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

Volume Author/Editor: Harold Barger and Sam H. Schurr

Volume Publisher: NBER

Volume ISBN: 0-87014-042-6

Volume URL: http://www.nber.org/books/barg44-1

Publication Date: 1944

Chapter Title: The Behavior of Mining Output

Chapter Author: Harold Barger, Sam H. Schurr

Chapter URL: http://www.nber.org/chapters/c6316

Chapter pages in book: (p. 13 - 58)

Chapter 2

The Behavior of Mining Output

IN THE STUDY of changes in production and productivity in the mining industries the first phase of our inquiry must evidently be concerned with the measurement of physical output. We need to know what has been produced, how various minerals compare in importance, and what shifts have occurred in the positions they occupy. In accordance with the practice adopted in other reports in this series,[1] data on the physical output of as many minerals as possible have been combined, with values as weights, into group and total indexes. For the most part, the results are presented for each year from 1899 to 1939. For details of index number construction, and for the various minerals included in the over-all index in different years, the reader is referred to Appendix A. The new index of mining output is shown in Table 1 and in Charts 1, 2 and 3.

MINING AND OTHER SECTORS OF THE ECONOMY

Our index of mining output may be compared with the familiar measure published by the Federal Reserve Board, and with other mining indexes. The Board's index of mineral production, for the period since 1919, is based upon nine series only—bituminous and anthracite coal, crude petroleum, iron ore, copper, lead, zinc, gold and silver—which together accounted for slightly less than 80 percent of the value of all mineral products reported by the Bureau of Mines for 1929. The National Bureau index of course includes many more items, and for the period since 1919 covers the output of more than 99 percent of all minerals for which value data are available. The most important items not covered by the Reserve Board index (but included in the index presented here) are natu-

[1] Solomon Fabricant, *The Output of Manufacturing Industries, 1899–1937* (National Bureau of Economic Research, 1940); Harold Barger and Hans H. Landsberg, *American Agriculture, 1899–1939: A Study of Output, Employment and Productivity* (National Bureau of Economic Research, 1942). The statistical methods employed in the present study resemble closely those followed in these reports.

TABLE 1

INDEXES OF PHYSICAL OUTPUT FOR MINING, MANUFACTURING AND AGRICULTURE, 1899–1939

1899:100

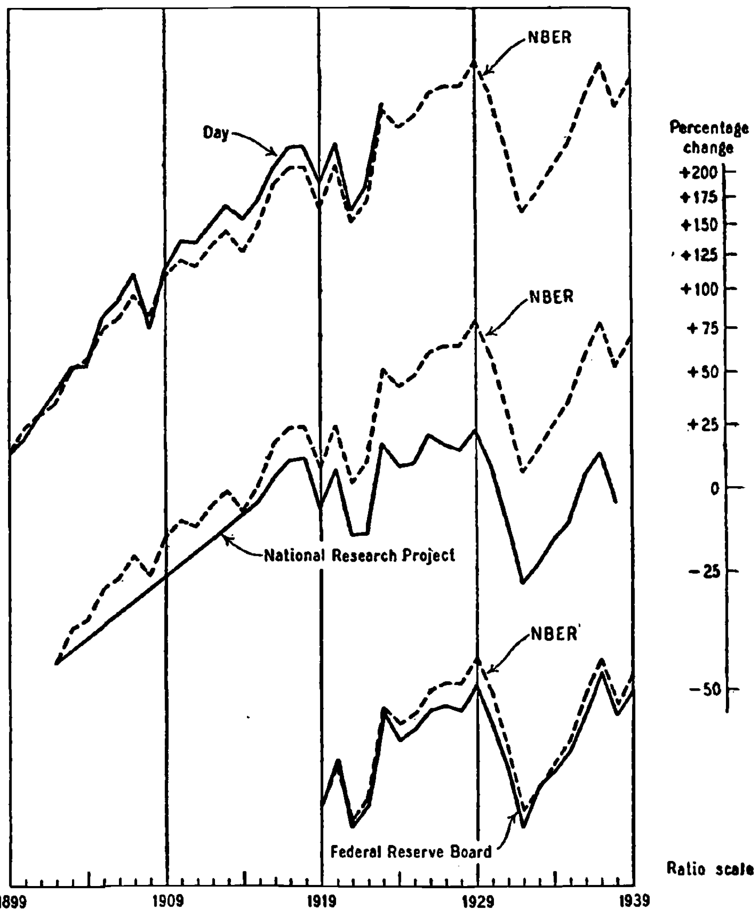
Year	Mining[a] Metals	Mining[a] Fuels	Mining[a] Other Non-Metals	Mining[a] Total	*Manu-facturing*[b]	*Agricul-ture*[c]
1899	100	100	100	100	100	100
1900	109	106	108	108	102	101
1901	111	116	105	114	115	99
1902	120	118	116	119	129	103
1903	120	141	128	134	132	104
1904	125	142	149	138	124	109
1905	141	157	184	154	148	108
1906	149	162	222	160	159	118
1907	145	188	231	173	161	110
1908	139	172	223	162	133	112
1909	170	187	255	184	158	111
1910	175	203	264	195	168	114
1911	166	204	261	192	161	117
1912	184	215	278	206	185	123
1913	192	230	281	217	198	119
1914	172	218	258	202	186	129
1915	212	226	253	220	218	129
1916	264	248	279	254	259	119
1917	259	276	281	268	257	124
1918	249	286	245	270	254	130
1919	184	259	235	234	222	125
1920	195	305	288	271	242	130
1921	99	268	247	222	194	118
1922	155	269	300	239	249	130
1923	214	374	383	329	280	132
1924	207	346	386	310	266	137
1925	226	352	422	321	298	138
1926	235	386	447	348	316	146
1927	223	401	475	357	317	141
1928	230	397	482	357	332	147
1929	252	434	507	389	364	144
1930	197	393	459	343	311	145
1931	136	346	344	286	262	150
1932	76	301	221	230	197	144
1933	88	327	223	249	228	140
1934	111	346	251	271	252	120
1935	144	365	265	293	301	133
1936	195	410	362	344	353	134
1937	251	449	396	387	376	153
1938	176	403	340	331	295	152
1939	224	430	382	366	374	159

For footnotes see next page.

ral gas and gasoline, crushed stone, and sand and gravel. According to our index mineral production in 1939 was significantly below that of 1929, whereas the Reserve Board index shows practically no change between these two years. This and other slight

Chart 1

INDEXES OF MINING OUTPUT



For source and notes see Appendix E

Footnotes to Table 1.

[a] See Appendix Table A-7.

[b] Solomon Fabricant, *Employment in Manufacturing, 1899–1939: An Analysis of Its Relation to the Volume of Production* (National Bureau of Economic Research, 1942), p. 331.

[c] Harold Barger and Hans H. Landsberg, *American Agriculture, 1899–1939: A Study of Output, Employment and Productivity* (National Bureau of Economic Research, 1942), p. 21. The index refers to net output, and is based on crop year data in the case of crops, calendar year data in the case of livestock.

discrepancies are no larger than might be expected in view of the difference in coverage between the two indexes.

The index of mineral output for 1899–1923 constructed by Day[2] has a coverage (96 percent) comparable to that of our own index, and the two agree well. It employs fixed (value) weights instead of the modified chain method used in this study,[3] but otherwise is very similar in scope. The National Research Project index of mining output also has a high coverage—from 94 to 97 percent, according to the author of the report[4]—but for the last two decades of the period it exhibits a marked downward bias in comparison with the National Bureau index. This difference is attributable primarily to the fact that the authors of the former index used manhour instead of value weights. As we shall see, the output of petroleum and natural gas is one of the fastest rising component series included; but its share of the value of mineral products is far greater than its share of manhour employment. Consequently our index, based as it is on value weights, rises more rapidly during the 1920's and 1930's than does an index based on manhour weights.

In Chart 2 our index of mineral production is compared with the National Bureau indexes of physical output in manufacturing and agriculture, and with population growth. It will be seen that since 1899 the production both of minerals and of manufactures has outstripped the increase of population, whereas agricultural output has failed to keep pace with population growth. Between 1899 and 1929 mineral production, like manufacturing output, increased roughly fourfold. During the 1930's a sharp contraction occurred in both kinds of production, followed by an equally sharp recovery; and in 1939 the level of each was about equal to the peak reached ten years previously. Viewing the four decades as a whole, we should not feel inclined to say that the upward movement of either curve has ceased as yet. To be sure, there is in each case some evidence of retardation in the growth of output, for it is obvious that a parabola fitted to the logarithmic data in

[2] Edmund E. Day, "The Volume of Production of Basic Materials in the United States, 1909–21," *Review of Economic Statistics* (July 1922), and "The Physical Volume of Production in the United States for 1923," *Review of Economic Statistics* (July 1924).

[3] See Appendix A.

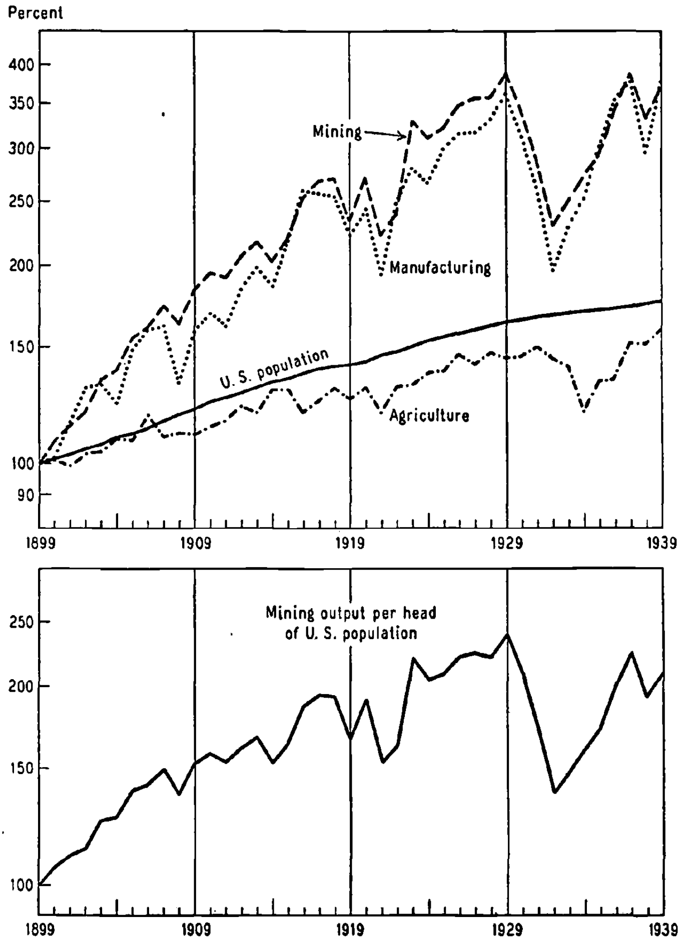
[4] Vivian E. Spencer, *The Mineral Extractive Industries, 1880–1938* (National Research Project, Philadelphia, 1940), p. 4. The arithmetic index with 1929 weights (*ibid.*, p. 9) is the one shown in Chart 1.

Chart 2

OUTPUT OF MINING, MANUFACTURING AND AGRICULTURE

National Bureau Indexes

(1899 : 100)



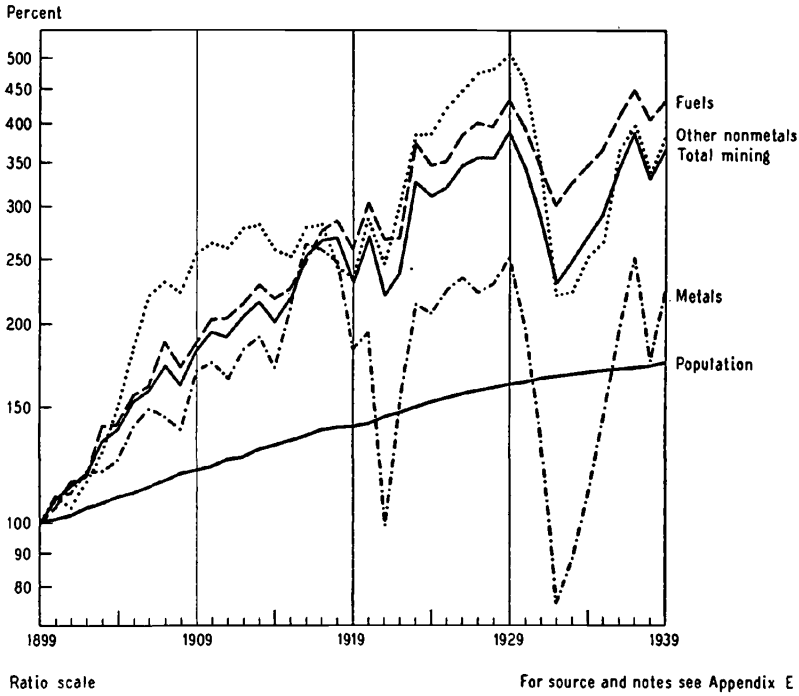
Ratio scale

For source and notes see Appendix E

Chart 2 would be convex upward, both for manufacturing and for mining. It does not appear, however, that such slackening of growth much exceeds the similar slackening apparent in the rate of population increase.

That mineral production should have kept pace with manufacturing output is at first sight surprising, particularly when we recall that in recent decades the nation's factories have achieved striking economies in the use of mineral raw materials. Moreover, in the case of many extractive industries output has shown little sign of growth or has actually contracted during the last twenty years. For example, coal, which receives more attention than many mining industries because of its fertility as a source of social problems and its quantitative importance, has experienced a marked

Chart 3
MINING: GROUP INDEXES OF OUTPUT
(1899 : 100)



For source and notes see Appendix E

contraction in output. Indeed, it would be accurate to conclude that mining as a whole has reached a declining stage of its development were it not for the sensational growth of petroleum and natural gas production. It is the expansion in the output of these two commodities which has largely compensated for the retardation, or more than outweighed the actual decline, of the older forms of mineral extraction.

GROUP INDEXES OF OUTPUT

Mineral production falls naturally into three rather unequal divisions. Fuels ranked first in importance in 1937, the latest year for which we have appropriate data, with a mine value of $2¾ billion, not quite two thirds of which consisted of oil products, and the remainder of coal.[5] Second in importance came metals, with a value of $640 million, one third of this being accounted for by iron ore. The remaining group, which comprises nonmetals other than fuels, was valued in 1937 at slightly less than $400 million. Among these, crushed limestone, sand and gravel, and sulfur were the most important; this third group includes also numerous minor minerals, from marl to ground soapstone.

Indexes for the output of each of these three groups of minerals, and for total output and population, will be found in Chart 3. Here the failure of the metals to grow as rapidly as the other groups is clearly evident. While the output of metallic minerals barely kept pace with the growth of population, indexes for both the fuels and the other nonmetals rose considerably faster than population. An important element in the slower growth of the metals is undoubtedly the increased availability of scrap: [6] metal once mined may be used again, but fuel burned is gone forever. Besides growing less rapidly than the other groups, the metals appear to fluctuate more violently. The amplitude of fluctuation for mineral output as a whole is very similar to that for manufacturing output (Chart 2). However, among different types of mineral the metals are much more sensitive to business cycle influences than the nonmetals. The extremely low levels of the metals index in 1921 and 1932 are especially noticeable (Chart 3). The very low level of this group in 1921 is associated with the liquidation of inventories accumulated during the war, and the short-lived post-war boom. The low point in 1932 reflects, in turn, the extreme decline of the important iron ore component, which fell by almost nine tenths from 1929 to 1932; as Chart 4 shows, iron ore output in 1932 was less than half as great as it had been at the turn of the century.

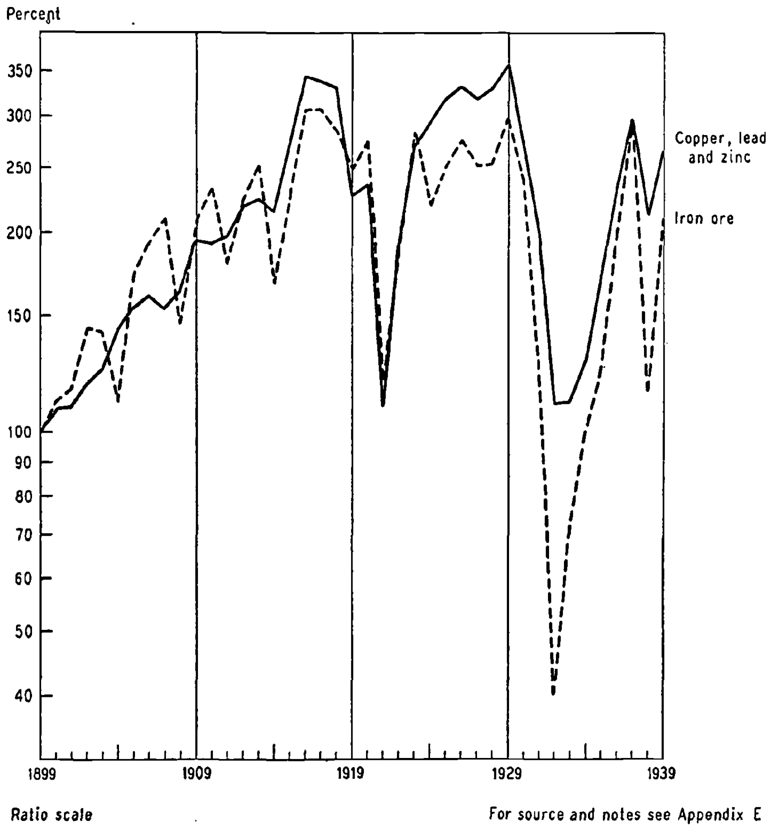
[5] The value of individual minerals for 1899, 1909, 1919, 1929 and 1937 will be found in Appendix Table A-2.

[6] Our indexes relate to ore mined and do not include the recovery of secondary metal.

METALS

We estimate the mine value of all metals produced in 1937 at \$642 million.[7] Of this total, \$608 million was accounted for by the combined value of iron ore (\$207 million) and the major nonferrous and precious metals, copper, lead, zinc, gold and silver (together \$400 million [8]). As for the remainder, \$34 million, molybdenum was valued at \$20 million, and antimony, bauxite, chromite, manganese, mercury, platinum, tungsten, uranium, vanadium and ti-

Chart 4
COPPER, LEAD AND ZINC, AND IRON ORE: OUTPUT
(1899 : 100)



For source and notes see Appendix E

[7] The value of individual minerals for 1899, 1909, 1919, 1929 and 1937 will be found in Appendix Table A-2.
[8] Included in this sum is the value of a small amount of (nonmetallic) fluorspar which appears as a byproduct of lead and zinc.

tanium—no one of which accounted for as much as $5 million separately—made up the other $14 million. It should be remembered that a substantial fraction of this country's consumption of copper, bauxite (aluminum), manganese and mercury, and virtually its entire supply of nickel and tin, are imported either as concentrates or as metal.[9] Domestic production, with which we are here concerned exclusively, is therefore a poor gauge of the relative importance of different metals from the standpoint of consumption.

Chief among the industrially important metals of domestic origin are iron, copper, lead and zinc. In 1937 the value of the output of iron ore was about half that of copper, lead and zinc combined; however, the former weighed, in terms of metal, around twenty times the latter. Indexes for the output of iron ore and for copper, lead and zinc production are compared in Chart 4. It will be seen that, broadly speaking, the movements of the two series are similar. Between 1899 and 1916–18 the production of iron ore and of the three nonferrous metals tripled. Since the close of the first World War the trends of both series have been stationary or slowly declining. Both show marked cyclical fluctuations, and both fall to low levels in the depressions of 1921 and 1932. On the other hand the iron ore series fluctuates with greater violence than does the series for nonferrous metals. This difference in behavior may perhaps be related to differences in degree of diversification among the uses to which the two kinds of metal are put. It is probably attributable also to the great importance and continuous availability of iron and steel scrap, which in periods of depression is often substituted for iron ore in the manufacture of steel.

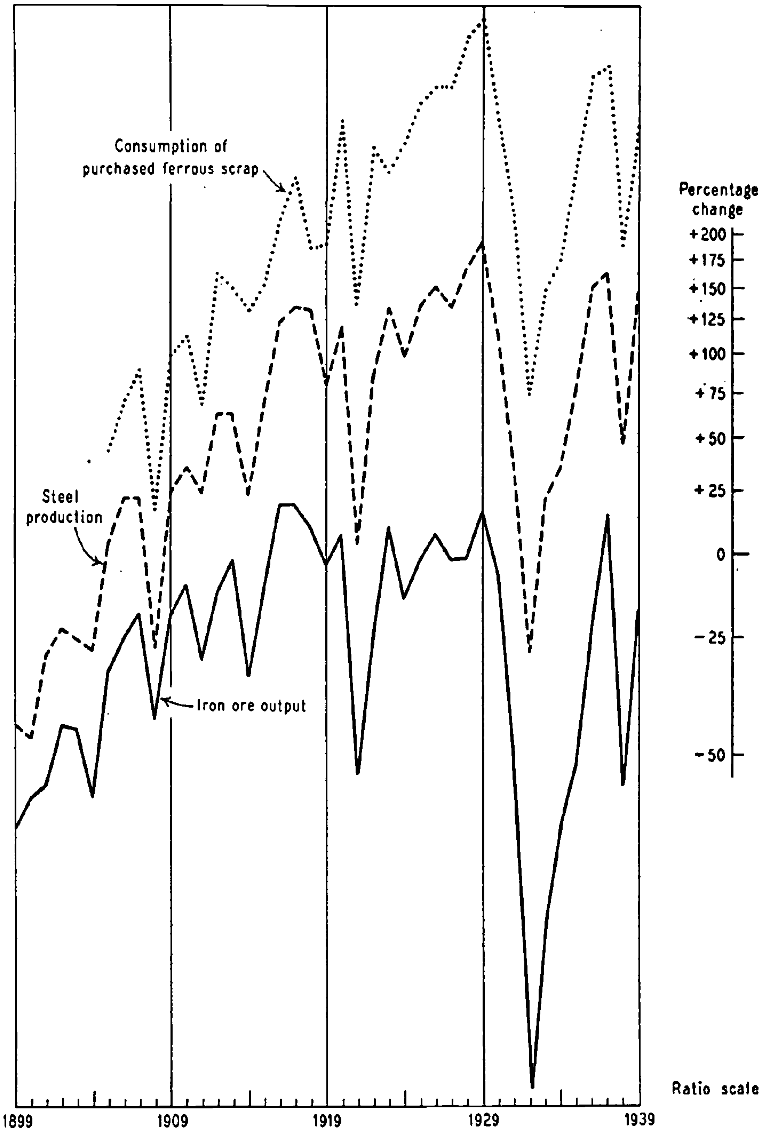
Iron Ore

The demand for iron ore is derived primarily from the demand for steel. As we should expect, the short run fluctuations in the output of the former follow a pattern very similar to that shown by movements of the latter (Chart 5). It is obvious, however, that although the two curves resemble each other in shape, the production of iron ore has lagged behind the growth of steelmaking.

[9] In the case of copper, imports of ore and concentrates are usually offset, or more than offset, by exports of refined metal.

Chart 5

IRON ORE OUTPUT, STEEL PRODUCTION AND CONSUMPTION OF SCRAP



For source and notes see Appendix E

The failure of iron mining to keep pace with steel production is to be explained by three separate factors whose relative importance is not easy to assess. In the first place the substitution of steel for cast or wrought iron—a substitution which began with the invention of steel itself—has continued: for example 28 percent of pig iron and ferro-alloy output went for other uses than steelmaking in 1899, compared with only 18 percent in 1937.[10] This means that relatively less and less ore has been used for other purposes than steelmaking. In the second place the steel industry, like other branches of manufacture, has made economies in the use of raw materials: in 1937 about 10 percent less ferrous materials were used in the production of a ton of steel than were required in 1909.[11] Perhaps still more important is a third factor—the substitution of scrap iron and steel for pig iron as a raw material in steelmaking. It will be seen from the uppermost curve in Chart 5 that the consumption of purchased scrap[12] by steelmakers increased at a faster rate than steel production and very much more rapidly than the production of iron ore. This increased use of scrap in steelmaking is to be explained partly by its greater availability, and partly by technical changes in the manufacture of steel. We should notice, in regard to the availability of scrap, the retardation which has occurred in the growth of steel production itself: the ratio of past steel output (i.e. at the time when currently available scrap was freshly manufactured) to present steel output has perhaps never been so high as it is today.[13]

Of the three factors mentioned, each of which has tended to retard the growth of iron ore production in comparison with the output of steel, the last would appear to be the most important at

10 Fabricant, *The Output of Manufacturing Industries, 1899–1937*, p. 273.

11 *Ibid.*, pp. 265-66.

12 Substantial quantities of scrap are produced by the steelmakers themselves, and used by them as raw material (e.g., ingots too short to roll, and trimmings left in rolling or forging); data on the consumption of this scrap (which of course does not enter commercial channels) have been available only since 1935. In recent years purchased scrap has accounted for about half of total scrap consumption. Not quite all scrap is used for making steel; small amounts are consumed in the manufacture of iron products.

13 The availability of scrap appears also to have been increased during recent decades by the obsolescence of reciprocating engines on the advent of the turbine, and the short life of the automobile in comparison with older forms of transportation equipment: see Erich W. Zimmerman, *World Resources and Industries* (Harper, 1933), pp. 600-05. In some uses, to be sure, technological advance may have lengthened rather than shortened the useful life of the metal, but this contrary tendency does not seem to have been important.

the present time, whatever has been the case in past eras. To the substitution of steel for iron, and to economy in the use of materials in steelmaking itself, there are definite limits which are already being approached. On the other hand, there is still considerable scope for further increases in the use of scrap. In the short run scrap and pig iron from ore are by no means perfect substitutes for the manufacture of steel, although with appropriate technical adaptation it is entirely possible to use either exclusively. It may be that in the future the requirements of the steel industry for pig iron will be further reduced: certainly the supply of scrap has grown steadily in recent decades and appears likely to increase still further.

Alloy Metals

Steel is now the principal product for which iron ore is used, but by no means all steel is of the ordinary carbon or "tonnage" class. Increasing amounts of a great variety of alloy steels are manufactured for different purposes. Of all steel made, alloy steels rose from less than 1 percent in 1909 to 5 or 6 percent in the years immediately preceding the present war (Chart 6). These percentages are in terms of weight; by value they run much higher.

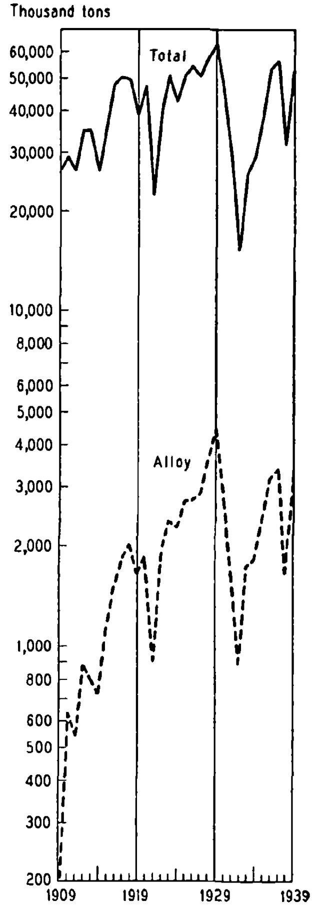
Among the metals used in ferro-alloys (in addition to iron) manganese is quantitatively the most important.[14] First added to Bessemer steel in 1856, it is employed to secure uniformity of structure and to lessen the effect of impurities. Variations in the production of manganese are shown in Chart 7. It will be seen that the fluctuations in manganese output are much more violent than in iron ore output, but the movements in the two series are usually in the same direction except for the years 1901–14. The low level of manganese compared with iron ore production during this period was apparently associated with increased dependence on imports of manganese. Since iron ore is bulky and low in value, imports are normally of negligible importance (Table 2). In contrast, a substantial fraction of our manganese requirements has always been supplied from abroad. A high level of imports during the decade preceding the first World War was followed after 1914

[14] The technical information in this section is largely taken from J. M. Camp and C. B. Francis, *The Making, Shaping and Treating of Steel* (5th ed., Carnegie-Illinois Steel Corp., 1940), pp. 908-1057.

by lessened dependence upon foreign sources: since then imports and domestic production have usually expanded and contracted in unison.

Smaller quantities of many other metals are used for making steel alloys. Tungsten is a constituent of all high-speed tool steels, and vanadium, molybdenum, nickel or cobalt are usually added as well. Nickel steels not only possess magnetic properties, but are less brittle than ordinary carbon steels; they are used for making high pressure boilers and heavy duty gears. Chrome steels are exceptionally hard; they appear in files, ball bearings, gears and small tools. Chromium, moreover, has become important recently because of its ability, alone or in combination with other alloy metals, to improve the resistance of steel to high temperatures. Many industries using equipment made of steel have pushed temperatures and pressures to levels at which ordinary steels would break down; in this connection chrome steel has improved the efficiency of the high pressure steam boiler, of the internal combustion engine, of apparatus for cracking or hydrogenating petroleum, and of many types of equipment in the chemical industry. Chromium has found further application in the manufacture of stainless steel, which may contain as much as 10 to 30 percent of the alloy metal; by contrast, most other special steels contain only 1 to 4 percent of alloy metal.

Chart 6
STEEL INGOTS AND CASTINGS
Production, 1909-39



Ratio scale
For source and notes see Appendix E

Molybdenum steels, easily machined and particularly suitable for welding, are used for structural plates and heavy welded pipe. Vanadium steels make excellent forgings, and hence are employed for crankshafts; also for tools, dies, taps and razor blades. So large

TABLE 2

IRON ORE AND ALLOY METALS

Value of Domestic Production and Imports, Averages for Years Shown

Million dollars

		1899–1901	1914–16	1917–19	1927–29	1937–39
Iron ore	*Production*	49.4	118.4	226.6	168.0	146.9
	Imports	1.3	4.4	3.2	6.5	5.7
Manganese	*Production*	1.0	1.3	8.2	4.8	3.1
	Imports	1.7	4.4	12.2	7.4	8.6
Tungsten	*Production*	[b]	5.5	4.8	.7	3.9
	Imports	[c]	2.8	7.4	1.1	1.4
Molybdenum	*Production*	[b]	.1	.7	2.1	21.4
	Imports	[c]	[c]	.1[d]	[b]	[b]
Vanadium	*Production*[a]	[c]	.7	1.1	[c]	1.0[e]
	Imports	[c]	[c]	[b]	.5	.8
Chromite	*Production*	[b]	.3	1.7	[b]	[b]
	Imports	.3	1.0	1.8	2.0	5.3
Nickel	*Production*	[b]	.5	.4	.3	[c]
	Imports	1.4	7.5	9.9	14.2	22.1
Cobalt	*Production*	[b]	0	[b]	0	0
	Imports	.1	.3	.6	2.0	2.6

Source: Annual issues of *Mineral Resources* and its successor, *Minerals Yearbook* (U. S. Bureau of Mines).

[a] Includes uranium.

[b] Less than $50,000.

[c] Not available.

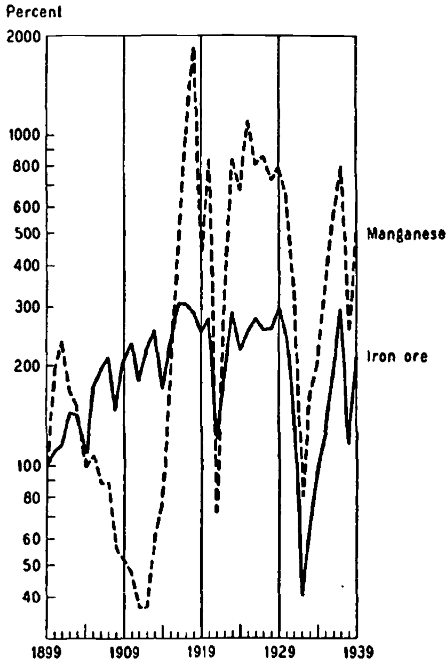
[d] Annual average for July 1918 to December 1919; data for remainder of period not available.

[e] Average 1938 and 1939; data for 1937 not available.

a variety of steels contain more than one alloy metal that only a few illustrations can be given here: manganese-nickel and manganese-molybdenum alloys are common in railroad equipment, where resistance to fatigue and to sharp impacts is important; manganese-chromium-molybdenum steels are used for chisels and punches, chromium-molybdenum for large springs and forgings, nickel-molybdenum for axles, shafts and armor plate, and other purposes requiring high tensile properties and high fatigue resistance; nickel-chromium steels, being easily machined yet wear-resistant, are particularly suited for gears and oil well bits.

Fluctuations in the output of the alloy metals are so erratic that we have not thought it worth while to chart them, except in the case of manganese (Chart 7). Such output data as can be assembled for individual minerals will be found in Appendix Table A-1 and have been included in our indexes. Variations in domestic production and in imports are reflected in Table 2, which presents value data for iron ore, and for the seven principal metals used in

Chart 7
IRON ORE AND MANGANESE: OUTPUT
(1899:100)



Ratio scale For source and notes see Appendix E

steel alloys. Here it is shown that although none of these metals compares in importance with iron ore itself, the two most significant in value terms are nickel and molybdenum. Particularly impressive is the increasing importance of molybdenum, the only one of the seven alloy metals of which the United States has an adequate domestic supply. In normal times there is no domestic production of cobalt; output of chromite is insignificant, and of nickel very small. As for manganese, tungsten and vanadium, domestic production is sufficient to fill a substantial part, but by no means all, of our needs.

Nonferrous Metals

It is difficult to devise a satisfactory industrial classification of nonferrous-metal mines. If we adopt the most convenient treatment, a fourfold division into lead-zinc mines, copper mines, gold-silver mines and placer workings, we must bear in mind that while mines in the first group yield lead and zinc almost exclusively, copper mines also produce gold and silver, and gold-silver mines provide some lead and zinc in addition to the precious metals. Placer operations produce gold and a little silver. Since employment is associated with a mine, rather than with the production of a single metal from that mine, we have had to use the industrial classification just described in order to measure productivity (Chapter 4, below). In the present chapter, however, we are interested rather in the individual metals for their own sake: copper from a gold or silver mine is just as good for most purposes as copper from a copper mine. For each metal, therefore, the outputs from different types of mine have been aggregated, and in Chart 8 the total for each is shown, irrespective of the type of mine from which it came.[15]

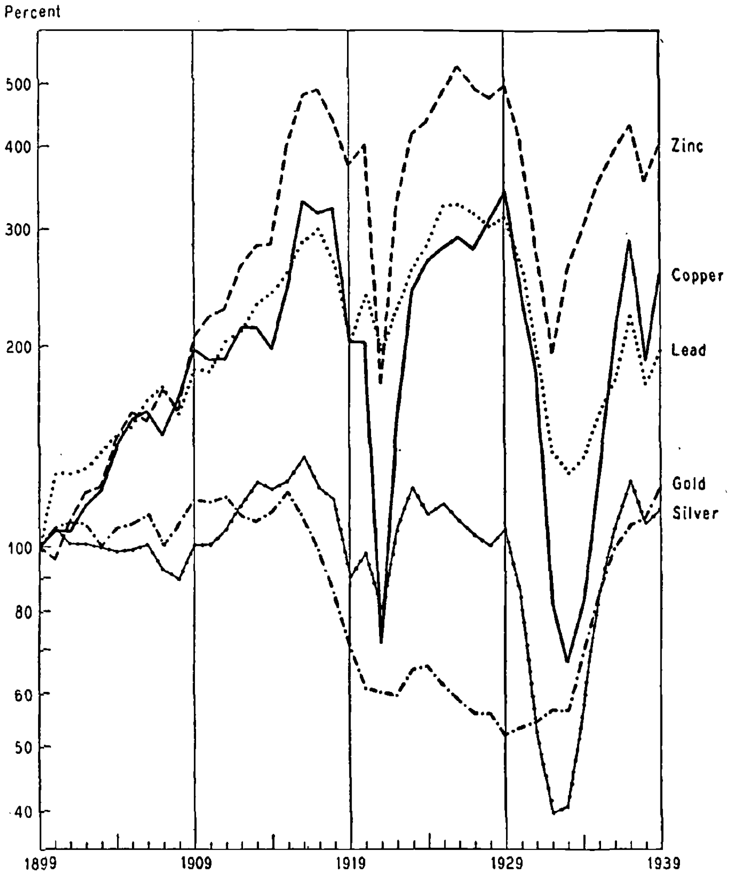
There are striking contrasts in the behavior of the five metals. During the first two decades of the present century the three metals for which the demand is primarily industrial, copper, lead and zinc, increased their output substantially in comparison with the two precious metals, gold and silver. Thereafter the trends of the five metals were less dissimilar. In 1939 the output of gold and silver was only 10 to 20 percent above the 1899 level, whereas lead output had doubled, copper output had more than doubled, and zinc output had quadrupled. In amplitude of fluctuation, and especially in cyclical behavior, equally sharp contrasts may be observed. The widest variations in output are to be seen in copper, and after copper in zinc and silver. Cyclical movements in lead are somewhat less marked, and in gold they scarcely show at all.

In the case of gold, the lack of positive correlation with the business cycle accords with expectation, and is due to its fixed selling price; indeed, one can observe here an inverse correlation with general movements in business. The sharp decline in gold output from 1915 to 1920 must be ascribed to the rising monetary costs

[15] The classification of nonferrous metal mines is considered further in Appendix B.

of its production, the equally sharp recovery from 1933 to 1939 to the devaluation of the dollar. As for silver, its greater sensitivity to movements in business seems at first sight surprising, for its industrial applications are not much more important than are

Chart 8
NONFERROUS METALS
Output of Individual Minerals
(1899 : 100)



Ratio scale

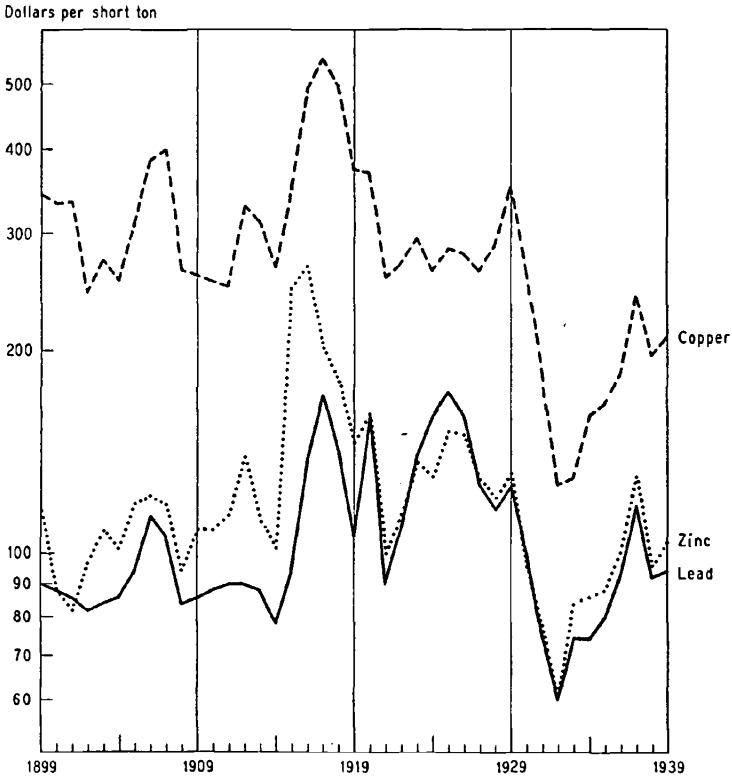
For source and notes see Appendix E

those of gold. However, silver is to a large extent a byproduct of other nonferrous metals, so that changes in its output result chiefly from fluctuations in the demand for these metals. The sharp rise in silver output after 1933 is obviously connected with the silverbuying policy of the United States Treasury—a policy which must also have affected indirectly the production of gold and copper, with which it is jointly produced.

Copper, lead and zinc may be considered together. Each is—at least in some of its uses—a substitute for the other, and the prices

Chart 9

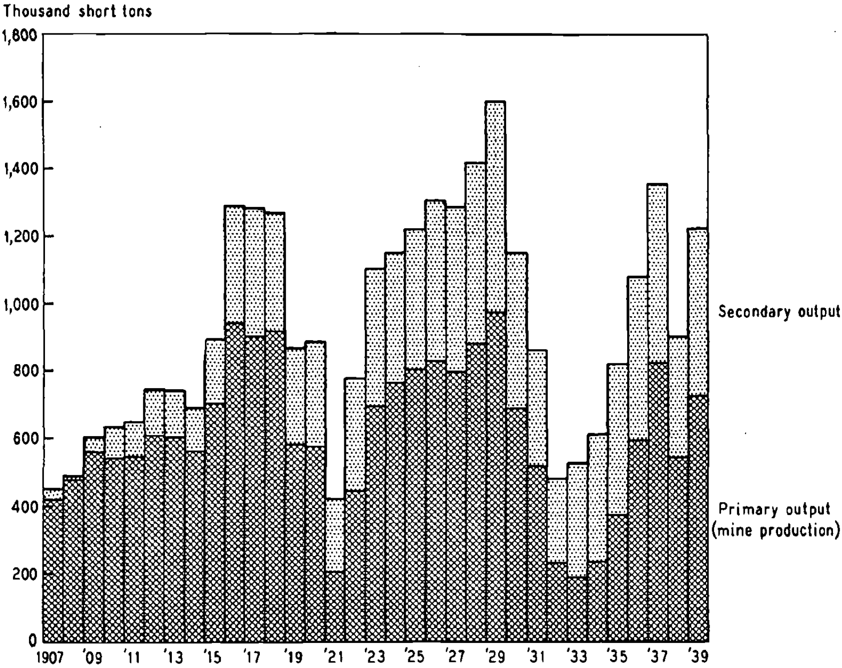
COPPER, LEAD AND ZINC: PRICES



For source and notes see Appendix E

of all three tend to move in the same direction (Chart 9). Copper is more expensive than either lead or zinc, a fact which probably restricts its uses in comparison with the other two metals; for this reason either lead or zinc, if equally applicable, will be preferred to copper (especially in building construction). The premium in the price of copper appears, however, to be steadily diminishing. This development is difficult to explain. It can hardly be attributed to an expansion in copper output in relation to the supply of the other metals, for copper production in this country has lagged behind that of zinc, and has shown scarcely any increase as compared with lead. Increased output in Chile and in Africa no doubt played a part. At any rate it is noteworthy that during 1922–28 the price of copper was about the same as before the first

Chart 10
COPPER
Primary and Secondary Output, 1907 – 39



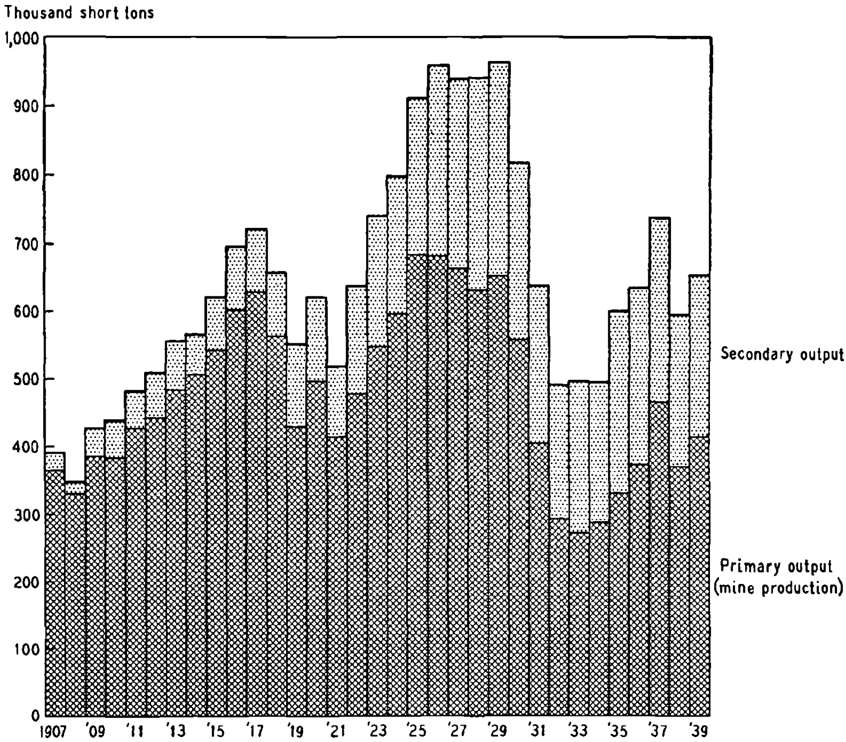
For source and notes see Appendix E

World War, whereas lead and zinc were both considerably more expensive than in the pre-war era. Except for a period of dear copper during 1928–30, this decline in the premium of the copper price over the prices of lead and zinc has persisted. Some substitution of copper for the other two metals must have taken place.[16]

[16] "It is evident that the low selling price of copper in recent years has encouraged consumption, discouraged the search for substitutes, and resulted in the finding of many new uses for the metal. Undoubtedly substitutes would have been employed for some uses had prices been higher, whether or not such substitutes could have met requirements quite as well as copper." C. E. Julihn and Helena M. Meyer, "Copper," *Mineral Resources of the United States, 1925* (U.S. Bureau of Mines), Part I, p. 351.

The three metals show differences in trend which are not to be explained entirely by the relations among their prices. Zinc output grew from 1908 to 1917 at an appreciably faster rate than either copper or lead, and since then the corresponding increase in the relative importance of zinc has persisted. The price of zinc,

Chart 11
LEAD
Primary and Secondary Output, 1907 - 39



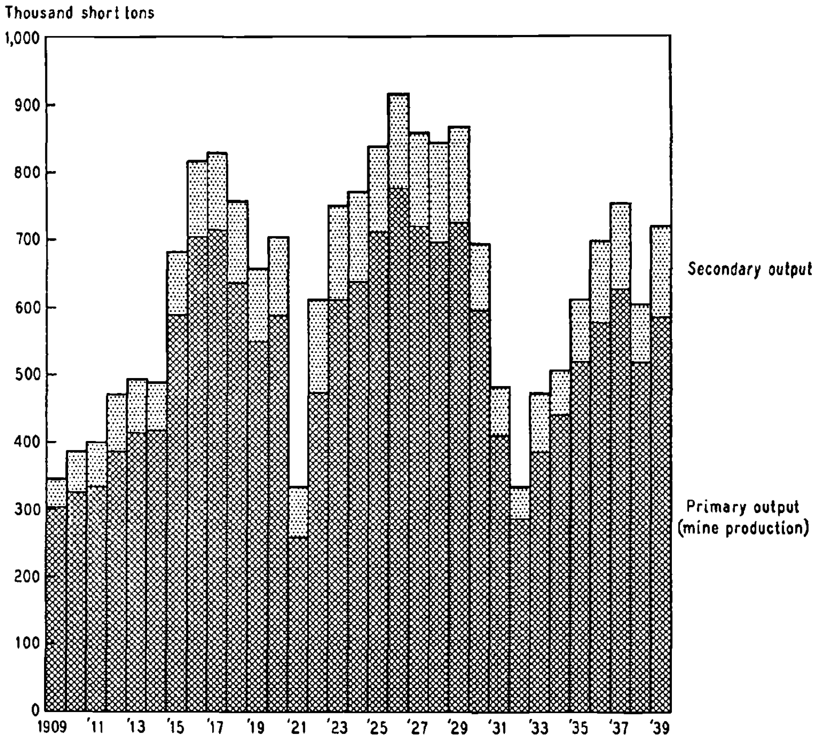
For source and notes see Appendix E

which was comparatively high during 1915–16, has declined no more rapidly than the price of copper, and has fallen only slightly in relation to lead. Lead is distinguished from the other two metals considered here by the fact that it is apparently much less sensitive to business cycle fluctuations: in 1921, for example, lead output was only slightly below its level for the two preceding years, whereas zinc and copper dropped precipitously, numerous copper mines closing down completely. In 1929–32 the contrast is less marked, for lead declined as much as zinc, though not so sharply as copper. Finally, while the three metals show slight sign of positive growth since the peaks reached in 1916–18, lead alone appears to have begun a definite downward trend. During 1937–

Chart 12

ZINC

Primary and Secondary Output, 1909 - 39

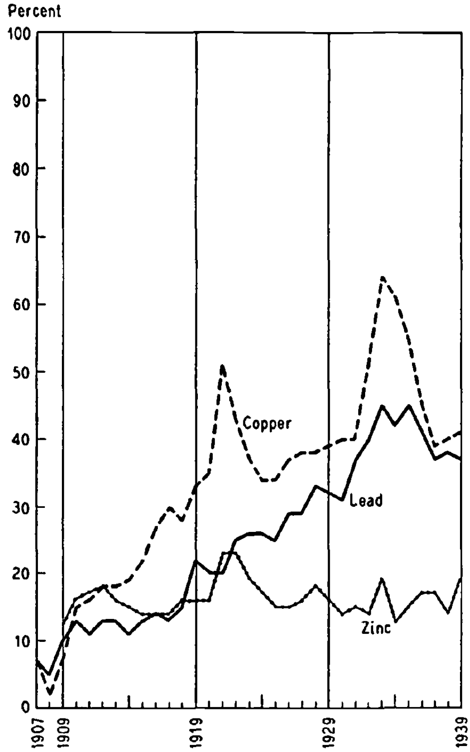


For source and notes see Appendix E

39—the most recent peacetime years—the output of all three metals was lower than it had been ten years previously: zinc had declined 19 percent, copper 21 percent, but lead as much as 36 percent. Perhaps business in general was not as good in 1937–39 as it had been in 1927–29, but the comparison seems a fair one, for the two periods occupy roughly corresponding positions in the business cycle. These differences in behavior appear to be due partly to the relative availability of secondary sources of supply, and partly to variations among the principal uses to which each metal is put.

Let us first consider the scrap situation. The only output included in the indexes presented in this volume of course consists of new metal from the mines. But the actual supply of any metal available for use at a given time consists only partly of mine output:

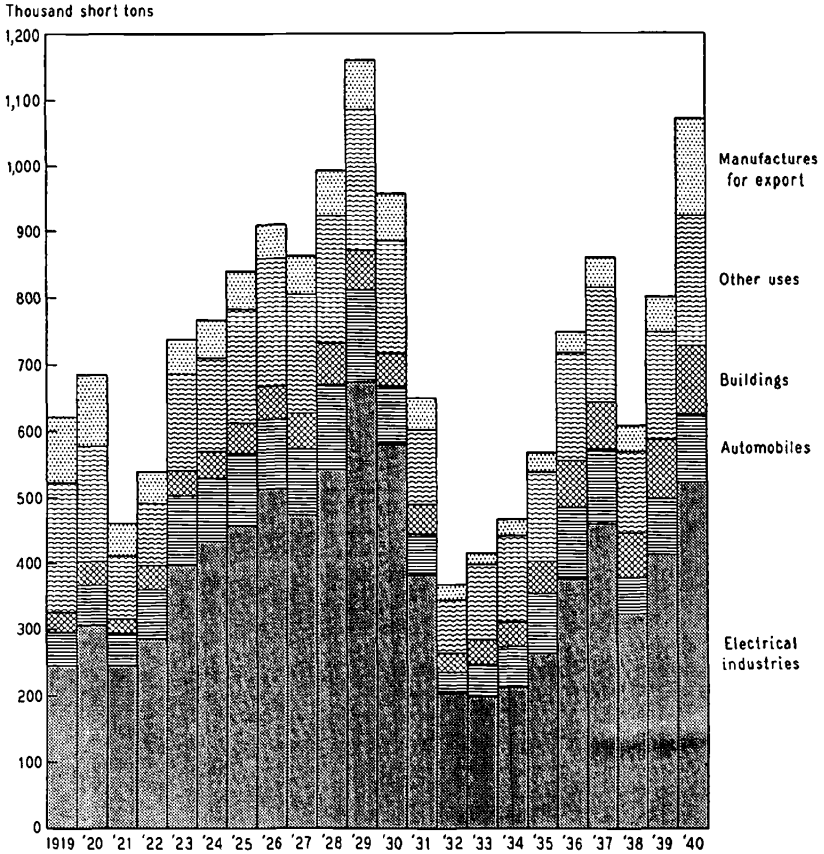
Chart 13
COPPER, LEAD AND ZINC
Ratio of Secondary Output to Secondary plus Primary Output
1907-39



For source and notes see Appendix E

put: there is always available a larger or smaller amount of scrap, either recovered during the manufacturing process or derived from articles discarded by their users. The elasticity of supply of secondary metal is very difficult to determine. Scrap recovered from manufacturing processes is practically a byproduct, and probably very inelastic in supply. The supply of old nonferrous scrap turned in by large industrial enterprises, such as the railroads, must also be comparatively insensitive to the price it fetches. Scrap from the ordinary junk pile or automobile graveyard, on the other hand, is considerably more troublesome to collect and

Chart 14
COPPER
Consumption by Use, 1919 - 40



For source and notes see Appendix E

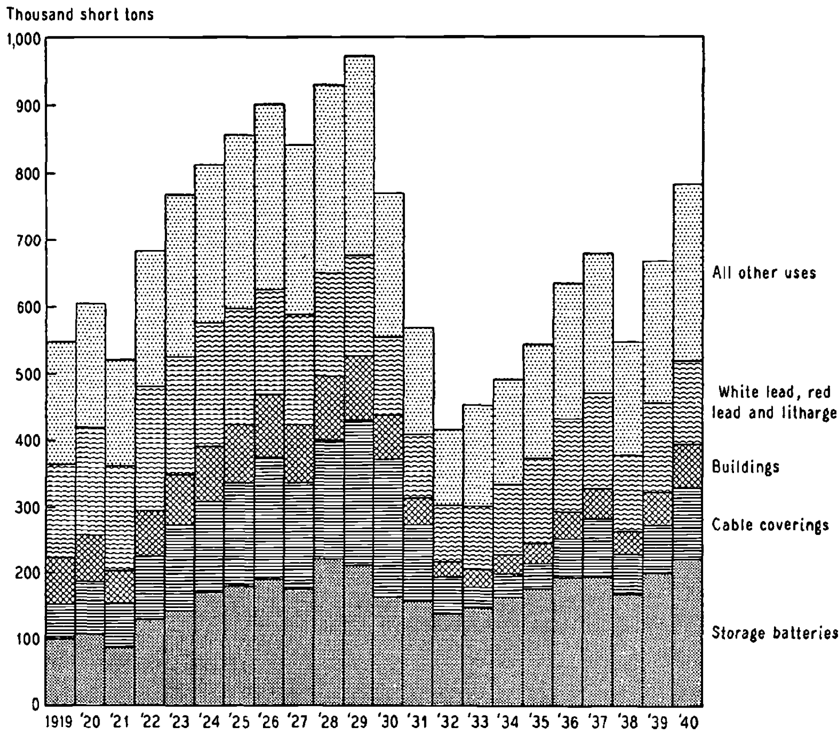
process, and hence must be much more elastic in supply. Unfortunately, statistics fail adequately to distinguish between these various sources of scrap. If the supply of scrap were perfectly inelastic, we might regard mine output as determined—apart from inventory changes—by the demand for the metal minus the supply of scrap. The actual situation is so complicated, however, that this simple treatment cannot be employed.

That secondary output plays an important role in the total supply of each of the three metals under consideration is clearly apparent from an inspection of Charts 10, 11 and 12, in each of which secondary is superimposed upon primary output. Indeed,

Chart 15

LEAD

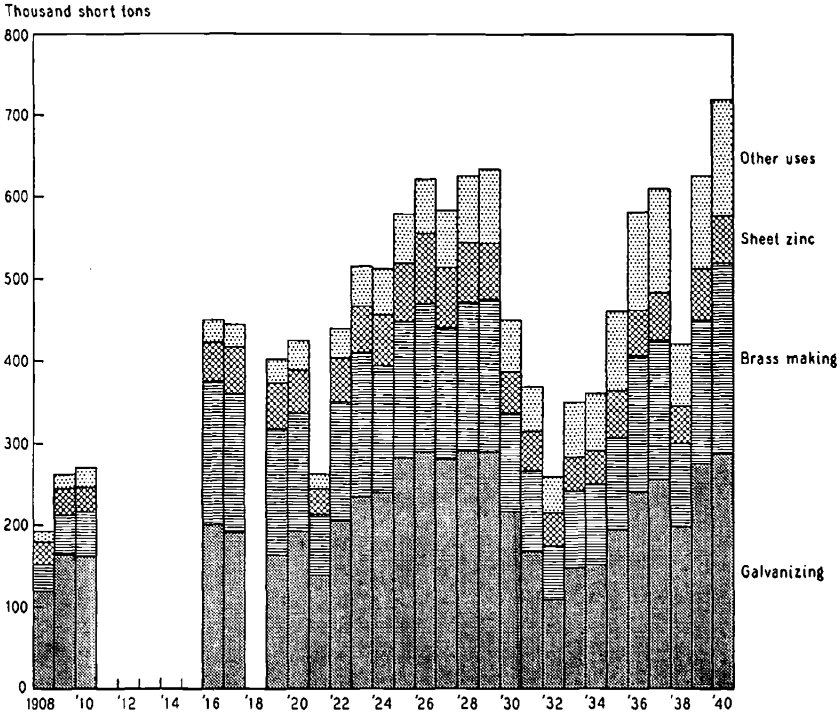
Consumption by Use, 1919 - 40



For source and notes see Appendix E

in the case of copper secondary exceeded primary production during several years of the period. Chart 13 summarizes the three preceding charts and shows the ratio of secondary output to total supply for each metal. For all three, but most notably for copper and lead, secondary appears through time to have grown in importance in relation to primary output. This is not surprising, for the stock pile of old metal in the hands of ultimate consumers (whether business firms, governmental agencies or private households), and so also potentialities of recovery, must continually have increased from decade to decade. In this connection we must not overlook the increasing quantities of lead used for storage batteries (Chart 15); unlike other applications of this metal, practically the whole amount used in batteries returns to the manufacturer as secondary material within a very few years. This probably

Chart 16
ZINC
Consumption by Use, 1908 – 40



For source and notes see Appendix E

accounts for the large increase in secondary lead output (Chart 11), as well as for the decline in its mine production over the past fifteen years (Chart 8) which we have already noted.

About half the secondary output of copper is new rather than old metal, i.e., it is a byproduct of the casting and machining of copper and brass or other alloys.[17] The supply of this new scrap

[17] In 1939, 57 percent of secondary copper was old scrap; the remainder was new scrap. Corresponding ratios for old scrap were 87 percent for lead, but only 24 percent for zinc.

must obviously fluctuate, often subject to a time lag, with the consumption of copper by industries using the metal (Chart 14). The appearance of large supplies of secondary copper shortly after a period of great activity in these industries is therefore to be looked for. Something of the sort appears to have occurred during the sharp recession of 1920–21. The extremely violent fall in the output of primary copper in 1921, which no doubt reflected in part the cumulative effect of large inventories of the metal remaining from the period of hostilities and the brief post-war boom, appears also to have been attributable to large supplies of scrap.[18] The dependence of secondary output upon activity in the recent past is further suggested by the continued decline in the consumption of scrap copper during 1922, at a time when the output of primary metal had started to recover (Chart 10).

In the case of zinc also a substantial fraction of the secondary supply comes from the zinc-using industries rather than from the junk pile, and thus roughly parallels activity in metalworking. Indeed the junk pile is a less important source of zinc than of the other nonferrous metals. While some scrap zinc comes from old brass, zinc is peculiar among the three metals in that a high proportion of its output is entirely consumed and disappears permanently from circulation. Like lead paint, zinc paint completely dissipates the metal in use. But large amounts of zinc are employed also for galvanizing (Chart 16), and here again the metal is completely lost. This feature undoubtedly accounts for the rather minor importance of secondary as compared with primary output in the case of zinc (Charts 12 and 13), and the maintenance of the primary output of zinc in relation to that of lead and copper (Chart 8).

Other Metals

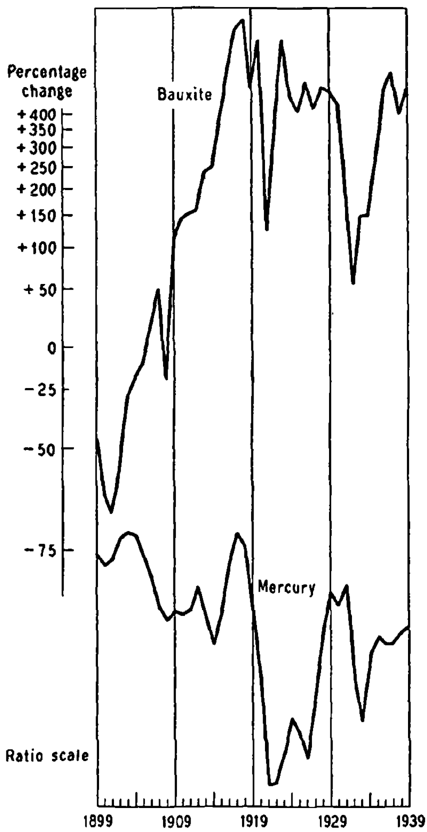
The only remaining metallic minerals for which we have satisfactory output data are bauxite and mercury.[19] With products worth \$2.4 and \$1.5 million respectively in 1937, these two industries are the subject of Chart 17. The bauxite industry, which produces

[18] See N. E. Crump, *Copper* (William Rider, London, 1925), pp. 115-16.
[19] The various minor metals used for making ferrous alloys have already been discussed.

the raw material for aluminum, resembles mercury mining in that both are subject to competition from abroad: in neither metal is the United States self-sufficient in normal times. In 1939, 45 percent of bauxite and 83 percent of mercury consumption was supplied domestically. But there are also striking differences between the two industries, for bauxite is a new and mercury an old min-

Chart 17

BAUXITE AND MERCURY: OUTPUT

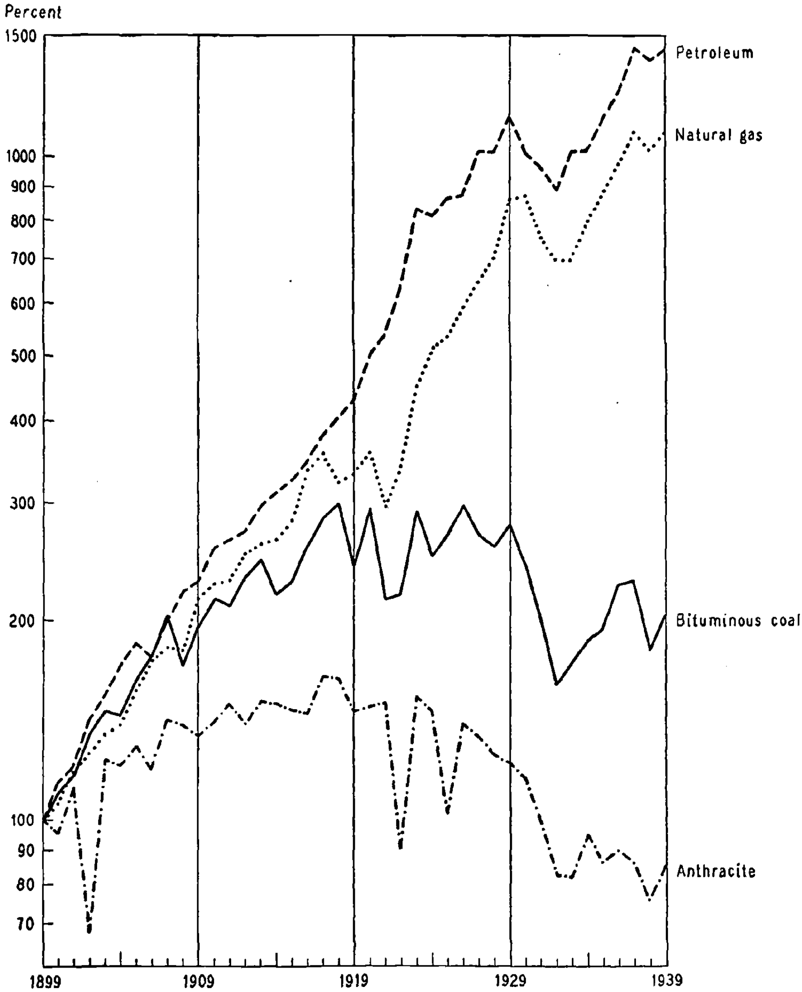


For source and notes see Appendix E

ing enterprise. Until a few decades ago, aluminum was a curiosity, and the bauxite mines of Arkansas have a very brief history. Thus for the first half of the period 1899–1939, bauxite output expanded with the rapidity characteristic of a very young industry.

Mercury, by contrast, has been mined in California continuously since about 1850. A number of the deposits are exhausted, and now, not infrequently, the poorer grades of ore have to be worked. The trend of output appears downward, despite something of a revival in recent years.

Chart 18
FUELS
Output of Individual Minerals
(1899: 100)



Ratio scale

For source and notes see Appendix E

FUELS

Valued in 1937 at about $2.8 billion, fuels account for nearly three quarters of the value of all minerals produced in the United States.[20] Of the total value of fuels, more than half was contributed by crude petroleum ($1,513 million), less than a third by bituminous coal ($831 million), and the remainder by Pennsylvania anthracite ($198 million), natural gas ($123 million) and natural gasoline ($97 million). On this basis petroleum is now nearly twice as important as bituminous coal, but it still furnishes substantially less total energy than the latter (Chart 19).

We have already seen (Chart 3) that the production of fuels rose during our forty-year period somewhat more rapidly than mineral output as a whole. An inspection of Chart 18 reveals that this result is attributable wholly to the sensational growth in the output of petroleum and natural gas, for bituminous coal gained only moderately and anthracite, in 1939, stood at a lower level than at the opening of the period. Compared with mineral output as a whole, which increased nearly fourfold, petroleum production was about fourteen times, and natural gas more than ten times, as large as in 1899. By contrast the output of bituminous coal, which tripled between 1899 and the peak year 1918, stood in 1939 at only twice the earlier level, while anthracite suffered a net decline of about 15 percent over the four decades.

TABLE 3

GROWTH OF THE ENERGY SUPPLY, 1889–1939[a]

Year	*Total Consumption (trillion BTU)*	*Per Capita Consumption (million BTU)*
1889	4,316	70
1899	7,426	99
1909	14,182	157
1919	18,883	180
1929	26,534	218
1939	24,620	188

[a] *Minerals Yearbook, 1937,* pp. 807-08, and *1941* (preprint). Water power is included with constant fuel equivalent.

Let us reduce these several fuels to a common denominator. Apart from a few minor uses, the purpose of each is to supply the

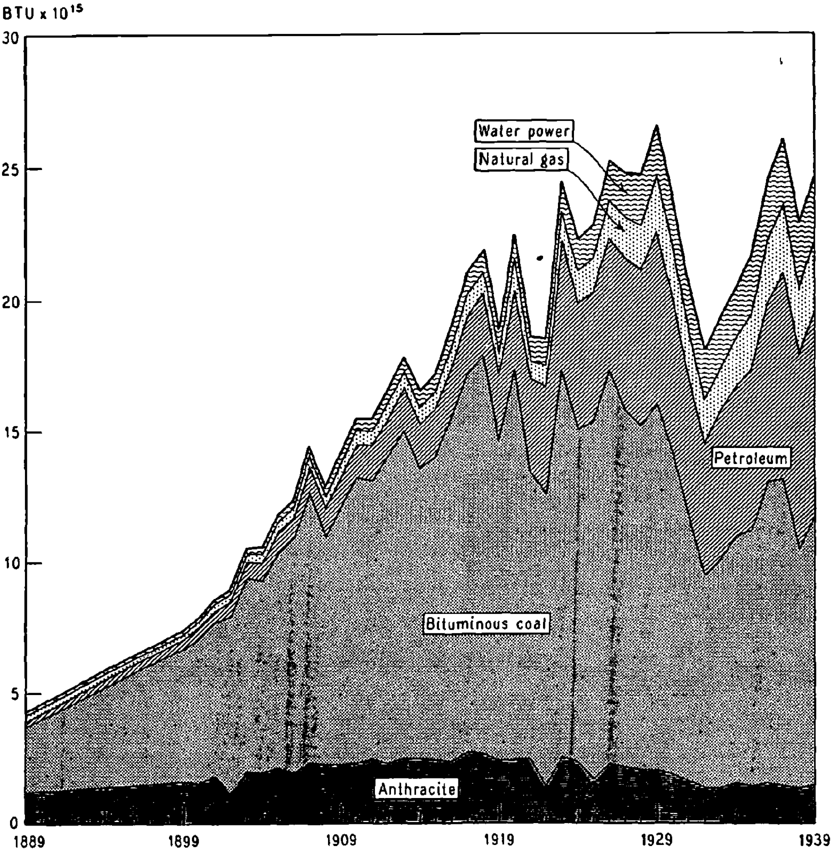
[20] The value of individual minerals for 1899, 1909, 1919, 1929 and 1937 will be found in Appendix Table A-2.

nation with energy.[21] According to Table 3 the consumption of energy in all forms (coal, oil, gas and water power) jumped more than threefold, and per capita consumption doubled, between

Chart 19

THE ENERGY SUPPLY

Distribution by Source, 1889 - 1939



For source and notes see Appendix E

1899 and 1929—the latter year representing an all-time high. Then there came a slump, followed by a revival which carried total (but not per capita) energy consumption back to the 1929 level for the first time in 1940. Economy in the use of fuel and the elimination

[21] Energy is measured by engineers in British thermal units. One BTU is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit. The BTU value of a fuel is determined by complete combustion in a calorimeter, and therefore represents the maximum energy obtainable if there were no losses in consuming the fuel.

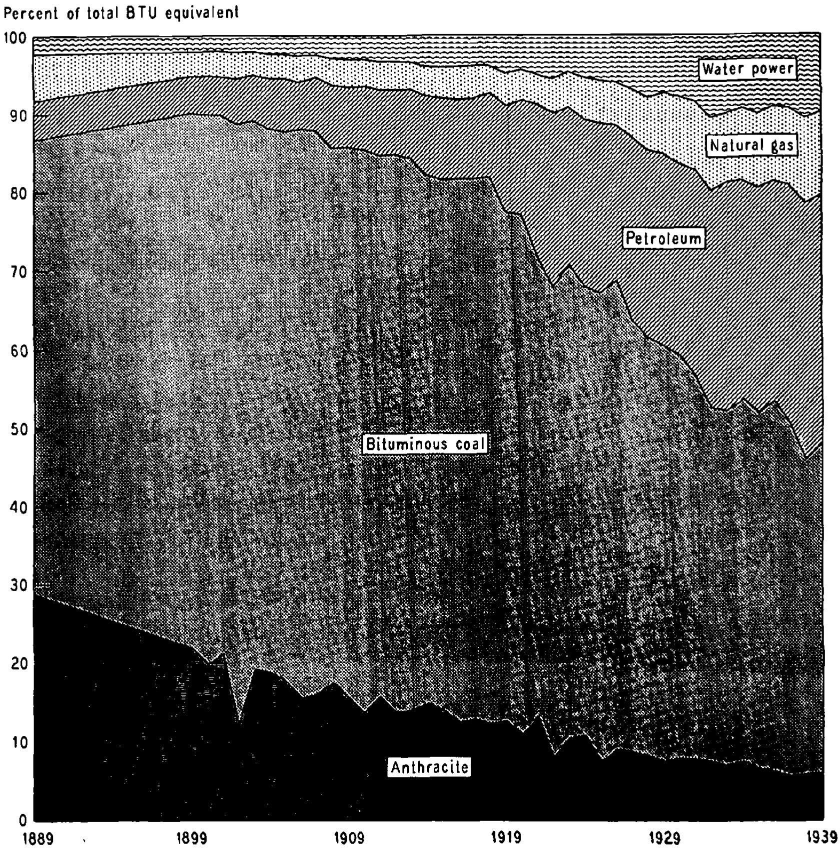
of energy waste have prevented total consumption from growing more rapidly in recent years, but it seems very unlikely that per capita consumption has reached the saturation point.

Even more interesting are the changes that have occurred in the sources from which the nation's energy supply is derived (Charts

Chart 20

THE ENERGY SUPPLY

Relative Contributions of Individual Sources, 1889 - 1939



For source and notes see Appendix E

19 and 20). Today petroleum and natural gas together yield about as much energy as bituminous coal alone, yet they still supply substantially less than bituminous and anthracite in combination. Coal still provides about half the total energy used in the United States, even when allowance is made for water power.

The Decline in Coal Consumption

In its heyday anthracite was preeminently the domestic fuel of those northern and eastern states within easy reach of the mines. The decline in its importance derives partly from economies in the use of anthracite (the result of more efficient heating systems), but chiefly from the discovery that fuel oil provides greater efficiency and convenience. The present widespread use of oil for domestic heating is a development that dates from the middle 1920's. So far as is known, anthracite reserves greatly exceed oil reserves, and the day may come when we shall be forced to return to anthracite for domestic heating. But at present a single manhour of labor in the mining industries will produce several times as many BTU in the form of oil as in the form of coal (Table 14 below).

The case of bituminous coal, the consumption of which is shown in Chart 21, is more complicated. Its decline, both relative and absolute, may be traced to three types of influence: (1) substitution, direct or indirect, of other fuels or of water power; (2) a change in the manner in which the coal is utilized, resulting indirectly in fuel economy; (3) direct savings of coal in existing uses. All three have been important.

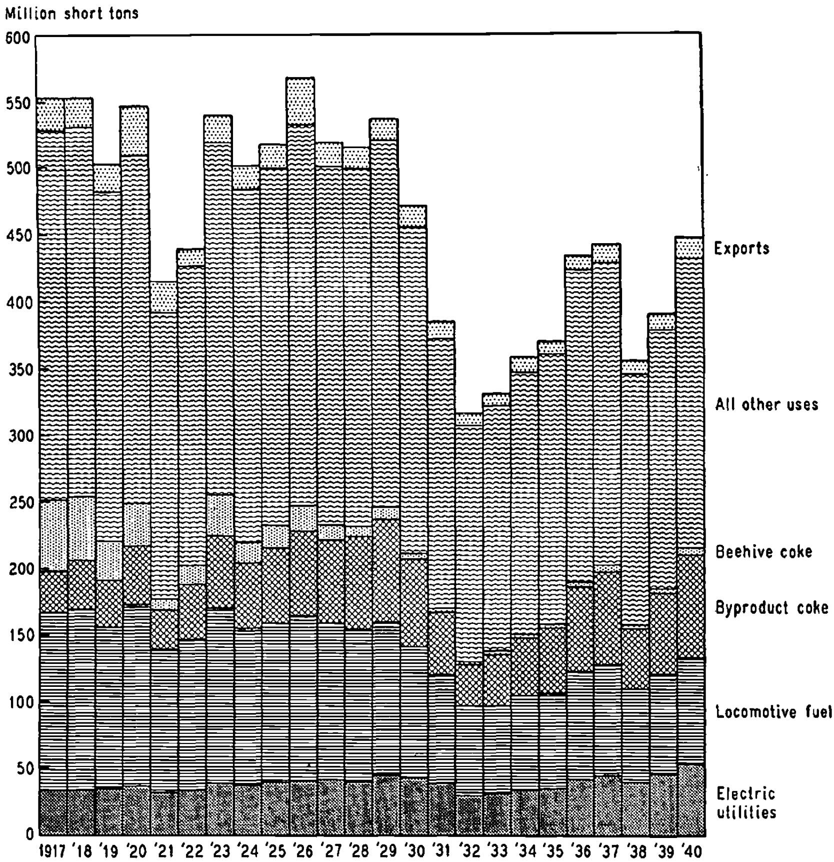
First, with regard to substitutes, we should note that bituminous coal has yielded some ground to natural gas for industrial purposes;[22] for most uses, however, petroleum products do not offer an acceptable substitute. Competition between the coal mine and the oil well is, for the most part, indirect. The demand for locomotive coal is reduced, not by a resort to oil for firing locomotives (though this has occurred), but through the development of the gasoline-driven highway vehicle.

Second, the manner in which coal is utilized has changed. The substitution of electricity, even when generated from coal, for the steam-driven prime mover has resulted in large economies of fuel. The small steam engine is notoriously inefficient, particularly if the load factor is adverse, whereas electric current can be generated in a large plant under optimum conditions of scale. A small-scale prime mover like the railroad locomotive may have a thermal efficiency of 10 percent; in a large central station, current can be generated, from the same coal the locomotive uses, perhaps

[22] For example in cement manufacture; see Nicholas Yaworski and others, *Fuel Efficiency in Cement Manufacture, 1909–35* (National Research Project, Philadelphia, 1938), pp. 17-18.

twice as efficiently.[23] Further, much electric power is produced by hydraulic means, without the consumption of any coal whatever. Where energy requirements are large and continuous, as in the production of aluminum and of fertilizer, it is more economical

Chart 21
BITUMINOUS COAL
Consumption by Use, 1917 – 40



For source and notes see Appendix E

to use current generated from water power than from coal. In several instances this fact has become a decisive influence upon industrial location.

[23] National Resources Committee, *Energy Resources and National Policy* (1939), pp. 107-08.

Third, and perhaps most important, large declines in coal consumption have resulted from increased efficiency in the use of fuel. Quickened by the high price of coal during the first World War, interest in the subject of fuel economy became intense.

> The runaway prices of 1917, 1920, and 1922 produced little effect at the time, but they set up influences which have persisted ever since. The electric utilities, especially, found themselves pinched between the rising price of coal and the fixed prices of their product. Efficiency in the use of coal was their only salvation. Fuel economy became the fashion. The route to promotion was seen to lead through the boiler room, and the best brains of the electric-power industry were directed to squeezing more and more kilowatt-hours out of the same ton of coal.[24]

The average amount of coal consumed by the electric light and power industry per kilowatt hour of current generated fell from 3.2 pounds in 1919 to 1.4 pounds in 1939, or by more than one half.[25] In spite of large increases in the output of coal-using electric plants, the consumption of coal for the generation of electricity has remained practically stationary for a quarter of a century (Chart 21). Lesser, but still large, economies were also achieved by other fuel-using industries. Between 1919 and 1939 the railroads cut coal consumption per passenger train car-mile by one fifth, per gross freight ton-mile by one third.[26] In the iron and steel industry the amount of coke needed to produce a ton of pig iron fell by one fifth, while more efficient use of coal in coking (especially with byproduct ovens) produced a like saving of energy in the coking process itself.[27] In addition, the substitution of scrap for iron ore as a raw material in steelmaking has further reduced the consumption of fuel, for scrap does not have to be smelted. Evidently it would be a mistake to think of the decline in coal consumption purely in terms of a shift toward other fuels.

These economies result partly from more efficient combustion

[24] F. G. Tryon, O. E. Kiessling and L. Mann, "Coal," in *Mineral Resources, 1926,* Part II, p. 446.

[25] Bituminous coal varies widely in energy content; in calculations of the kind indicated, a standard energy equivalent is to be understood, e.g., 13,100 BTU per pound (*Minerals Yearbook, Review of 1940,* p. 777).

[26] Gross ton-miles refer to the combined weight of load and equipment moved.

[27] Data quoted are from *Minerals Yearbook, Review of 1940,* p. 772.

and reduced heat losses, partly from mechanical improvements which diminish friction, and partly from improvement of the load factor (in power generation) and the recovery of byproducts (in the manufacture of coke). They seem likely to be intensified in the future. Much evidence, from the age distribution of steam locomotives still in service to the dispersion of thermal efficiencies among electric power stations,[28] assures us that a wide gap still exists between optimum and merely average practice in the fuel consumption field. As older is replaced by more modern equipment, further savings will doubtless accrue, even in the absence of technological developments in the future. Moreover, the most efficient plants now engaged in converting coal into mechanical energy do not have thermal efficiencies in excess of 30 percent, so that there would appear to be ample scope for technological progress as well.[29]

Petroleum and Natural Gas

The vast increase in the output of crude petroleum, depicted in Chart 18 above, may be further analyzed with the help of the partial account of refinery output available since 1917 and shown in Chart 22. The products of the modern cracking process are numerous indeed: in addition to those listed they include especially wax, road surfacing materials and a variety of crude chemicals. The output of only the four most important items—gasoline, fuel oil, kerosene and lubricants—appears in Chart 22. While these are still to some extent joint products, this is much less true than formerly, for considerable latitude exists today in the proportions in which they come from the stills. Thus the extent to which the expansion of petroleum output has reflected a rise in the demand for gasoline is suggested by the much more rapid growth of gasoline production than of the output of the other

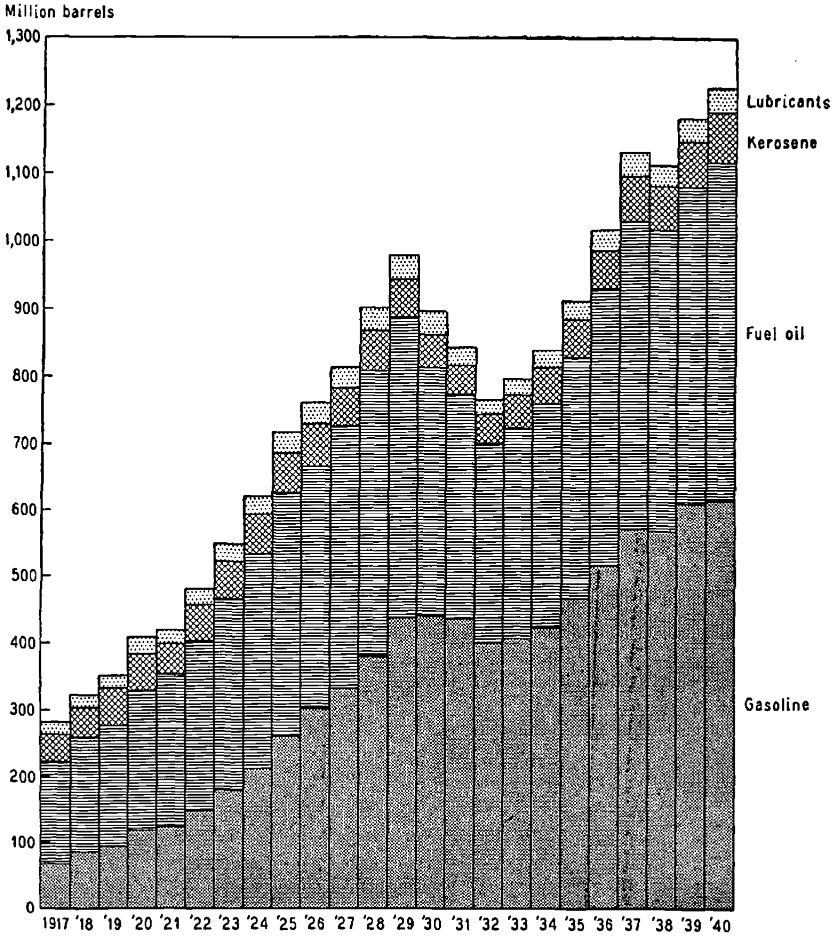
[28] Against the countrywide average of 1.4 pounds per kilowatt hour quoted above, we may contrast the performance of individual stations which, working with steam and mercury vapor at high temperatures and pressures, generate a kilowatt hour for as little as 0.7 pounds of coal. Again, in 1937 average pounds per kilowatt hour by states ranged from 1.1 to 3.6 (A. A. Potter, "The Production of Power," in *Technological Trends and National Policy*, National Resources Committee, 1937, p. 256; *Energy Resources and National Policy*, pp. 108-09). See also the wide dispersion of coal consumption per barrel of product at cement plants (Yaworski and others, *Fuel Efficiency in Cement Manufacture*, p. 61).

[29] *Energy Resources and National Policy*, p. 107.

Chart 22

PETROLEUM

Output of Principal Refined Products, 1917 - 40



For source and notes see Appendix E

petroleum products shown in Chart 22. Between 1917 and 1939 gasoline output increased ninefold, fuel oil only fivefold.[30]

Let us summarize. Fuel oil has been substituted directly for anthracite, and natural gas for coal gas, in domestic heating. Similarly natural gas has sometimes superseded coal for industrial purposes, and gasoline has been substituted indirectly for

[30] See also Fabricant, *The Output of Manufacturing Industries, 1899–1937*, pp. 234-38.

bituminous coal through diversion of traffic from the railroad to the highway.[31] But the story is really more complicated than this simple statement would suggest. For on the one hand large economies have been effected in the use of solid fuels; and on the other the development of the automobile has led to an expansion in the use of transportation which would have been impossible had there been no escape from dependence upon the steam engine.

OTHER NONMETALS

Nonmetals other than fuels had a value in 1937 of about $390 million, or slightly more than one tenth of mineral output as a whole. Among these minerals, stone accounted for $170 million, or nearly one half the total value of the group.

Stone

Two principal kinds of stone are quarried—crushed stone and dimension or building stone. In value terms the former is now much the more important: in 1937 crushed stone output was worth $143 million, compared with $28 million for dimension. This disparity has not always been as great as it is today, for the output of dimension stone has tended downward, the output of crushed stone upward, in recent decades.

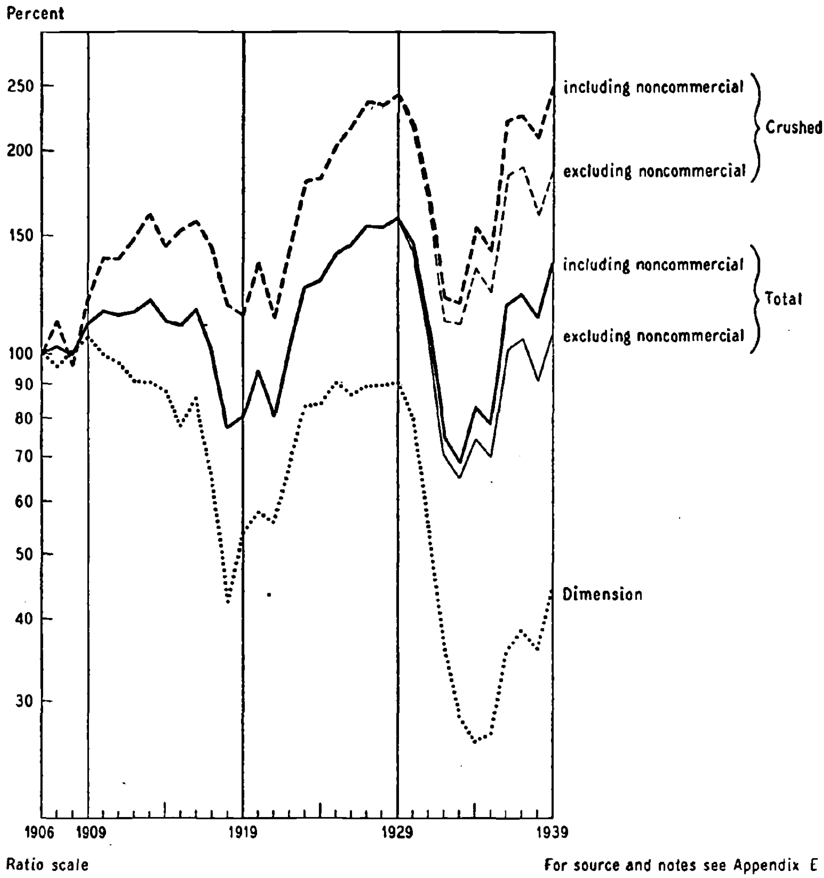
About one third of the output of dimension stone, measured by value, consists of granite; the remainder includes limestone, marble, slate and sandstone, in that order. Three quarters of all crushed stone produced is limestone; trailing far behind are the other varieties, basalt (or trap rock), granite, sandstone and slate. The types of stone used for building are also used for crushing, and crushed and dimension stone are often produced by the same quarry, for to some extent the former is a byproduct of the latter. Many of the largest crushed stone quarries, however, produce no dimension stone at all.

The indexes of output for dimension and for crushed stone, and for the stone industries as a whole, are shown in Chart 23. It will be observed that the trend in dimension stone is downward: by

[31] The latter development will be considered in detail in a forthcoming volume on *The Transportation Industries* by Harold Barger and Jacob M. Gould.

contrast, production of crushed stone, especially if noncommercial output is included, has expanded substantially during the period we cover in this study. No doubt the decline in dimension

Chart 23
STONE QUARRYING: OUTPUT, 1906-39
(1906:100)



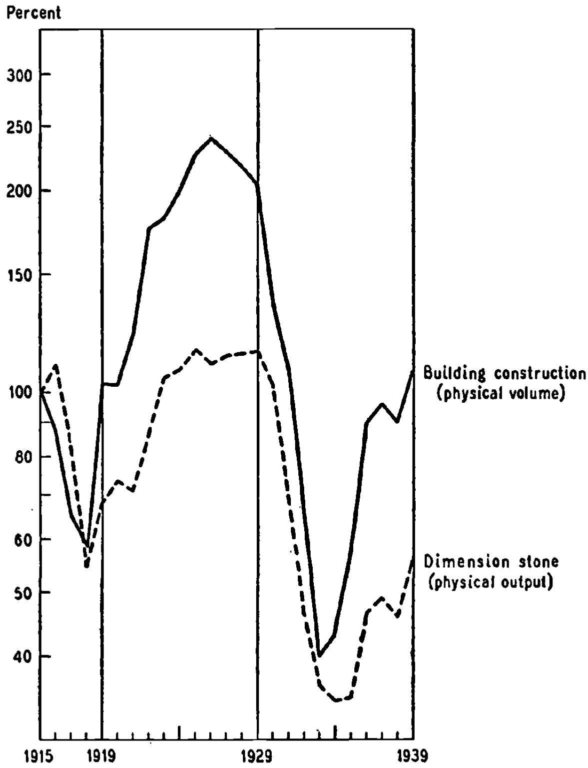
For source and notes see Appendix E

stone is to be explained partly by the low level of construction activity in recent years; but it has other causes also. In Chart 24 the output of dimension stone is compared with the best measure we could devise for the physical volume of building construction.[32] It will be seen that the consumption of building stone has

[32] See Appendix Table A-16.

not kept pace even with building activity, a fact which we must attribute mainly to the rising importance of steel and concrete construction. To a large extent this development has involved a substitution of crushed stone (in the form of cement rock, or of concrete aggregate) for traditional building stones. Even cheap

Chart 24
DIMENSION STONE OUTPUT AND BUILDING CONSTRUCTION, 1915-39
(1915:100)



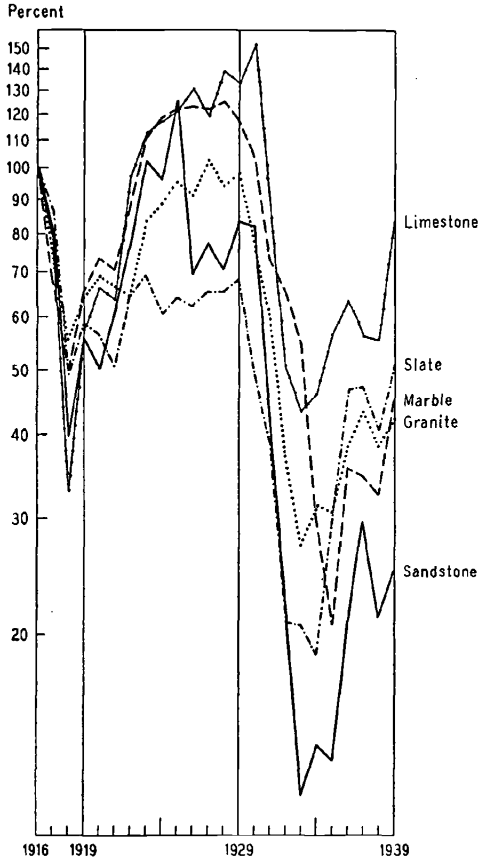
Ratio scale

For source and notes see Appendix E

varieties of building stone—for example, rubble, or stone with only one good face, formerly much used for foundations—have given way to concrete.

The output of individual varieties of dimension stone is shown in Chart 25. Among these varieties, granite is the principal monumental stone, mainly because of the sharp contrast in visual impressions afforded by its polished and unpolished surfaces, a factor which favors its use for inscriptions. It is also used largely for building, and to some extent for paving. Granite is widely distributed, being quarried in the Appalachian region and New

Chart 25
DIMENSION STONE
Output by Kind of Stone, 1916 – 39
(1916 : 100)



Ratio scale For source and notes see Appendix E

England, in Minnesota and Wisconsin, and in the Mountain and Pacific states. Dimension limestone is used almost exclusively for building: more than half its output comes from the single state of Indiana, and much of the remainder from Alabama and Kentucky. Marble is employed chiefly for building, and especially for interior work, because of its high polish and its ability to resist abrasion when laid as a floor or staircase. Most marble is quarried in the Appalachian belt, Tennessee and Vermont being the principal producing states. Slate, derived chiefly from Pennsylvania and Vermont, serves primarily as a roofing material, and is used to some extent also in the manufacture of electrical apparatus; in both these applications it has had to compete with numerous substitutes. The uses of sandstone are diversified: for exterior and interior building; for sea walls and dock facings (because of its resistance to erosion by water); for paving and curbing; and as an abrasive, in the form of grindstones, for sharpening tools or for grinding wood pulp. Sandstone is readily accessible, and is produced in most states.

In Chart 25 the output of the five varieties of dimension stone is shown on a 1916 base, the earliest year for which data for all five are available. In 1939 the production of dimension limestone was somewhat below the 1916 level; of slate, marble and granite about one half of the respective levels of that year; and of sandstone only about one quarter of its 1916 level. It is curious that sandstone, with uses at least as diversified as those of any other stone, should have suffered the largest decline.

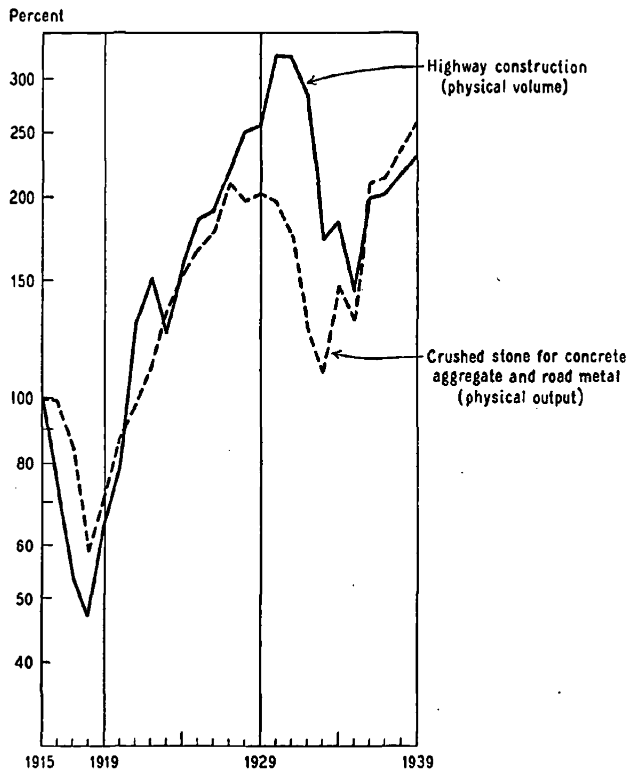
Unlike the output of dimension stone, that of crushed stone has expanded during recent decades (Chart 23). In large measure the growing popularity of concrete, both for building and for highway construction, has been responsible for this expansion. All varieties of crushed stone are used for making concrete. For the manufacture of the cement itself, crushed limestone or cement rock is required, while as aggregate the most conveniently available local crushed stone can be employed. Much crushed stone is used also for road metal and railroad ballast. The rather close connection between the output of crushed stone for concrete aggregate and road metal (including noncommercial production) and the physical volume of highway construction is illustrated in Chart 26.[33] The lag of crushed stone behind highway construction during 1927–31 is probably to be explained by the use of concrete containing crushed stone aggregate for many purposes other than roadbuilding; it is to be observed also that crushed stone is used for highway repairs as well as for new construction.

[33] See also Appendix Table A-17.

During these years other uses probably lagged behind the construction of new highways.

A breakdown of crushed stone output by use (Table 4) shows that in 1939 about half the total went into concrete aggregate and road metal. About two thirds consisted of limestone; the remain-

Chart 26
CRUSHED STONE OUTPUT AND HIGHWAY CONSTRUCTION, 1915–39
(1915: 100)



For source and notes see Appendix E

der comprised basalt, granite, sandstone, and a substantial fraction drawn from miscellaneous varieties. More than half of the stone used for railroad ballast and for refractory purposes in 1939 was also limestone. The outstanding position of limestone in other applications is less surprising. For making cement and lime, and in numerous minor industrial uses, stone is desired for its chemical rather than its physical properties, and limestone is the only variety that is technically satisfactory. For cement making an admixture of clay is an advantage, but pure limestone is necessary to produce lime. Most of the minor uses of limestone also require raw material of a high quality.[34]

TABLE 4

CRUSHED STONE
Consumption by Use, 1939[a]

Type of Stone and Use	*Thousand Short Tons*	*Percent of Total*
Concrete aggregate and road metal	96,894	52.5
Limestone for cement manufacture	30,463	16.5
Metallurgical uses (mainly limestone)	17,288	9.4
Limestone for lime	8,509	4.6
Railroad ballast	6,997	3.8
Riprap	5,812	3.2
Limestone for agricultural use	5,459	3.0
Limestone for alkali works	4,656	2.5
Refractory uses	1,492	.8
Limestone for sugar factories	622	.3
Slate granules and flour	352	.2
Limestone for paper mills	303	.2
Limestone for calcium carbide works	275	.1
Limestone for asphalt filler	266	.1
Limestone for glass factories	241	.1
Other uses	4,845	2.6
TOTAL	184,473	100.0

[a] *Minerals Yearbook, 1940,* pp. 1178, 1184-86. Consumption of stone produced at noncommercial operations is included.

Minor Nonmetals

Of the remaining nonmetals the following are the most important (values in 1937 in parentheses): sand and gravel ($79 million), sulfur ($49 million), clay ($18 million),[35] phosphate rock ($14 million), potash ($10 million), borates ($7 million), and bromine

[34] In alkali works the product is sodium carbonate; when obtained by the Solvay or ammonia soda process the calcium in limestone is replaced by sodium from common salt, ammonia being an intermediate reagent recoverable at the end of the process. In refining beet sugar, calcium hydroxide is used to remove all constituents except the cellulose. Calcium carbide is obtained by treating a mixture of limestone and coke in an electric furnace. In making glass, limestone is used to supply the calcium required in the final product. Limestone is also used in small quantities as a bone builder in animal feeding stuffs, to obtain carbon dioxide for refrigeration, and in the manufacture of mineral wool for insulation purposes. (See Oliver Bowles, *The Stone Industries,* McGraw-Hill, 1934, pp. 377-96.)

[35] Only fine clays are considered here, since satisfactory statistics for common clay (for brick making, etc.) are not available.

and gypsum ($5 million each). No other mineral had a product valued as high as $5 million in 1937.

The output history of these eight minerals is shown in Chart 27. Two of them—sand and gravel, and gypsum—are closely associated with the building industry. The output of both expanded rapidly during the first quarter of the present century, but within recent years levels of production—like construction activity itself—have failed to return to the peaks registered during the 1920's. Clay is used for pottery, oil refining, paper making and as a refractory material—the last being quantitatively the most important.[36] It is said that the life of blast furnace linings has doubled within the past ten years,[37] a fact which must account in part for the retardation in the growth of clay output. Phosphate rock, which is used almost entirely for the production of fertilizer, shows a slow but steady upward trend in volume.

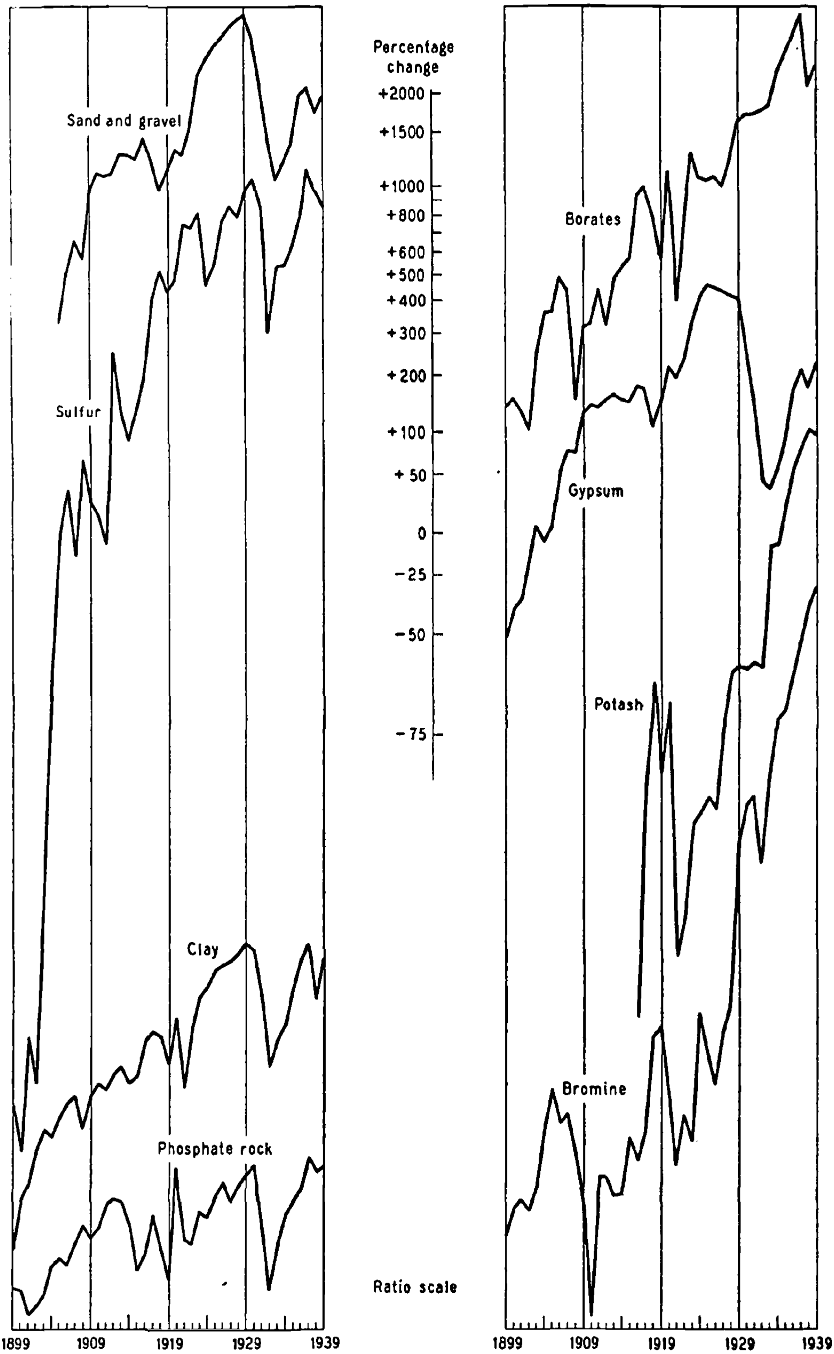
Sulfur, boron minerals, potash and bromine compounds—the remaining four minerals with a value in 1937 in excess of $5 million—are essentially raw materials for one or another branch of the chemical industry. Sulfur production, a new industry, was negligible at the beginning of the century; virtually all its growth coincides with the period following 1899. As with all new industries, phenomenal growth rates are to be observed in the early stages. Thus sulfur output was multiplied by ten between 1900 and 1903, by ten again between 1903 and 1906, and by ten once more between 1906 and 1930. Over the past decade growth has been inappreciable, and the industry appears to have reached adulthood. Sulfur is used chiefly in the manufacture of sulfuric acid, which in turn is required for the production of superphosphates (fertilizer), the refining of petroleum, the processing of textiles, the manufacture of explosives, and as the starting point for the synthesis of a wide range of chemical substances. More than 99 percent of domestic sulfur comes from Texas or Louisiana.

The output of borax and other boron minerals has shown steady and consistent growth, stimulated by both foreign and domestic demand, for this industry produces more than 90 percent of the world's supply. Among numerous applications, the manufacture of heat-resisting glass and vitreous enamelware are the most important.

[36] Clay used for brick making is not included in the production statistics.
[37] *Minerals Yearbook, Review of 1940,* p. 1234.

Chart 27

MINOR NONMETALS: OUTPUT



For source and notes see Appendix E

The mining of potash dates only from the first World War; as one would expect, the rate of growth has been very rapid, and the expansion of output has thus far shown little, if any, sign of retardation. Potash is used principally as a fertilizer ingredient. Almost the entire supply comes from natural brine, or from bedded saline deposits in California and New Mexico.

Bromine compounds, long obtained from brine on a small scale, have expanded enormously in output during the past fifteen years as a result of the development of antiknock fuels for the automobile. In addition to brine from wells, sea water has been enlisted as a source of supply.

Besides data for the minerals already discussed, we have collected and incorporated in our indexes figures for a dozen or more minor nonmetals, none of which reached a value in 1937 of as much as $5 million (Appendix Table A-2). These are pyrites, fluorspar, salts of calcium, sodium and magnesium, silica abrasives, asbestos, asphalt, barite, feldspar, graphite, magnesite, mica, talc. Output data for these minerals will be found in Appendix Table A-1; a brief note on each appears in the glossary at the end of the volume.