Volume Title: The Mining Industries, 1899-1939: A Study of Output, Employment, and Productivity

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# Part One

# Output and Employment

"There is not a single mineral substance of which the quantity used in the past century is less than the total of all the centuries that preceded." T. T. Read

Chapter 1

# Introduction

THE DEGREE to which our material wants are satisfied from day to day, and the possibility of improving the physical equipment of the community for future use, alike depend upon the kind and quantity of things produced in the economy. Our interest in physical output proceeds from two related standpoints. We may inquire what changes have occurred in the aggregate size of the flow of goods and services: this is the task of index number construction. Or we may be more concerned with the composition of this output: the emphasis is then upon the expansion or contraction of particular kinds of production, and the share of each in the total. In discussing the mining industries of this country we shall adopt both types of approach.

Measurement of the volume of output tells us something of the growth or decline of the economy, or of segments of it, but it yields at best an inadequate picture of changes in the efficiency of the productive system from one period to another. For it takes no account of the draft made upon the economic resources of the nation in turning out goods and services. To carry the analysis a step further we need to measure the input of factors of production. The input of resources—human and material—cannot be aggregated with the facility with which we can total the things emerging from a productive process. Partly for this reason, and partly because human resources are of special interest, we shall confine our measurements of input to labor, i.e., we shall measure only the volume of employment. Consequently our figures of productivity will be derived only in terms of labor, and will neglect the input of capital and other factors. But we should not lose sight of the fact that such figures tell us only part, if perhaps the most interesting and important part, of the story of industrial efficiency.

A study of production and productivity, such as that about to be undertaken for the mining industries, offers interesting material for the writing of economic history. It affords opportunity for an assessment of the results of technological progress and the application of scientific knowledge to industrial ends. It provides data which may inform us concerning the effects of public policy in economic matters, such as labor legislation, conservation and the tariff. It reflects changes in ways of living and of getting a living, in consumption standards and in working habits. And it points a signpost toward achievement in the future.

## THE MINING INDUSTRIES

For the purpose of this report, the mining industries include not only mining proper but also the quarrying of stone and the production of crude petroleum and natural gas. The operations in which we are interested cover every form of mineral extraction, and are carried on both beneath and above the ground. Although the geographic distribution of mining activity is extremely wide, the production of individual minerals is often concentrated in a single area; anthracite coal in Pennsylvania, phosphate rock in Florida, mercury in California, gold and silver in the western states. For obvious reasons the mining of a given mineral is more rigidly restricted topographically than any other form of economic activity.

Many more mineral deposits are known to exist than are in fact exploited at the present time; and doubtless still further deposits lie buried in the earth, undiscovered. Only the richer, the more easily worked, or the more accessible minerals are actively exploited in any given era. The profitability of working a particular ore body may change radically from one period to another because of variations in the market price of the product and for other reasons as well. For example, new concentrating techniques may lessen the advantage of the richer ore bodies, as has been found in copper mining. Improvements in transportation may render accessible certain deposits which formerly could not be worked: thus the extension of the railroad network was a prior condition for the development of base metal mines in the West. As the nineteenth century advanced there occurred a geographic redistribution of mining activity which was not unlike the shift experienced by staple agriculture. Just as the wheat fields of New England could not compete with the wheat fields of Kansas, so the iron mines of the Atlantic Coast gave place to the iron mines of

Minnesota. A prime characteristic of mineral deposits is their exhaustibility: ghost towns of the mountain states bear silent witness to the departure of metals for which they were once a source. Mines close because the good ore is worked out, so that if any deposits are left they are in poorer, narrower seams which must be worked at greater depths, or because newer, richer deposits are discovered elsewhere. Mining continues, but under other skies, perhaps with other methods.

As a source of livelihood the mining industries (including stone quarries and oil and gas wells) are of relatively minor importance in the United States. In recent years they have employed about 2 percent of the working population, and have produced somewhat less than 2 percent of the national income. One occupied person in five is engaged in manufacturing, and one in six tills the soil or cares for livestock, but only one in fifty is a miner, quarryman or oil-well operative. Yet the mining industries furnish practically all of our fuel (solid and otherwise), and satisfy the major part of our need for metals and building materials. By value more than half of the output of the extractive industries consists of fuels, with metallic ores accounting for most of the remainder.

Some mining industries are much older than others. The length of time during which deposits have been worked has an important influence upon the technological state of the industry today and upon the degree to which depletion of its resources has already occurred. Small amounts of coal and iron were extracted for the use of blacksmiths even in Colonial times; lead was probably the first nonferrous metal to be produced domestically in any quantity. But we are concerned rather with the age of the mining industry as we now know it, the length of time during which today's deposits have been worked, and the date when modern technological problems first had to be faced.[1]

We know, for example, that anthracite has been mined continuously in Pennsylvania since 1820, and bituminous coal in Virginia at least since 1800. As for iron, bog ores were smelted in Massachusetts during the eighteenth century, and ironstone was mined and smelted in Maryland and Virginia before 1800. During

[1] The remainder of this section is based largely upon J. D. Whitney, *The Metallic Wealth of the United States* (Lippincott, Grambo and Co., Philadelphia, 1854); Albert S. Bolles, *Industrial History of the United States* (Henry Bill Publishing Co., Norwich, Conn., 1878); and U. S. Bureau of the Census, *Special Reports*, "Mines and Quarries, 1902."

the first half of the nineteenth century each of the New England states and a number of others had a local iron industry, and it was around 1825 that iron ore mining as we now know it had its beginnings in Pennsylvania. In 1840, 300,000 tons of iron ore were produced, mainly in Pennsylvania; scarcely any came from the Lake Superior region until the following decade. Gold was obtained by washing in Colonial times, but apparently it was not until 1825 that the first mining of gold-bearing quartz occurred, in North Carolina. Almost no silver was produced in this country until it appeared as a byproduct of California gold mining after 1848. Silver mining began with the discovery of the fabulous Comstock lode in Nevada in 1859. During the eighteenth century copper was worked rather spasmodically in New Jersey and Connecticut; even the extensive workings started at Bristol in the latter state in 1836 seem not to have been profitable. The establishment of regular copper mining in this country dates only from the opening of the Lake Superior region of Michigan in 1843. Lead mining has a somewhat longer continuous history. First exploited by the French in 1720, the lead mines of Missouri have apparently been worked consistently since 1798, when underground mining was started and a reverberatory furnace constructed. In 1819 the state boasted 45 lead mines in operation. By 1854 fears were already heard that the Missouri lead mines would soon be exhausted: up to the present, however, this has not yet occurred. In Wisconsin, which was less accessible than Missouri, lead mining did not begin until 1823. Although zinc is often found in association with lead, serious efforts to mine that metal in this country were slow to develop. Writing in 1854, Whitney observes that zinc ores "have, as yet, hardly begun to be worked": New Jersey, the sole producer, yielded less than 1,000 tons in 1852. Mercury was first mined in California about 1850.

The quarrying of stone followed the first settlements only at a distance, for lumber and imported brick were the initial building materials. By the middle of the eighteenth century, however, there were a number of important quarries in existence, so that stone quarrying stands out as one of the older forms of mineral extraction on this continent. Salt mining also has a long history, dating from the latter part of the eighteenth century. Most other forms of nonmetallic mineral production are relatively young. The petroleum industry had its start in western Pennsylvania as recently as 1859, and phosphate rock was not mined until 1867.

It does not follow, as we shall see, that because an industry is old, and has faced the same problems for many decades, its technological state is correspondingly more advanced than that of a newer industry. It may happen that mining tradition or the original layout of the mine makes mechanization a more difficult undertaking than it would be in a newer enterprise. It is in the younger industries or in the relocation of old industries, as with the development of the porphyry coppers of the West, that the real technological revolutions are to be found. Age does, however, exert a more direct influence upon resource depletion. In anthracite mining, one of the oldest of the extractive industries, depletion has considerably increased the difficulty of obtaining the coal, although exhaustion is still a long way off.

## THE DISTINCTION BETWEEN MINING AND MANUFACTURING

The actual separation of a mineral from the earth is usually a small part of the business of mining. The product must be broken, more or less, at the pit face, must be transported to the surface, and must then be cleaned, crushed or purified. The latter operations may be performed either in the vicinity of the mine or at some distance, in which case further transportation is necessary. Finally, there is usually a series of processes at the end of which the mineral, or part of it, is burnt up or emerges as a constituent of some finished commodity. At what point, then, do mining operations cease and manufacturing processes begin? Output and employment in manufacturing are treated in other volumes in this series,[2] and it was naturally desirable, in writing the present report, to avoid duplication between mining and manufacturing as far as possible. Censuses of Mining have been by no means consistent in this respect,[3] but we have tried to arrange the data so that, within practical limits, a uniform definition might apply in measuring output and employment, and that this definition might

[2] Solomon Fabricant, *The Output of Manufacturing Industries, 1899–1937* (National Bureau of Economic Research, 1940), and *Employment in Manufacturing, 1899–1939: An Analysis of Its Relation to the Volume of Production* (National Bureau of Economic Research, 1942).

[3] For example the Census of 1909 admitted significant overlapping of its results with those of the Census of Manufactures of the same year. See *Thirteenth Census of the United States, 1910*, Vol. XI, pp. 15-17. In the 1902, 1919 and later Censuses greater pains apparently were taken to prevent duplication of the sort indicated.

include all processes up to, but not beyond, the point where operations of a kind covered by the Census of Manufactures begin. Accordingly, in the case of metallic ores, we regard as mining not only the physical separation of the mineral from the earth, but also milling, concentration, or other processes of beneficiation. We include the crushing of stone, but not the sawing or shaping of dimension stone; the mining, but not the calcining, of gypsum.

Practical decisions of this kind receive statistical application at two points in a study such as this one. First, in reference to *output*, our indexes use prices as weights, that is, they represent comparisons in dollar terms, constant unit values being employed for each comparison. Thus, the valuation of a mineral is intended to occur at the point at which it leaves the mining operation as defined above: this is what we mean by the "mine value" of minerals. Second, the *employment* included represents the labor expended up to this same point of division between mining, as we have defined it, and subsequent economic processes. The resulting relationship between output and employment reflects changes in the productivity of mining proper and beneficiating, of quarrying and stone crushing; but it is unaffected by changes in the technology of smelting,[4] of the dressing of dimension stone, or of petroleum refining, for these we regard as manufacturing processes.

## THE MEASUREMENT OF OUTPUT AND EMPLOYMENT

In accordance with the plan adopted in other studies in this series, our indexes of output combine the physical quantities of different products, with unit mine values serving as weights. They therefore offer comparisons between dollar aggregates reckoned in constant prices. A description of the precise method of construction of these indexes, together with the data on which they are based, is presented in Appendix A. At this point it is necessary merely to discuss briefly the physical units chosen for measuring the output of individual minerals, and the related concepts of gross and net output.

Ideally we should seek to assemble separate production data for

[4] However, we measure the output of most ores of the nonferrous metals in terms of recoverable content. An improvement in smelting techniques may raise the ratio of recoverable to actual content, and thus affect our measures of output and productivity. Changes in smelter recovery during the period appear, at least in the case of copper, to have been slight (see Appendix Table D-1).

every grade of ore or concentrate, weighting each by an appropriate price, for only by such a procedure could we take full account of changes in the quality of the mineral product whose output we are assessing. In the case of iron and manganese we have treated different grades of ore as separate commodities, combining the output of each with appropriate unit values as weights. In the case of petroleum, too, a breakdown is available to distinguish Pennsylvania grade from other crude oil, with appropriate prices for each. But in other instances lack of data made it impossible for us to follow this course, and the difficulty had to be surmounted in a different fashion. For the nonferrous metals (other than manganese) we do not have a breakdown of ore and concentrates which can be matched with a similar breakdown of their prices. Instead, we measure the mineral product of these industries in terms of its metallic content, using a single price or mine value for each metal.[5] In the case of anthracite, bituminous coal, natural gas and other minerals, we have for each a single output series which affords no means of allowing for such changes in the quality, or shifts in the composition, of output as may have occurred.

From this discussion it will be seen that our measures of mineral production are indexes of the *gross* physical output of the various mining industries, not of their *net* output. This distinction is important. No deduction to take account of fuel or other materials consumed during the production process has been attempted. These should, of course, be deducted [6] in the interests of strict accuracy. Otherwise fuel consumed, for example, in the copper industry is counted twice, once in the coal industry and once in the copper industry. It is possible that the amount of materials consumed per unit of output has increased during the period spanned by this study, in part because of the need to use more elaborate supports and larger amounts of power in mining at greater depths. But there are also definite indications of a contrary tendency. In several industries less product is wasted than formerly: in the petroleum industry natural gas, once dissipated, is

[5] The principal nonferrous metal mines were classified as follows: (1) lead and zinc in the Mississippi Valley, (2) copper, and (3) gold, silver and miscellaneous metal mines. For the products produced within each of these three industries, market prices had to be used for weighting purposes. In combining the output indexes for the three industries, unit mine values were used as weights. The necessity of this treatment is explained in Appendices A and B.

[6] I.e., materials consumed should be included in the output indexes with negative weights.

now marketed; and in the nonferrous metal industries the higher recovery ratios of modern concentrating techniques afford another illustration. Further, the shift to open cut mining has reduced the need both for mine supports and for pumping. Fuel has probably been economized in power production. Such considerations suggest a fall rather than a rise in materials consumed per unit of output in the mining industries as a whole. It is difficult or impossible to subject this question to a statistical test. But if the consumption of materials per unit of output has altered, indexes for the *net* output of the mining industries, in which the physical volume of materials consumed was deducted, would naturally behave somewhat differently from the indexes for gross output which we present. If materials have, on balance, been economized, an index of net output would plainly rise more rapidly than does our index of gross output. So would an index of net output per worker.

Thus in the realm of production statistics we can only approximate that which we would most wish to measure. The same is true in the employment field. First, the exclusion of workers engaged in manufacturing operations is sometimes troublesome, particularly in the quarrying of dimension stone. Second, since we do not regard additions to mining equipment or facilities as part of current mining output, a case exists for the exclusion of construction employees. But employees engaged in construction and other nonproducing activities, such as exploration, cannot usually be segregated from those who are actually digging the mineral. Because the amount of construction and development work varies rather sharply from year to year, short run variations in our productivity measures are probably not significant: the problem is less important when periods of ten or twenty years are being considered. The third way in which our employment figures may err is in the coverage of employees working for contractors. We have tried to cover these employees but we may not have been entirely successful. This disturbance to the results affects chiefly oil and gas wells. A similar difficulty occurs in connection with lead and zinc mining, where labor employed in leased workings may not be completely covered.

To the numbers of workers employed in mining industries we have paid slight attention. Fluctuations in mining activity from year to year are for the most part so violent, and mining operations have such a strong tendency to be intermittent, that the size of the labor force gives a poor idea of labor input, or the amount of human effort consumed. We have therefore preferred to express employment in terms of mandays or manhours, wherever these alternative measures could be developed. The manhour is perhaps the more fundamental unit of employment, but we have generally been forced to treat the manday as the basic unit of labor input in measuring productivity. Our reliance upon the manday is in the nature of a compromise. The majority of employment statistics in mining are still collected in terms of men on the payroll, and are converted by the Bureau of Mines or the Census Bureau into derived totals for mandays or manhours. Consequently manday totals involve fewer adjustments and are closer to the crude data than figures for manhours. Moreover, they are available generally for longer periods of time. In many cases we have given both types of data.

The measures of productivity which result from a comparison of output and employment are thus subject to numerous qualifications, some of which will be explored in greater detail in chapters dealing with individual industries.

In the remainder of Part One, Chapters 2 to 4 cover mining activity as a whole and embody the main statistical results of the study. In Chapter 2, which deals with output, an attempt is made to explain why the production of some minerals has expanded much more rapidly than that of others: in particular the role of scrap in the metal industries, and the economy of fuel and the substitution of oil for coal as a source of power, receive consideration. Chapter 3 reviews the major changes which occurred between 1902 and 1939 in the volume of employment, in its composition, and in the length of the work day. Chapter 4 examines the relationship between changing output and changing employment, and makes some comparisons of the trend of productivity in different branches of mining.

In Part Two, Chapter 5 presents a review of technological developments in various mining industries (except oil and gas wells, whose technology is discussed in the chapter on petroleum); in particular the trend toward nonselective mining is noted. This discussion is continued in Chapter 6, where various phases of the mechanization of the mining process are explored. Chapter 7 is devoted to the subsequent preparation of the mineral, and especially to the concentration of metallic ores and its relation to mining method.

In Chapters 8 through 13, which constitute Part Three, we examine the relations between output, employment and technology in major individual industries—bituminous coal, anthracite, petroleum, iron ore, copper and the quarrying of stone.

Part Four consists of a single concluding chapter, embodying a summary of the results and some reflections on their significance. In addition to appendices, a glossary of minerals and mining terms will be found at the end of the book.