alternative way of judging output and productivity in the fuel producing industries. If we employ our standard methods of gauging physical output, i.e., weighting each product by its average price in the two years to be compared, we find that the output of these industries rose from 100 in 1902 to 343 in 1937. But if change over the same period is measured in BTU, the output of fuels expanded only from 100 to 269. This difference emerges despite the fact that we used constant ratios to convert tons of coal, barrels of oil and cubic feet of natural gas to BTU. It results from the displacement of coal by oil and gas, coupled with the higher monetary value (measured in dollars per BTU) at which the latter are sold. Again, output per manhour at coal mines and oil and gas wells combined was nearly four times as high at the end of the period as at the beginning, if gauged according to our standard practice. But measured in BTU per manhour, the productivity of the fuel producing industries was only about two and a half times as high in 1937 as in 1902. According to Table 14, nearly a third of this expansion may be traced to the shift from coal with a low, to petroleum and natural gas with a high, BTU output per manhour.

MANDAY VERSUS MANHOUR MEASUREMENTS

For all mining industries except oil wells and stone quarries, figures for employment and productivity were given in Table 11 both in mandays and in manhours. Because of sizable reductions in the length of the shift (Table 10), manhours worked per year have declined in relation to mandays in all the industries for which data are given. For the same reason, output per manhour has in every case mounted more rapidly than output per manday (for details see Appendix Tables A-5 and A-6).

Despite the fact that all major branches of mining reported a larger output in 1939 than 1902,[7] only oil and gas wells increased their labor input in manhour terms; if the comparison is made for mandays, however, gypsum mining also used more labor in 1939 than in 1902. All other branches reduced their consump-

[7] Anthracite output was larger in 1939 than in 1902, but only because of the strike in 1902; output in 1939 was smaller than in 1901 or 1903. Anthracite employment, however, was smaller in 1939 than it was in any of the years 1901–03; this statement holds, both for manhours and for mandays, the strike notwithstanding.

tion of labor in manday terms, and still more in terms of manhours. Among the declines in employment, those in iron ore, anthracite (adjusted for the strike in 1902), and phosphate rock mining were particularly large.

Changes in output per manday range from a rise of 28 percent for anthracite mining to the sixfold growth for phosphate rock. The same two industries represent extremes of behavior with respect to output per manhour: the one shows a rise of but 72 percent, the other a more than sevenfold increase in manhour productivity.

Except in the case of oil wells, we know more about mandays than about manhours worked in the mineral industries. For this reason the emphasis in the remainder of this chapter, and in later chapters (except that devoted to petroleum) will rest primarily upon the behavior of output per manday. Throughout the discussion we should bear in mind, however, that the tendency has been for the length of the workday to contract rather steadily. In consequence—if we regard the manhour as the fundamental measure of labor input—we should remember that our indexes of output per manday (see, for example, Charts 28 to 32) understate the rise or overstate the decline that has occurred in the productivity of labor.

THE RELATION BETWEEN OUTPUT AND EMPLOYMENT

It cannot be said that there emerges from our results a clear picture which might be regarded as typical of all the mining industries. Instead a rather sharp contrast must be drawn between the experience of different branches of extraction. In spite of the fact that oil and gas wells show the second largest increase (following phosphate rock) in manhour productivity, this form of enterprise has expanded both its output and its employment. After petroleum, the output of gypsum has mounted more than that of any other mineral studied; here again employment has increased, at least in terms of mandays. But for the various metal mining industries, for bituminous coal and for phosphate rock—each of which increased its output substantially between 1902 and 1939—output per manhour or per manday rose more rapidly than the volume of production, so that here there were declines in employment. Productivity has risen least in anthracite mining, the only major form of mineral production with an output lower in 1939 than at the beginning of the century.

There is some tendency, as one would expect, for employment to rise most or fall least in the industries with the largest increases in output. An outstanding exception to this rule is phosphate rock, which stands third in output growth, but which nevertheless cut down its employment more than any industry except iron ore and perhaps also stone quarrying. There is evidence, too—though rather slender evidence—to support the view that increases in productivity are correlated with increases in output. Phosphate rock again appears somewhat of an exception, for it ranks first in productivity increase but only third when measured by rise in output. Iron ore also departs from the general pattern; it had the third largest increase in productivity but expanded its output only moderately. Generalizations of this sort are difficult to make, not only because of the exceptions which immediately present themselves, but also because the industries for which we have data are small in number and heterogeneous in size and other characteristics.

Petroleum and natural gas now account for about half the value of all mineral products, but their contribution to employment, though substantial, is disproportionately small. We have seen that output and employment expanded much more rapidly in oil and gas production than in any other mineral industry, and output per manhour more rapidly than in any of the others except phosphate rock. The causes of these striking changes will be examined further in Chapter 10. For convenience, the remainder of this chapter will be confined to a discussion of the extraction of minerals other than petroleum and natural gas.

If we exclude oil and gas wells, and make a further exception in the case of gypsum, we find that in the remaining industries employment decreased. In metal mining, coal mining, stone quarrying and the mining of phosphate rock, that is to say, the rise in productivity exceeded the rise in output. The experience of these industries, which (apart from petroleum) account for the bulk of mineral production and employment, therefore resembles the course of affairs in agriculture rather than the history of manufacturing. We do not have exactly comparable data: possibly output and productivity increased a little more rapidly in these mining industries (taken together) than in agriculture. But the similarity of change over the period is striking (Table 12) as is the contrast of both these groups with manufacturing. Such comparisons suggest that the mining industries (excluding petroleum) and agriculture perhaps had something in common that they did not share with manufacturing—at least during the period under review.

The most obvious feature common to mining and to agriculture is that they are both extractive industries. They both obtain products from the ground with more or less difficulty and are therefore affected by changing resource conditions; and both yield raw products which usually have to be processed before they can be consumed. Again, the movement toward greater use of scrap and economy of materials has somewhat lessened the demand for raw products in comparison with the demand for finished goods. Finally, changes in quality or purity have been slight in the case of minerals and farm products, whereas a tendency toward a greater degree of fabrication has persisted in the case of manufactured goods.[8] These factors would lead us to expect a greater rise in the physical output of fabricated products than of raw minerals or agricultural commodities. On the other hand, the set of factors associated with the concept of diminishing returns—depletion of soil or minerals, declining grade of ore, the need to mine at greater depths—are encountered first and foremost in the extractive industries and have little if any application to manufacturing. The level of productivity in mining at any given time reflects the current phase of an enduring struggle between technological advance and resource depletion. To the degree that mining is affected by the operation of diminishing returns, and that technological innovation is unable fully to overcome the effects of depletion, one would expect output per worker in mining to lag behind its upward progress in manufacturing.

Considerations of this order would appear to explain the smaller rise in output and in output per worker in the mining in-

[8] In the case of minerals these changes are confined almost entirely to variations in the grade of coal mined, or in the grade of metallic concentrates as they leave the beneficiating plant. It is quite unlikely that alterations in quality are taken account of at all adequately in our indexes of output, whether of minerals, of farm products or of manufactures. This neglect is certainly most serious in the case of manufactured goods. If proper allowance could be made for changes in quality, the recorded increase in manufacturing relative to farm and mineral output would be even more marked than it appears from the data in Table 12. Some discussion of changes in the quality of mineral output, with special reference to copper mining, will be found in Appendix D.

dustries (again with the exception of petroleum) than in manufacturing. But they do not explain why employment itself has diminished. This last development is plainly a reflection of the fact that the first set of factors mentioned above—those which tend to restrain output—have been more powerful during our period than the second set of factors—those acting to curb the rise in output per worker. In other words technological advance has so far been sufficiently successful in its struggle with depletion to raise productivity more rapidly than output has expanded. This is about all that can be said in a general way. For a more detailed treatment of the relation between output and employment in the individual industries concerned, the reader is referred to the last section of this chapter and to the later chapters in this book. The concept of diminishing returns as it applies to mining is examined more fully, in the light of experience in the mineral industries, in the final chapter which constitutes Part Four.

The discussion has been confined to mineral industries other than the production of petroleum and natural gas. Plainly the oil and gas wells of the nation form an exception to the generalizations made above. Output, employment and productivity all expanded in a manner more reminiscent of some rapidly growing branch of manufacturing than of any of the other mineral industries. Petroleum is a young industry; as we saw in Chapter 2, it has invaded markets previously secured to other fuels; and resource depletion has been made good by frequent discovery of new fields. These and other factors which distinguish it from the older forms of mining are considered in Chapter 10 below.

OUTPUT PER MANDAY IN INDIVIDUAL INDUSTRIES

As already explained, the relation between output and employment in the more important branches of mining will be the subject of separate chapters later in this volume. In any case a thoroughgoing account must consider changes in technology and their relation to resource depletion, and these have not yet been examined. The purpose of this section is to make some further comparisons between productivity changes in different mining industries. As in the preceding section, the discussion is confined to industries other than petroleum.

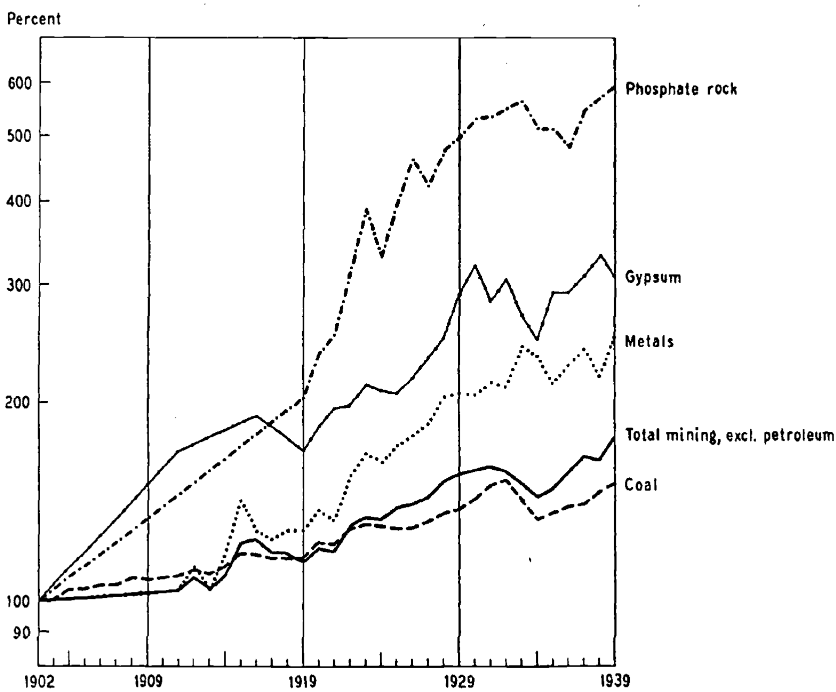
In Chart 29 our index for output per manday in mining and quarrying is broken down into separate indexes for metal mining, coal mining, phosphate rock and gypsum.[9] The very large expansion of manday output in the mining of phosphate rock is further illustrated. Largely confined to Florida, the phosphate

Chart 29

COAL, METAL, GYPSUM AND PHOSPHATE ROCK MINING

Output per Manday, 1902 - 39

(1902:100)



Ratio scale

For source and notes see Appendix E

rock industry is of course a comparatively small employer of labor. The greatest gains in productivity in this industry seem to have occurred before 1923, and to have been associated with the introduction of hydraulic methods of open pit mining soon after the beginning of the century.[10] In the case of gypsum much of the

[9] The separate indexes will be found in Appendix Table A-5. The breakdown in Chart 29 is exhaustive for 1902–11; thereafter the total includes data for stone quarrying. The latter, not distinguished in Chart 29, will be found in Chart 32.

[10] A. P. Haskell, Jr. and O. E. Kiessling, *Phosphate-Rock Mining, 1880–1937* (National Research Project, Philadelphia, 1938), pp. 13-16.

rise in output per manday seems to have occurred between 1902 and 1916: productivity appears almost to have doubled within 14 years. Too much confidence should not be placed in this result, for the mining of gypsum is often combined with calcining operations; it is possible that in 1911, and especially in 1902, the segregation, particularly of the employment data, was imperfect.[11] Since 1916 manday output in the gypsum industry has expanded at about the same rate as in metal mining.

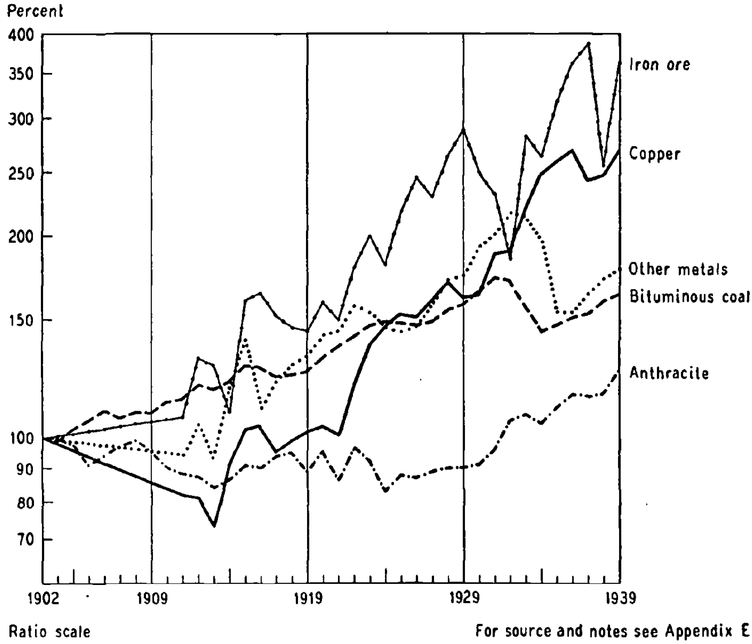
Between 1902 and 1912 productivity apparently increased rather slowly, both in metal mining and in coal mining: on the average the rise was about 10 percent, or 1 percent yearly, for each of these series. For the remainder of the period, however, manday output in metal mining increased about twice as rapidly as in coal mining. This divergence may be attributable in part to the fact that coal mines are commonly older than metal mines. Age has two disadvantages. First, in an old mine it is mechanization which has to be adapted to the existing layout, instead of the other way round. Second, resource depletion is more likely to be felt: narrower seams or poorer ore must be worked, the mine must be deepened, the haul from the working face to the shaft must be lengthened. The more rapid rise of manday output in metal than in coal mining may result also in part from the superiority of open pit to underground mining, and in part from new techniques for beneficiating metallic ores. On the whole the advance of technique seems to have been more rapid in open pit mining: no single innovation in underground methods can compare with the introduction of the power shovel in stripping operations. This implement has had little application in the coal industry, still mainly carried on below ground. Again, such changes as selective flotation and new milling techniques, so important in metal mining, have left coal mining unaffected. It is to considerations of this order that we must look if we wish to explain the differing fortunes of these two groups of industries.

Contrasts of much the same sort may be discerned in Chart 30 where productivity changes are shown separately for individual metal and coal mining industries. As we have already noted, among the metal mining industries manday output increased most rapidly in the mining of iron ore. Preeminently an open pit in-

[11] As elsewhere, output and employment are intended to exclude manufacturing operations, of which calcining is an example.

dustry, iron ore mining has derived full benefit from the modern power shovel; nor has it had, as yet, to combat serious depletion of resources. Copper mining made little progress during the first two decades of the century: deep mining, especially in Michigan, was relatively more important than it is today, and grade of ore

Chart 30
COAL AND METAL MINING
Output per Manday, by Individual Industries, 1902 – 39
(1902 : 100)

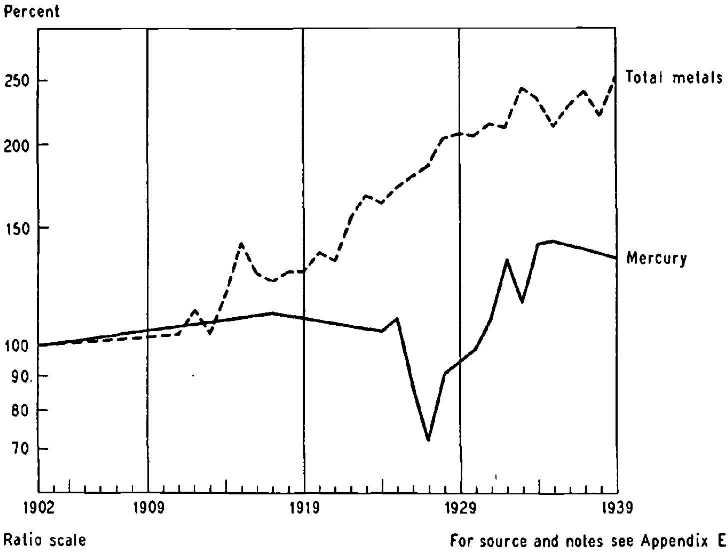


was of course declining.[12] After 1921 large scale open pit developments in the West, in conjunction with improved techniques for concentrating low grade ores, appear to have asserted their influence, for manday output has more than doubled since that time. The mining of "other metals" (especially gold, silver, lead and zinc) is carried on mainly below ground,[13] and while productivity has increased, it has risen little more rapidly than in the case of bituminous coal. Among these "other metals" we may segregate

[12] See Table 22 below.
[13] Placer mining is excluded from the statistics in this chapter.

mercury mining, for which output per manday is shown in Chart 31. For the first three decades of the century the trend of productivity in mercury was steady or downward, but within the past fifteen years it has risen rather rapidly. Over the period as a whole the curve for mercury resembles that for anthracite (Chart 30).

Chart 31
MERCURY MINING AND RECOVERY
Output per Manday, 1902–39
(1902:100)



For source and notes see Appendix E

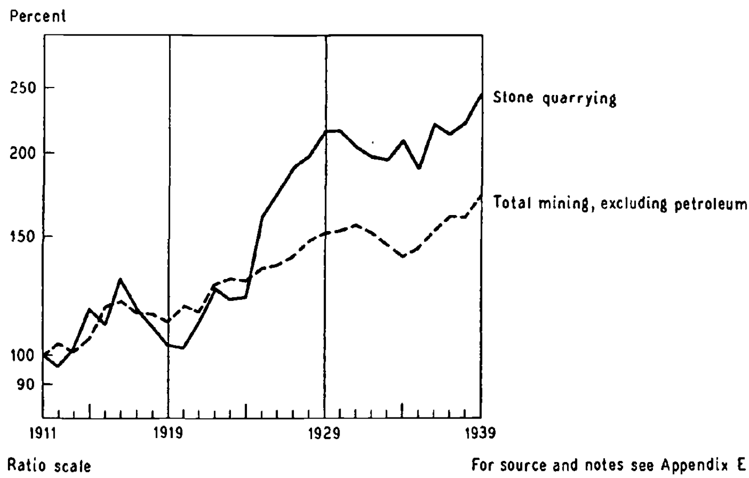
In these two industries the tendency for productivity to decline during the early part of the period must be attributed to the effects of depletion, but the reasons for the recovery both have registered in output per manday in recent years appear to vary. Thus the improvement in the efficiency of anthracite mining seems rather definitely connected with the mechanization of loading operations (see Chapter 9 below). On the other hand the recent rise of productivity in mercury mining is not susceptible of any obvious explanation, but appears to have been occasioned by general improvements in organization. The gain here is all the more remarkable when we consider that despite a decline in the average mercury content of domestic ores, from 0.54 percent in

1926 to 0.41 percent in 1933–34, the output of mercury per man-hour rose from 0.64 pounds in 1926 to 0.85 pounds in 1933.[14]

The experience of bituminous coal mining differs sharply from that of anthracite: productivity has risen steadily, if not sensationally, in soft coal production. In the latter industry mechanization has proceeded on a scale which narrow, inclined seams made impossible in anthracite mines.

Finally, in Chart 32 the course of events in stone quarrying is summarized. Because satisfactory physical output data for 1902

Chart 32
STONE QUARRYING
Output per Manday, 1911–39
(1911 : 100)



For source and notes see Appendix E

are lacking, our productivity measures begin only with 1911. It will be seen that manday output moved somewhat erratically until the middle 1920's, but rose sharply thereafter. This rise is to be explained by the increasing importance of crushed stone, a product obtained almost exclusively from open pit workings with the aid of the power shovel. Modern techniques were introduced into crushed stone quarries somewhat later than in metal mining, but their effect is no less clear.

These summary comparisons represent all that can be said in the present context. We have seen that, if oil wells are included,

[14] *Minerals Yearbook, 1935,* p. 457.

productivity increased even more rapidly in mining than in manufacturing. Striking contrasts exist between the experience of different branches of the mineral industry. The effectiveness of labor increased much more rapidly in metal than in coal mining. Progress in extracting the nonmetals has occurred largely in the actual winning of the mineral; among metallic ores it has depended increasingly upon elaborate beneficiating techniques. In some fields open cut mining has increased its scope, proving a very efficient form of operation. The foundation for these changes has been mechanization of the mining process. In Part Two we turn to a review of technological development in the extraction of minerals from the earth. It is this development which has been responsible, in large measure, for the increases in the return to the miner's effort which we have noted. In subsequent chapters, in Part Three, the relation between output, employment and technology in some of the more important branches of mining will be further explored