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Some Aspects of Development in the Coal Mining Industry, 1839–1918

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I

Introduction

This paper is concerned with three aspects of the development of the coal industry: (1) growth and regional distribution of production, measured in physical quantities and current values; (2) increase in consumption and use, reflecting the slow shift of the U.S. energy base from wood to coal; and (3) estimates of the labor force engaged in coal mining and of changes and regional differences in the ratio of output to employment. None of these aspects can be treated over a period of some eighty years—from 1839 to 1918—in the detail that would be desirable because reliable information on the development of the industry during the early years is scanty. Even for the period during which coal became closely associated with the process of industrialization and mechanization—roughly from the middle of the nineteenth century—the data are not as precise as one could wish and sometimes are poorly related to the earlier records.

A huge body of literature exists on many economic and technological problems connected with coal mining, but as yet no comprehensive economic history of the coal mining industry, as such, has been compiled. This gap has been filled only partly by comparatively recent studies which deal with the history of coal from special viewpoints—Eavenson, for example, on coal production, and Schurr, Netschert *et al.* on coal as part of the total U.S. energy pattern.[1] The development of the industry during the later part of the period under review—roughly from the mid-1880's when coal overtook wood and became the predominant source of energy—has been documented and analyzed in numerous studies and

[1] Howard N. Eavenson, *The First Century and a Quarter of American Coal Industry*, Pittsburgh, 1942; and Sam H. Schurr and Bruce C. Netschert, with Vera F. Eliasberg, Joseph Lerner, and Hans H. Landsberg, *Energy in the American Economy, 1850–1975*, Baltimore, 1960.

surveys. Aspects of changes within the industry and of its changing position within the energy economy and the national economy as a whole have been treated in different detail, from different approaches, and with different emphasis on interrelationships. In fact, as far as statistical records and quantitative analysis are concerned, coal mining from the end of the nineteenth century is possibly one of the best-covered major industries. This does not hold true for the earlier phase. On the contrary, in the period during which coal mining experienced its most rapid expansion, its growth and its contribution to the growth of the national economy were underestimated to an extent that seems surprising in view of the attention devoted to less important industries.

For this reason, in this paper special attention is given to the period 1840 to 1890. The attempt is made to adjust measures other than output in physical quantities in accordance with the improved production series which in recent years has replaced earlier and less accurate data on the growth of coal output. If, as is recognized today, coal production has been underestimated for forty to fifty years, starting with 1840, by anywhere from 10 to 40 per cent, it seems reasonable to assume that value of output in current prices, estimates of value added, the size of the labor force engaged, and income originating in the industry, as originally reported, have also been substantially understated.

At the beginning of the period examined here, during the 1830's, the coal industry was of minor importance, restricted to small mines which produced for local markets. Not yet established on a commercial level, its role as a source of energy was negligible. By the middle of the period, in the 1880's, coal mining had developed into a major basic industry and had become the principal source of energy, supplying approximately one-half the fuel and power used by the United States economy. In the first decade of this century, its share rose to three-quarters of the total, a level which was maintained until after World War I when its relative importance in the total began to decline. Actual production peaked during World War I and again during World War II and its immediate aftermath.

Coal entered the economic scene of this country practically unnoticed and for a long time its potentials were ignored. The coal fields, widely spread throughout the eastern part of the United States, were not strange to many immigrants who came from European countries where coal mining had been well established for several centuries. Thus in some regions coal was mined as soon as settlement began. The earliest records go back to around 1700, from which time through the eighteenth century the mining and use of coal remained largely localized. Production for

a "market" was pursued only where coal deposits were close to streams which would provide easy transportation. The year 1758 marks the first recorded commercial shipment: thirty-two tons from the James River district in Virginia shipped mainly to New York. By 1800 coal was mined—or rather gathered from outcroppings—in five states: Pennsylvania, Virginia (including West Virginia), Maryland, Kentucky, and Ohio.

TABLE 1

ESTIMATED ENERGY USE BY PRINCIPAL SOURCES, 1850

		Bituminous Coal Equivalent Required to Supply Same Amount of Heat and Power[a] (million net tons)
Fuel consumed for heat		
Wood (million cords)	96.0	76
Anthracite and bituminous coal (million net tons)	2.6	2.5
Horsepower-hours of mechanical work performed (billions) derived from:		
Windpower	1.4	12
Waterwheels	0.9	8
Steam power from coal	0.7	6
Steam power from wood	0.6	5
Work animals	5.4	48
Total energy use (except human labor)		158

Source: Shurr, *et al.*, *Energy in the American Economy*, Chap. 3 and Appendix, "A Note on the Measurement of Direct Waterpower and Windpower."

[a]The following conversion factors were used: 1 cord of fuel wood = 0.8 net tons of bituminous coal; 1 net ton of anthracite = 0.97 net tons of bituminous coal. It has been estimated that in 1850, on the average, 17.6 pounds of coal were required to obtain 1 horsepower-hour of effectively utilized mechanical work. These estimates indicate an efficiency of converting coal into mechanical energy of 1.1 per cent.

Production estimates for this period vary between 100,000 and 200,000 tons. Apparently coal was used west of the Mississippi as early as 1817. By 1830 the five coal-producing states had increased to ten to include Rhode Island, Alabama, Illinois, Indiana, and Missouri, but the total output was still less than 1 million tons. This wide distribution of a small industry is certainly one reason coal mining attracted so little interest in its initial stages of development, in marked contrast to those metal industries that were more concentrated. Further, there was little need at the time for coal as a source of energy. The quantities of fuel and power used in this country were already substantial in 1850, but fuel was supplied

almost entirely by wood and mechanical power, by wind, water, and work animals.

The position of coal in the U.S. economy in 1850 may be put in perspective in the following manner: Estimates of the total amounts of energy utilized by the economy in 1850 (including that provided by work animals) are necessarily crude but if they are converted to comparable tons of coal, about 158 million tons of coal would have been consumed. About 80 million tons of coal equivalent were used for domestic purposes and industrial process heat. Mechanical work performed (measured in horsepower-hours of work) by the utilization of inanimate energy sources would have required some 30 million tons of coal. The work done by animals would have required about 48 million tons of coal (see Table 1). The quantity of coal actually consumed (for heat and mechanical work), however, was 8.6 million tons, or about 5.4 per cent of the total combined sources of energy converted to coal equivalents.

In short, by the middle of the nineteenth century coal was beginning to play a modest role as a source of energy in certain regions of the country, while in others it was unknown, ignored, or regarded with skepticism. Numerous contemporary reports bear evidence of this. When, for instance, the new fuel was offered for sale to steamboats on the Mississippi River, the engineers (or firemen) rejected it because "such fuel would not make steam."[2]

II

Output

MAIN SOURCES OF INFORMATION

Until comparatively recent times the main source of information on the early phases of the coal mining industry on a nationwide scale was the decennial Census reports, supplemented from the mid-1880's by data compiled by the U.S. Geological Survey. Over the years, the Survey attempted to fill in the gaps between Census dates with annual estimates, and to push the data back to 1820.

The *Sixth Census, 1839-40*, in its section on manufactures, includes a set of statistics on coal production, broken down by states. At that time the distinction between the "new" mineral fuel, i.e., coal, and the traditional fuel derived from wood was not always sharply drawn. The term applied could depend on use as much as on source; any fuel

[2] Eavenson, *The First Century*, p. 277.

used in smelting might be called "coal"—even in official statistical data. Anthracite was measured in long tons but bituminous coal in bushels, and in a few instances charcoal was included under bituminous coal.

The *Seventh Census, 1849-50* gives output data in current dollar values but not in physical quantities. However, it is possible to derive estimates of the tonnage of production during that period by means of comparative information included in the 1859-60 Census and also by use of estimates made later by the Geological Survey.

The *Eighth Census, 1859-60* includes somewhat more detailed data on coal output in its volume on manufactures, but ten years elapsed before the first serious effort was made to collect more comprehensive information on the role of mineral industries in the U.S. economy. This was incorporated in a volume entitled *The Statistics of the Wealth and Industry of the United States*.[3] This marked progress. Nevertheless, it was not until the 1879-80 Census that mining was officially recognized and treated as a distinct sector of the U.S. economy, sufficiently important and different from manufacturing to warrant a separate detailed survey.[4]

We are dealing in this section with production, in which, as in many other respects, the early official statistics are frequently so defective that a seriously distorted picture emerges. Fortunately, as far as the growth of coal output is concerned, this state of affairs has been largely corrected by Eavenson's detailed study.[5] Eavenson combed the shipment records of canal companies and railroads, the pioneer railroad and coal trade journals, reports of state legislatures, and numerous other sources, and succeeded in eliminating most of the previous deficiencies inherent in the official statistical data on coal production. In recent years this comprehensive account has been recognized as superior to all formerly available statistics, and his series on coal production has been incorporated into the long-term energy studies of Resources for the Future,[6] the 1960 edition of the Census Bureau's *Historical Statistics*,[7] and the Bureau of Mines' historical data. The same series has been adopted without change as the primary set of statistics for this paper (see Table A-1) and forms the basis for adjustments and corrections of related statistics on value of production, consumption, and employment.

[3] *Ninth Census of the United States, 1870*, Vol. III.

[4] *Tenth Census of the United States, 1880*, Vol. XV, *Mining Industries (Excluding Precious Metals)*.

[5] Eavenson, *The First Century*.

[6] See Schurr *et al.*, *Energy in the American Economy*.

[7] *Historical Statistics of the United States, Colonial Times to 1957*, 1960.

OUTPUT, 1830'S TO WORLD WAR I

A summary of the growth of coal production during the period under consideration is presented in Table 2.[8] In order to gain a clearer view of long-term trends by smoothing out fluctuations caused by business cycles and work stoppages, the output data in Table 2 are shown as annual averages of ten-year periods. In a similar manner, the annual

TABLE 2

AVERAGE ANNUAL COAL PRODUCTION, BY DECADES, 1830-1919
(thousand net tons)

Decade	Bituminous Coal	Anthracite	Total Coal
1830-39	944	707	1,650
1840-49	2,124	2,517	4,641
1850-59	6,927	7,596	14,523
1860-69	12,444	13,669	26,127
1870-79	30,868	23,752	54,620
1880-89	75,923	38,293	114,216
1890-99	138,356	53,425	191,781
1900-09	302,479	71,286	373,765
1910-19	471,644	90,476	562,120

Source: Eavenson, *The First Century*, Part II, pp. 432-434; and U.S. Geological Survey, *Mineral Resources of the United States*, 1921, p. 482.

TABLE 3

AVERAGE ANNUAL INCREASE IN COAL PRODUCTION, BY DECADES, 1830-1919
(per cent)

Period	Bituminous Coal	Anthracite	Total Coal
1830-39 to 1840-49	8.5	13.5	10.9
1840-49 to 1850-59	12.5	11.7	12.1
1850-59 to 1860-69	6.1	6.1	6.1
1860-69 to 1870-79	9.5	5.7	7.7
1870-79 to 1880-89	9.4	4.9	7.7
1880-89 to 1890-99	6.2	3.4	5.3
1890-99 to 1900-09	8.1	2.9	6.9
1900-09 to 1910-19	4.5	2.4	4.2

Source: Table 2.

[8] Throughout this paper the traditionally accepted classification of all coal mined in the United States, that is, the distinction between anthracite and bituminous coal, has been retained.

rates of growth have been computed as averages for decades and are summarized in Table 3.

As may be expected when tracing the development of a major industry almost to its origins, the most striking expansion is concentrated in the earlier period. It took barely fifty years, from the mid-1830's to the 1880's, for coal output to grow one hundredfold, whereas during the following three decades its expansion was considerably less.[9]

Because we are dealing here with only two commodities, anthracite and bituminous coal, for which we have output data in physical units, little additional information would be conveyed by the construction of output indexes based on prices for certain years. It is sufficient to note that

TABLE 4

SHARE OF BITUMINOUS COAL AND ANTHRACITE IN TOTAL COAL PRODUCTION BY DECADES, 1830-1919
(per cent)

Decade	Bituminous Coal	Anthracite
1830-39	57.2	42.8
1840-49	45.8	54.2
1850-59	47.7	52.3
1860-69	47.7	52.3
1870-79	56.5	43.5
1880-89	66.5	33.5
1890-99	72.1	27.9
1900-09	80.9	19.1
1910-19	83.9	16.1

Source: Table 2.

anthracite was the more valuable fuel, except possibly during the very early years, and that its share in total coal output (measured in tons) declined significantly from more than 50 per cent in the midcentury decades to a mere 16 per cent in the decade from 1910 to 1919 (see Table 4).

Although Eavenson's series on coal production has by now become official historical data, related information based on the earlier Censuses has, to the knowledge of this writer, not hitherto been adjusted. The adjustments presented later in this paper may be interpreted more readily if reference is made to a comparison between original Census data on output and the presently recognized production series. This is shown in Table 5.

[9] After a long-lasting steep decline, the 1918 output figure was again reached and surpassed by about 1 per cent in 1944 and 1947, when unusually large exports pushed production up.

It has been known for some time that coal production was underestimated in the early Census reports. Underestimates range from about 20 per cent in the 1839-40 Census to as high as 40 per cent in the official 1859-60 returns. With one exception (1869-70), the discrepancies tend to be more marked for bituminous coal than for anthracite, probably because anthracite mining was always concentrated in a comparatively

TABLE 5

COAL PRODUCTION, ORIGINALLY REPORTED AND ADJUSTED, SELECTED YEARS, 1839-90
(thousand net tons)

	Reported, Census Year	Adjusted, Calendar Year	Per Cent by Which Original Census Data Have Been Raised
	1839-40	1840	
Anthracite	963	1,129	17.2
Bituminous coal	1,108	1,345	21.4
Total	2,071	2,474	19.5
	1849-50	1850	
Anthracite	4,138	4,327	4.6
Bituminous coal	2,308	4,029	74.6
Total	6,446	8,356	29.6
	1859-60	1860	
Anthracite	8,115	10,984	35.3
Bituminous coal	6,219	9,057	45.6
Total	14,334	20,041	39.8
	1869-70	1870	
Anthracite	17,528	19,958	13.9
Bituminous coal	19,279	20,471	6.2
Total	36,807	40,429	9.8
	1879-80	1880	
Anthracite	28,641	28,650	--
Bituminous coal	42,841	50,757	18.5
Total	71,482	79,407	11.1
	1889	1890	
Anthracite	45,545	46,469	2.0
Bituminous coal	95,685	111,302	16.3
Total	141,230	157,771	11.7

Source: Data reported, Bureau of the Census, *1954 Census of Mineral Industries;* data adjusted, 1840-80, Eavenson, *The First Century,* Part II, production tables; 1890, *Mineral Resources of the United States,* 1921.

small area while bituminous coal fields were worked in numerous widely separated regions of the country. Anthracite, moreover, was produced for markets in the cities of the eastern seaboard at a time when a large portion of bituminous coal was still being mined solely for local use.

This latter point is significant since one of the most valuable sources of information on early coal output is not the mining statistics but the records of shipments carried on canals and somewhat later on railroads, coal "exported" thus being covered much more completely than the quantities consumed locally. But even these records of shipments are far from complete or continuous. It should therefore be kept in mind that, although the adjusted output statistics show substantially larger quantities than the contemporary Census reports do, they are still on the conservative side and are more likely to be understated than exaggerated. To quote the author of the corrected series: "It must be emphasized that while these tables show larger outputs over the years than has heretofore been thought, that [sic] in practically every case where accurate data were found after an estimate had been made, the estimate was found to be too small." [10]

For the sake of balance, one should also take into consideration that, in Table 5, data for Census years are compared with those for calendar years. For the period during which the industry expanded from around 6 to over 15 per cent annually, the transposition by roughly a half-year somewhat exaggerates the discrepancies between the two series.[11]

From the 1880's onward, Census data became increasingly reliable and complete. Disparities between the decennial Census reports and the annual surveys conducted by the Geological Survey are comparatively minor and are caused partly by slight differences in the time period covered (up to six months) and by the fact that the Survey workers make a greater effort than the Census takers to include as many as possible of the multiple small, irregular, or "farm" mines worked by local people only part of the year. For the period from 1885 onward, the data compiled by the Geological Survey have been adopted in this paper without change.

VALUE OF OUTPUT

In view of the size of the underestimates of coal output in the early period, it seems useful to attempt to adjust the original data on value of production which have been carried with only minor changes since they were published in the early Census reports. Information on the value of coal production at the location of the mine, in current prices, was included in all Census reports from 1849-50 on. In Table 6 these value data have been raised by the ratio of adjusted to original output estimates for anthracite and

[10] Eavenson, *The First Century*, p. xi.

[11] Yet even here a comparison of Census data with adjusted output data for the average of two calendar years shows underestimates of 16 per cent for 1839-40, 24.4 per cent for 1849-50, and 36.9 per cent for 1859-60—all rather close to the data in Table 5.

TABLE 6

VALUE OF COAL PRODUCTION, ESTIMATED VALUE ADDED, AND COST OF LABOR, ORIGINALLY REPORTED AND ADJUSTED, SELECTED YEARS 1849-90
(current prices)

	Reported, Census Year	Adjusted, Calendar Year	Reported, Census Year	Adjusted, Calendar Year
	1849-50	1850	1859-60	1860
Value of production (mill. $)				
Anthracite	5.3	5.5	11.9	16.0
Bituminous coal	1.9	3.3	8.4	12.2
Total	7.2	8.8	20.2	28.2
Estimated value added (mill. $)				
Anthracite	5.1	5.3	10.2	13.8
Bituminous coal	1.8	3.2	7.3	10.6
Total	6.9	8.5	17.5	24.4
Wages and salaries (mill. $)				
Anthracite	3.0	3.1	5.5	7.4
Bituminous coal	1.1	1.9	4.1	6.0
Total	4.1	5.0	9.7	13.4
Wages and salaries as per cent of value of product				
Anthracite	56.0		46.4	
Bituminous coal	60.0		49.5	
Total	57.0		47.7	
	1869-70	1870	1879-80	1880
Value of production (mill. $)				
Anthracite	38.4	43.7	42.3	42.1
Bituminous coal	35.1	37.3	53.5	63.4
Total	73.5	81.0	95.8	105.5
Estimated value added (mill. $)				
Anthracite	34.8	39.6	35.5	35.4
Bituminous coal	33.0	35.1	48.6	57.6
Total	67.9	74.7	84.2	93.0
Wages and salaries (mill. $)				
Anthracite	23.0	26.1	22.8	22.7
Bituminous coal	21.3	22.7	33.2	39.3
Total	44.3	48.8	55.9	62.0
Wages and salaries as per cent of value of product				
Anthracite	59.8		53.8	
Bituminous coal	60.8		62.0	
Total	60.3		58.4	
	1889	1890		
Value of production (mill. $)				
Anthracite	65.7	66.9		
Bituminous coal	94.5	110.2		
Total	160.2	177.1		
Estimated value added (mill. $)				
Anthracite	52.6	53.5		
Bituminous coal	85.7	99.9		
Total	138.2	153.4		
Wages and salaries (mill. $)				
Anthracite	39.3	40.0		
Bituminous coal	69.9	81.4		
Total	109.1	121.4		
Wages and salaries as per cent of value of product				
Anthracite	59.8			
Bituminous coal	73.9			
Total	68.1			

NOTES TO TABLE 6

Source: Data reported, value of production, wages and salaries, and value added, 1849-50-1889: *Census of Mineral Industries, 1954*, Vol. 1, *Summary and Industry Statistics*. The rough measures of value added were computed by subtracting from the value of production the cost of supplies, the value of coal produced and used at the same establishment and, from 1889 on, the cost of contract work. Data adjusted, reported value of production, value added, and wages and salaries were each increased by the ratio of adjusted to reported coal output (for adjusted coal output see Table A-1).

bituminous coal. Reported estimates of value added and labor cost also have been changed by the ratio of adjusted to original output estimates.[12]

OUTPUT BY REGIONS

The major coal deposits of the country are found in three extensive geological regions: the eastern (Appalachian) region, the Mississippi Valley region, and the Rocky Mountain region. For convenience, the Mississippi area is frequently subdivided into a central interior region east of the river and a western interior region west of it. These large regions are then broken down by states and all regional data are shown on a state-by-state basis. This seems a convenient arrangement for combining the state data to fit any desired regional breakdown.

The regional development of coal mining, summarized in Table 7, shows the adjusted output data for the beginning, the midpoint, and the end of the period under review. The table illustrates the slow extension of coal mining from the Appalachians to the Mississippi Valley and thence to the Rocky Mountain region. More important, it indicates that regional shifts were of comparatively minor importance in the development of the coal mining industry as a whole. Throughout the entire period coal mining remained concentrated in the same five states. In 1840, Pennsylvania, the area of West Virginia, Ohio, Kentucky, and Illinois produced 94 per cent of the total United States output; by 1880 the share of these states was 85 per cent, and in 1918 it still amounted to 79 per cent.[13]

The principal change in regional terms was the slow and persistent decline of the dominant position of Pennsylvania. In 1840 four-fifths of all coal mining was concentrated in this one state; by the end of World War I its share had declined to two-fifths. This was caused partly by the

[12] Our unadjusted (i.e., reported) value-added figures come from the *1954 Census of Mineral Industries*, for which rough estimates of value added were made on a nationwide basis, using data from the early Census reports. The 1954 Census also contains the wage and salary data from the earlier Censuses.

[13] This regional distribution has hardly changed even since World War I; in 1960 the same five states accounted for 84 per cent of the total output. Table A-1 gives production data by states for every tenth year from 1830 to 1910, and for 1918.

TABLE 7

U.S. COAL PRODUCTION, 1840, 1880, AND 1918, BY REGION

Region	1840		1880		1918	
	Net Tons (millions)	Per Cent of Total	Net Tons (millions)	Per Cent of Total	Net Tons (millions)	Per Cent of Total
Total coal	2.47	100	79.41	100	678.21	100
Anthracite						
Pennsylvania	1.13	46	28.65	36	98.82	15
Bituminous coal, total	1.35	54	50.76	64	579.39	85
Eastern (Appalachian)	1.28	52	36.02	45	386.79	57
Pennsylvania	0.70	28	21.28	27	178.55	26
West Virginia	0.31	13	2.18	3	89.94	13
Virginia	0.09	4	0.04	--	10.29	2
Ohio	0.10	4	7.96	10	45.81	7
Kentucky[a]	0.06	2	1.20	1	31.61[b]	5
Maryland	0.01	--	2.23	3	4.50	1
Alabama	c	--	0.25	--	19.19	3
Tennessee	0.01	--	0.72	1	6.83	1
North Carolina	c	--	c	--	c	--
Georgia	--	--	0.16	--	0.07	--
Central interior	0.05	2	8.77	11	121.44	18
Illinois	0.04	2	6.48	8	89.29	13
Indiana	0.01	--	2.16	3	30.68	5
Michigan	--	--	0.13	--	1.47	--
Western interior	0.01	--	4.16	5	29.18	4
Iowa	c	--	1.79	2	8.19	1
Kansas	--	--	0.77	1	7.56	1
Missouri	0.01	--	1.36	2	5.67	1
Nebraska	--	--	0.08	--	--	--
Arkansas	--	--	0.02	--	2.23	--
Oklahoma	--	--	0.12	--	4.81	1
Dakotas	--	--	0.02	--	0.72	--
Rocky Mountain	--	--	1.31	2	35.54	5
Colorado	--	--	0.46	1	12.41	2
Wyoming	--	--	0.59	1	9.41	1
Utah	--	--	0.25	--	5.14	1
Montana	--	--	--	--	4.53	1
New Mexico	--	--	0.01	--	4.02	1
Other regions[d]	0.01	--	0.51	1	6.44	1

Source: Calculated from Table A-1.

[a]Kentucky is the only state which has within its borders parts of two great coal regions. The eastern counties are underlain by Appalachian coal beds, the western district includes part of the central interior coal fields. At the beginning of the period under review coal mining was concentrated in eastern Kentucky, then the center of production shifted to the western district and, during the 1910's, again back to the eastern part of the state.

[b]Of which 20.7 million tons in the eastern and 10.8 million tons in the western district of Kentucky.

[c]Less than 5,000 net tons.

[d]Including Oregon, California, Washington, Texas, Rhode Island, and Massachusetts.

larger increase in the production of bituminous coal than of anthracite. Although Pennsylvania was the leading bituminous coal producer until 1930, long after World War I, its share in bituminous coal production fell from three-fifths around 1840 to one-third in 1918.[14]

III

Consumption

For the 1830–80 period already outlined, information on coal consumption, and especially on the various uses of coal, is scanty; indeed, it is

TABLE 8

APPARENT AVERAGE ANNUAL COAL CONSUMPTION IN THE UNITED STATES, BY DECADES, 1830-1919
(million net tons)

Decade	Bituminous Coal	Anthracite	Total
1830-39	1.1	0.7	1.8
1840-49	2.3	2.5	4.8
1850-59	7.1	7.6	14.7
1860-69	12.6	13.7	26.3
1870-79	31.1	23.4	54.5
1880-89	76.2	37.6	113.7
1890-99	137.3	52.1	189.4
1900-09	296.8	68.9	365.8
1910-19	454.9	86.0	540.9

Source: Apparent consumption equals production (Table 2) plus net imports. 1830-69, net imports assumed to be bituminous coal entirely; 1870-1919, net imports for bituminous coal and anthracite separately are from *Historical Statistics of the United States, Colonial Times to 1957*, Washington, 1960, pp. 356-359.

almost nonexistent for the earlier years. For the period under review, therefore, we shall assume that consumption is equal to adjusted production plus or minus the foreign trade balance.[15] These data are presented in Table 8 as annual averages, by decades.

For nearly one century foreign trade was of comparatively minor importance for the coal industry. During the 1830's, net imports of bituminous coal amounted to approximately 6.5 per cent of total production. The imported coal was burned mainly in the larger cities on the eastern seaboard where coal, frequently brought in as ballast on ships,

[14] It was only after 1930 that West Virginia overtook Pennsylvania in bituminous coal output and became the leading state. By 1960 its bituminous coal production had become nearly twice as large as that of Pennsylvania.

[15] Coal imports and exports appear in Table A-2.

was less costly than domestic coal from the Appalachian field. With the rapidly expanding output and improved transportation of the 1860's, net imports of bituminous coal declined to 0.6 per cent of production. In the following decade the United States became a net exporter of coal. Net exports grew from 0.1 per cent of output during the 1870's to 4.3 per cent for the 1910–19 decade.

By the middle of the nineteenth century the total energy consumption of the United States economy was already huge in absolute terms, as can be seen in Table 1. Apparently it was larger in per capita terms than that of any other country, including the industrially more advanced such as Great Britain.[16] Even when the mechanical energy derived from wind, water power, and work animals is disregarded and only fuel material are considered, per capita use around 1850 was the rough equivalent of four tons of bituminous coal per year. Nine-tenths of this (measured in btu content), however, consisted of wood burned at the rate of about four cords per person per year, while only one-third of a ton of coal per year per person was being used.

From around 1850 to 1890, the over-all consumption of fuel materials increased threefold, yet during the same four decades the per capita consumption of fuel materials appears hardly to have increased at all (see Table 9), in spite of the rapid advance in industrialization and construction of a huge railroad network.

Behind this phenomenon lies the fact that clearing the land for cultivation went hand in hand with the lavish use of a seemingly unlimited supply of fuel wood. Most of it went up in smoke through the chimneys of newly established homes, resulting in a large energy consumption in statistical terms in the early years of that period. It was only with the development of larger cities on the eastern seaboard and with advances in industrialization, especially the change from small-scale local iron shops operated by individual blacksmiths to the beginnings of a modern iron and steel industry, that coal slowly began to prove its advantages over wood. The fact that coal is a more compact energy source, both in volume and in weight, became significant at a time when mushrooming centers of population and industry were depleting nearby supplies of wood.

Coal gradually began to replace wood from about the middle of the nineteenth century onward, initially largely as fuel used in industry and transportation. Although substantiated information is lacking, it appears that around 1850 possibly as much as three-quarters of the still rather modest output of coal (some 8.5 million tons) was transformed into steam

[16] Schurr *et al.*, *Energy in the American Economy*, p. 153.

power and mechanical work, while wood continued to fulfill the greater portion of domestic demands.

By the year 1870, coal supplied about one-quarter of total fuel material needs; ten years later it furnished some 40 per cent, and by 1885 it had overtaken wood as a source of heat and mechanical power. Even at that

TABLE 9

PER CAPITA CONSUMPTION OF FUEL MATERIALS, SELECTED YEARS, 1850–1900

Year	Fuel Wood (cords)	Coal (net tons)	Crude Oil (barrels)	Natural Gas (thous. cubic feet)	Total in Bituminous Coal Equivalent (net tons)
1850	4.39	0.36	--	--	3.9
1855	4.16	0.60	--	--	3.9
1860	4.00	0.63	0.02	n.a.	3.8
1865	3.70	0.69	0.05	n.a.	3.6
1870	3.46	1.02	0.05	n.a.	3.8
1875	3.04	1.24	0.04	n.a.	3.7
1880	2.71	1.58	0.34	n.a.	3.8
1885	2.26	1.94	0.13	1.35	3.8
1890	1.90	2.48	0.44	3.79	4.2
1895	1.58	2.74	0.43	1.97	4.2
1900	1.31	3.45	0.52	3.09	4.8

Source: Schurr *et al.*, *Energy in the American Economy*, Statistical Appendix to Part I, pp. 519 and 521.

time, the greater portion of all coal used went into industry and transportation, but nonetheless it was also well established as a domestic fuel, largely because the price of coal was falling relative to the price of wood in the urban centers of consumption. Valuable information on this aspect is included in the 1879-80 Census, which gives the retail prices for coal and fuel wood in various cities located in different parts of the country for the year 1879 (summarized in Table 10). Comparing these prices and keeping in mind that one cord of wood equals about 0.8 tons of coal in heat equivalents (but is nearly twice as heavy and bulky), we see clearly the improved competitive position of coal as the less costly and more convenient fuel material.

The same Census includes a survey of the consumption of wood as fuel for domestic and industrial purposes in 1879. Since this is the only comprehensive study of the use and value of fuel wood ever made, a summary of the information it contains is reproduced in Table A-3. At this point it seems sufficient to note that, while a large portion of all

TABLE 10

RETAIL PRICES OF COAL AND FUEL WOOD, 1879

	Coal ($ per net ton)		Fuel Wood ($ per cord)	
	Bituminous Coal	Anthracite	Hardwood	Softwood
Boston, Mass.	n.a.	4.25-6.50	10.00	8.00
Philadelphia, Pa.	n.a.	4.50-5.25	--	--
New Castle, Pa.	2.80	n.a.	--	--
Reading, Pa.	--	--	4.00	n.a.
New Cumberland, W. Va.	1.75	2.80	2.25	2.00
Springfield, Ohio	3.75	6.50	3.50	n.a.
Cincinnati, Ohio	3.70	6.68	6.00	6.00
Jacksonville, Ill.	2.50	7.00	3.50	n.a.
Indianapolis, Ind.	3.45	n.a.	--	--
Lawrenceburg, Ind.	--	--	4.00	n.a.
Louisville, Ken.	2.86-3.42	n.a.	--	--
Leavenworth, Kan.	3.50	11.00	6.50	n.a.
Cedar Rapids, Iowa	5.00	7.50	5.00	n.a.

Source: *Tenth Census, 1880*, Vol. XX, *Report on the Statistics of Wages in Manufacturing Industries; With Supplementary Reports on the Necessaries of Life and on Trades Societies, and Strikes and Lockouts*, pp. 94-101 of section on Necessaries of Life, Miscellaneous.

wood used in households never entered the market, wood consumed by industry and transportation did, but the quantities sold were rather small—some 5 million cords, or 3.6 per cent of all fuel wood used during that year. During the same year, 1879-80, coal production was about 30 million tons of anthracite and 50 million tons of bituminous coal. Prices per ton at the mine averaged $1.47 for the former and $1.25 for the latter. Even if transportation and delivery costs doubled these prices, coal for use in industry and transportation by that time was less costly than wood in most areas.

The quantity of charcoal used is shown in the 1879-80 Census as 740,000 tons; the average price as $7.13 per ton. The overwhelming part, nearly 700,000 tons, was consumed in the manufacture of iron and steel. The quantity of wood required to produce that amount of charcoal may be estimated at 1.5 million tons, a mere 1 per cent of all wood burned. While wood was still abundant in large areas of the country, pockets of scarcity existed around the manufacturing centers and transportation costs continued to rise. Both factors are reflected in the high price of charcoal. Even before 1850, blast furnaces were frequently abandoned

when local wood supplies were exhausted and new ones were built closer to timber sources in order to reduce the cost of fuel transportation.

From the 1830's on, coke from the huge bituminous coal supplies had been used experimentally as blast furnace fuel in the Pittsburgh area, but progress was slow, and during the mid-1850's only some 55,000 tons of coal per year went into coke production in that region. In eastern Pennsylvania, however, where anthracite was readily available, the shift to coal began on a larger scale. By the mid-1860's more than one-half of all pig iron produced was smelted with anthracite, about one-fifth with raw bituminous coal or coke, and still close to 30 per cent with charcoal. By 1880, the share of charcoal as fuel in iron production had declined to 12.5 per cent and coke from bituminous coal had begun to surpass anthracite (see Table A-4).

In the Census year 1879-80, 4.36 million tons of coal went into the production of 2.75 million tons of coke, of which more than 2 million tons were used in blast furnaces. The price of coke f.o.b. cars at ovens averaged $1.95 per ton for the country as a whole, ranging from $1.81 in Pennsylvania, where more than 80 per cent of all coke was produced and consumed, to $5.00 in Colorado. Even with transportation costs added, this is far below the average price of $6.79 paid by the iron industry in the same year for a ton of charcoal. For certain purposes charcoal was still considered the superior metallurgical fuel and, measured by weight, the amount of charcoal required in smelting was about the same as the amount of coke. In terms of volume, however, nearly three times as much charcoal as coke was required for the production of one ton of iron. When, in addition to that disadvantage, the price of charcoal reached a level about three times as high as that of coke, charcoal was priced out of the fast-expanding iron and steel market. Pig iron smelted with coke was first used in large amounts in the manufacture of rails. By 1880, steel production amounted to 1.4 million tons, of which more than half was rolled into rails. At that time, the railroad network had expanded to 90,000 miles and the indirect demand of the railways for coal needed by the iron and steel industry was overshadowed by the larger requirements for coal as locomotive fuel.

During the 1870's bituminous coal production surpassed the output of anthracite; by the turn of the century the latter amounted to only about one-quarter of all coal mined. The role of anthracite as industrial fuel began to decline when bituminous coal in the form of coke became the dominant metallurgical fuel. From the last decades of the nineteenth century anthracite was used mainly for space heating, while the bulk of

bituminous coal continued to be consumed in manufacturing and transportation.

Reasonably comprehensive data on bituminous coal consumption by main-use categories became available in the mid-1880's. They are shown

TABLE 11

U.S. CONSUMPTION OF BITUMINOUS COAL, BY CONSUMER CLASS, SELECTED YEARS, 1885-1905

(million net tons)

Year	Railways	Coke	Industrial and Household	Total	RFF Estimate of Total U.S. Consumption
1885	29.4	8.1	31.1	68.6	71.9
	(43%)	(12%)	(45%)	(100%)	
1890	45.9	18.0	40.3	104.2	110.8
	(44%)	(17%)	(39%)	(100%)	
1895	50.4	20.8	54.7	125.9	134.0
	(40%)	(17%)	(43%)	(100%)	
1900	78.4	32.1	84.3	194.8	207.3
	(40%)	(16%)	(43%)	(99%)	
1905	109.3	49.5	131.7	290.5	308.8
	(38%)	(17%)	(45%)	(100%)	

Source: H.S. Fleming, *A Report to the Bituminous Coal Trade Association on the Present and Future of the Bituminous Coal Trade*, New York, 1908, p. 10. Resources for the Future estimate, Schurr, *et al.*, *Energy in the American Economy*, p. 508.

in Table 11. In 1885, the year when total coal consumption began to overtake wood, the largest portion, 43 per cent, was burned as locomotive fuel; coke production consumed 12 per cent; and the remainder was distributed among all other industrial and domestic uses. By 1918, at the end of the period under review, the railroad market reached its peak in absolute terms but its share in total bituminous coal consumption had declined to one-quarter. Coke production took some 16 per cent; a fast-expanding new market, electric utility plants, absorbed 6 per cent. Manufacturing industries and retail consumers together accounted for 51 per cent.

Stimulated by war demand, total coal consumption had reached its World War I peak of 651 million tons, about 90 per cent of which was bituminous coal. But by this time it was already faced with a new competitor, fuel oil, which even in 1918 had displaced as much as 8 per cent of total coal consumption.

IV

Employment

ADJUSTMENT OF BASIC DATA

Being of minor importance to the national economy, coal mining did not warrant careful statistical treatment during the early part of the period examined. Although the number of persons employed in the industry was reported in every Census from 1839-40, except for 1849-50, the data are incomplete and vary in definition and detail from one Census to the next.

The 1849-50 Census omits coal miners from a detailed enumeration of more than three hundred occupations and professions of (free) males 15 years of age and over. It does, however, list charcoal burners (159 persons). Coal miners are included under more general classifications, such as miners, laborers, etc. It is only in a footnote to this occupation survey that employment in coal mining is listed for four states: Pennsylvania, Virginia, Kentucky, and Ohio. However, the next Census (1859-60) does include a comparatively detailed section on the coal industry wherein, with other information, total employment is given for the 1849-50 Census year.

The Census reports attempted to show the average number of persons employed during the year, but apparently in many cases either the maximum number or the number employed at the Census date was listed. Further, the treatment is not consistent from one Census to the next. The 1869-70 survey, for example, shows the number of boys under 15 years employed in coal mines—some 17 per cent of the labor force in the anthracite industry but less than 3 per cent in bituminous mining. The 1879-80 Census, however, differentiates between "miners," "laborers," and the "administrative force" for the anthracite industry, but gives no similar detail for bituminous coal mining. Here the labor force was still broken down between men and boys employed above and below ground, although at that time the number of boys under 16 years of age had declined to 1.5 per cent of the total work force.

The 1879-80 Census made a great effort to distinguish between "regular establishments"—i.e., commercial mines that were worked during the entire Census year, or at least throughout most of it—and "irregular establishments," or so-called "farmers' diggings." The latter comprised

TABLE 12

EMPLOYMENT IN COAL MINING ORIGINALLY REPORTED AND ADJUSTED, SELECTED YEARS, 1839-1918
(thousand persons)

	Reported, Census Years	Adjusted, Calendar Years
	1839-40	1840
Anthracite	3.0	3.5
Bituminous coal	3.8	5.5
Total	6.8	9.0
	1849-50	1850
Anthracite	n.a.[a]	10.6
Bituminous coal	n.a.[a]	9.4
Total	15.2	20.4
	1859-60	1860
Anthracite	25.1	34.0
Bituminous coal	11.4	16.0
Total	36.5	50.0
	1869-70	1870
Anthracite	53.1	60.4
Bituminous coal	41.7	44.3
Total	94.8	104.7
	1879-80	1880
Anthracite	70.7	70.7
Bituminous coal	109.0	129.0
Total	179.7	199.7
		1890
Anthracite		126.0
Bituminous coal		192.2
Total		318.2
		1900
Anthracite		144.2
Bituminous coal		305.0
Total		449.2
		1910
Anthracite		169.5
Bituminous coal		555.5
Total		725.0
		1918
Anthracite		147.1
Bituminous coal		615.3
Total		762.4

Source: See Tables A-5 and A-6.

[a]See source to Table A-5.

a large number of small producers who had some outcroppings of bituminous coal on their land and did some irregular surface mining when time and weather conditions permitted. In some instances, such producers employed a few helpers, who are enumerated in the Census as some 9,000, compared with 100,000 persons in regular establishments of the bituminous coal industry.

For the latter part of the period examined, from 1890 to 1920, employment data compiled by the Geological Survey have been adopted without change or adjustment. The statistics of the survey refer to the average number of men employed during the year in production and development work, but exclude office personnel, proprietors, and the labor force of coke works connected with bituminous mines.

To arrive at adjusted labor force data for the period from 1839-40 to 1879-80, the Census ratio of employment to output has been applied to the adjusted production series for each of the five most important coal mining states and for all other states as a group. A summary of the original data and the adjusted labor force estimates is shown in Table 12. Details may be found in Tables A-5 and A-6.

EMPLOYMENT BY REGION

There is, of course, a close relationship between the distribution of coal mining employment and the distribution of coal production among the various states. Around 1840, five states—Pennsylvania, Virginia (including West Virginia), Ohio, Kentucky, and Illinois—accounted for 90 per cent of the total adjusted labor force in coal mines. By the end of World War I, the same states still included 77 per cent of the U.S. labor force in the coal mining industry.[17] As was to be expected, Pennsylvania consistently accounted for the bulk of coal mining employment—about 70 per cent of the total in 1840, and still 42 per cent at the end of World War I.

EMPLOYMENT IN COAL MINING IN RELATION TO ALL MINERAL EMPLOYMENT AND TO TOTAL U.S. EMPLOYMENT

Available Census data show that employment in coal mining accounted for more than one-half the labor force engaged in all mineral industries from 1870 to 1939. Between 1840 and 1860, the labor force in metal

[17] In contrast with the output data, employment for the earlier years cannot be broken down for the areas which later were to become Virginia and West Virginia. Hence, since Virginia is included in the original and adjusted employment data for the period between 1840 and 1860, the size of the labor force is slightly overstated in relation to output statistics for the five leading coal-producing states.

mining appears to have matched that in the coal industry. By 1870 the share of the coal mining industry in all mineral employment had reached nearly two-thirds, and by 1910 it accounted for three-quarters (on the basis of Census data). The number of workers engaged in coal mining continued to increase until the early 1920's, but their share in the labor force of the total mining sector began to decline about a decade before a decrease in absolute numbers set in.

Measured against the total labor force of the United States, the number of persons engaged in all mining industries[18] was never large—1.2 per cent

TABLE 13

EMPLOYMENT IN COAL MINING AS A PERCENTAGE OF TOTAL EMPLOYMENT IN PRINCIPAL COAL-PRODUCING STATES AND THE UNITED STATES, SELECTED YEARS, 1840-1920

	1840	1850	1860	1870	1880	1890	1900	1910	1920
Pennsylvania				7.7	7.6	9.6	9.7	11.0	9.4
West Virginia and Virginia				1.4	3.1	5.5	8.9	15.3	18.2
Ohio				0.9	2.2	1.6	1.8	2.4	2.1
Kentucky				0.3	0.7	0.9	1.3	2.3	4.6
Illinois				0.9	1.7	2.1	2.2	3.2	3.3
United States	0.2	0.3	0.5	0.8	1.1	1.4	1.5	1.9	1.8

Source: Adjusted coal mining employment data are from Tables A-5 and A-6. Total employment: 1840-60, estimated at 1.2 times the no. of employed (free and slave) males aged 15 to 60 years, listed in *Historical Statistics*, 1960, p. 10. 1870-1920, from Perloff *et al.*, *Regions, Resources and Economic Growth*, Table A-1.
"1920" is 1918 coal employment divided by 1920 U.S. employment.

in 1870 increasing to 2.5 per cent in 1910. Over the same period, the share of workers in coal production relative to total employment expanded at a considerably faster rate—from 0.8 to 1.9 per cent of total employment, as shown in Table 13. Earlier, between 1840 and 1860, coal mining appears to have grown at an even faster pace, from 0.2 to nearly 0.5 per cent of the national labor force. Such a relative increase does not appear unreasonable, but it should be borne in mind that for these early years both sets of data—total U.S. employment as well as the number of persons in coal mining—are crude estimates.[19]

[18] As enumerated by the Census.

[19] For the years 1840, 1850, and 1860, the total U.S. labor force has been estimated to be 1.2 times the number of males (free and slave) aged 15 to 60 years. This is the ratio underlying the total employment data for 1870 in the source used (see H. S. Perloff *et al.*, *Regions, Resources, and Economic Growth*, Baltimore, 1960).

In a few states the work force in coal mining constituted a much larger proportion of total employment. In Pennsylvania employment in the coal industry was between 8 and 11 per cent in the fifty years from 1870 to 1920. In Virginia (including what is now West Virginia) coal mining grew from 1 per cent of total employment in 1870 to 18 per cent in 1920. In Kentucky coal accounted for 5 per cent of the labor force around World War I. In Ohio and Illinois, the remaining leading coal-producing states, coal employment was about 2 to 3 per cent during the coal industry's peak period (see Table 13).

EMPLOYMENT COMPARED WITH OUTPUT

During the entire period under review there were wide variations in the ratio of output to employment, not only between regions and states but also from one mine to another. It was not unusual for production per man to be several times as large in one mine as in another located in the same county. Another obstacle to statistical analysis is variation in the number of days worked per year. For example, anthracite mines in Pennsylvania worked for 200 days in 1890, on the average, while bituminous coal mines in the United States worked 239 days, ranging from 201 days in Ohio (one of the leading coal-producing states) to 289 days in Utah (a state of minor importance for the industry as a whole). Unfortunately, precise information on this aspect is not available in the statistics prior to the 1880's. Still another problem is the varying length of the working day, not only over time but also from one state to another and frequently from one mine to the next. For those years for which reliable statistics on working time have been compiled—namely, from 1890 onward for days worked during the year, and from 1902 onward for the hours comprising an average full working day—the average outputs per man-year, per man-day, and per man-hour in the anthracite and bituminous coal mining industry have been computed and analyzed in several studies and this information need not be repeated here in detail.[20]

For the earlier years, one has to rely on employment data even though changes in the number of persons employed are by no means identical with changes in labor input. Nevertheless, a comparison of the expansion of production with the growth of employment over an eighty-year period can supply a rough approximation of changes in the amount of labor used per unit of output. Such a comparison is shown in Table 14 for the bituminous coal and anthracite industries, based on Census production

[20] See Harold Barger and Sam H. Schurr, *The Mining Industries, 1899–1939: A Study of Output, Employment and Productivity*, New York, NBER, 1944; Vivian E. Spencer, *The Mineral Extractive Industries, 1880–1938*, Philadelphia, 1940; and Geological Survey, *Mineral Resources of the United States*, various issues.

TABLE 14

OUTPUT PER MAN-YEAR IN MAJOR COAL-PRODUCING STATES AND THE UNITED STATES, SELECTED YEARS, 1840-1918
(net tons)

	1840	1850	1860	1870	1880	1890	1900	1910	1918	Annual Increase Between 1880 and 1918 (per cent)
Bituminous coal, U.S.	243	430	567	462	393	579	696	751	942	2.3
Pennsylvania	259	n.a.	579	518	542	690	861	858	1,024	1.7
West Virginia[a]	427	n.a.	397	598	396	604	777	898	1,005	2.5
Ohio	323	n.a.	754	374	363	559	687	733	946	2.6
Kentucky	113	n.a.	378	237	331	514	551	720	804	2.4
Illinois	112	n.a.	509	466	374	535	659	632	1,039	2.7
Anthracite	323	390	323	330	405	369	398	498	672	1.3

Source: Tables A-1, A-5, and A-6. The ratios for individual states are calculated from Census data from 1840 to 1880. The U.S. ratios for bituminous coal for the same years are calculated from Eavenson's output data *(The First Century)* and our adjusted employment data as given in Table A-5.

[a] Including Virginia in 1840, 1850, and 1860.

and employment data. It would seem from this table that during the 1840–1918 period the output per man-year doubled in anthracite mining, but more than quadrupled in the bituminous coal industry.

The increase in productivity was very irregular during the decades from 1840 to 1880. This may be attributable to deficiencies in the data or may be real since atypical conditions may be present in any one Census year. From 1890 on, the decadal increases in output per man-year are more nearly the same in each sector and from decade to decade. These output

TABLE 15

OUTPUT PER MAN-DAY IN MAJOR COAL-PRODUCING STATES, SELECTED YEARS, 1880–1918
(net tons)

	1880	1890	1900	1910	1918	Annual Increase Between 1880 and 1918 (per cent)
Bituminous coal, total	1.90	2.56	2.98	3.46	3.78	1.8
Pennsylvania	2.47	2.97	3.56	3.61	3.81	1.1
West Virginia	1.97	2.66	3.36	3.94	4.22	2.0
Ohio	1.60	2.78	3.20	3.61	4.24	2.6
Kentucky	1.84	2.34	2.43	3.26	3.50	1.7
Illinois	1.65	2.62	2.92	3.95	4.37	2.6
Anthracite	n.a.	1.85	2.40	2.17	2.29	0.8[a]

Source: 1880, *Tenth Census, Mining Industries of the United States*, p. 683. 1890–1918, *Mineral Resources of the United States*, 1921, p. 497.

[a] 1890 to 1918.

per man-year data are, of course, influenced by various short-term factors, such as business cycles, labor disputes, and changes in transportation facilities which are reflected in significant variations in the number of days worked. Thus the number of working days per year ranged in anthracite mining during the 1890–1918 period from a low of 116 to a high of 293; in the bituminous coal industry, for the country as a whole, from 171 to 249.

Available data on output per man-day are given in Table 15. In bituminous coal mining the tonnage rose from 2.56 in 1890 to 3.78 at the end of World War I; the increase in anthracite mining was considerably less—from 1.85 to 2.29 net tons. These figures represent an average annual growth rate in production per man-day of 1.4 and 0.8 per cent, respectively. Since working hours per day declined during that period, the increase in output per unit of labor input was even greater, possibly as much as one-fifth more than is suggested by Table 15.

Among the five leading bituminous coal-producing states listed in Table 14, there has been a substantial but diminishing variability in output per man-year as measured by the coefficient of variation:

1840	.56	1880	.22
1850	—	1890	.12
1860	.30	1900	.17
1870	.32	1910	.14
		1918	.10

For the period after 1880 when data were more reliable than in earlier years, the increases in output per man-year were quite uniform among the leading states other than Pennsylvania, whose increase of 1.7 per cent per year was substantially less than the approximately 2.5 per cent rate of growth enjoyed by the other four states. Output per man-year grew more slowly from 1880 to 1918 for anthracite than for bituminous coal mining, 1.3 per cent against 2.3 per cent.

Growth of bituminous coal output per man-day from 1880 to 1918 showed more variation among the five states than did output per man-year. Also, output per man-day grew at the same or a slower rate than did output per man-year from 1880 to 1918 in each state and also for the United States as a whole. The same was true for anthracite. This result is not attributable solely to factors peculiar to 1880 or 1918, for a similar relation holds more often than not for all the adjacent decadal increases that can be calculated for output per man-day and man-year from 1880 to 1918.

During the first two decades of the twentieth century, trends in output per man-day differed widely between anthracite and bituminous coal mining. In the anthracite industry production per man-day hardly changed. In contrast to the bituminous industry, deteriorating resource conditions of the long-worked deposits were not offset by development of richer or more easily accessible supplies. The average width of the seam declined steadily, while the depth of the anthracite mines increased. The industry was particularly difficult to mechanize, largely because of the steep slope of many of the coal beds. In the bituminous coal industry, on the other hand, one-quarter of the total production was mined by machines by 1900. Ten years later this share had risen to 42 per cent and by the end of World War I to 56 per cent. But even here the most intensive progress in mechanization and the most rapid increase in productivity still lay in the future.

TABLE A-1

COAL PRODUCTION, BY MAIN GEOLOGICAL REGIONS AND STATES, SELECTED YEARS, 1830-1918
(thousand net tons)

	1830	1840	1850	1860	1870	1880	1890	1900	1910	1918
Anthracite										
Pennsylvania	235	1,129	4,327	10,984	19,958	28,650	46,469	57,368	84,485	98,826
Bituminous coal, total	646	1,345	4,029	9,057	20,471	50,757	111,302	212,316	417,111	579,386
Appalachian Region										
Pennsylvania	398	700	2,148	4,710	9,224	21,280	42,302	79,842	150,522	178,551
Ohio	25	104	617	1,850	2,959	7,957	11,495	18,988	34,210	45,813
Maryland	9	12	243	438	1,820	2,229	3,358	4,025	5,217	4,497
West Virginia	78	305	348	365	991	2,181	7,395	22,647	61,671	89,936
Virginia	103	88	138	112	90	43	784	2,394	6,508	10,290
Kentucky	19	63	76	131	282	1,203	2,701	5,329	14,623	31,613
Tennessee	--	8	60	165	133	718	2,170	3,510	7,121	6,831
Alabama	a	1	2	15	11	250	4,090	8,394	16,111	19,185
Mississippi Valley Region										
Illinois	4	37	259	858	3,041	6,476	15,292	25,768	45,900	89,291
Indiana	a	9	7	46	559	2,164	3,306	6,484	18,390	30,679
Iowa	—	3	27	48	283	1,792	4,022	5,203	7,928	8,192
Missouri	6	10	100	280	622	1,360	2,735	3,540	2,982	5,668
Kansas	--	—	--	5	33	771	2,260	4,468	4,921	7,562
Rocky Mountain Region										
Colorado	—	--	—	--	14	463	3,077	5,244	11,974	12,408
Utah	—	--	--	2	11	252	318	1,147	2,518	5,137
Wyoming	—	—	--	--	105	590	1,870	4,015	7,533	9,439
Other states (and/or regions)	5	6	4	32	291	1,028	4,127	11,318	18,982	24,294
Total coal	881	2,474	8,356	20,041	40,429	79,407	157,771	269,684	501,596	678,212

Source: 1830-80, based on Eavenson, *The First Century*, Part II, Production Tables, pp. 426-434; 1890-1918, *Mineral Resources of the United States*, 1921, p. 482.

[a]Less than 1,000 net tons.

TABLE A-2

AVERAGE ANNUAL NET IMPORTS OR EXPORTS OF COAL, BY DECADES, 1830-1919

Decade	Total Coal Production	Net Imports (thousand net tons)	Net Exports (thousand net tons)	Net Imports (per cent of production)	Net Exports (per cent of production)
1830-39	1,650	107		6.5	
1840-49	4,641	132		2.8	
1850-59	14,523	150		1.0	
1860-69	26,113	145		0.6	
1870-79	54,620		68		0.1
1880-89	114,216		473		0.4
1890-99	191,781		2,404		1.3
1900-09	373,765		7,996		2.1
1910-19	562,120		21,231		3.8

Source: 1830-69, based on Eavenson, *The First Century*, pp. 436-439. 1870-1919, *Historical Statistics*, 1960, pp. 356-359, and Table 2.

TABLE A-4

PERCENTAGE OF ANNUAL PIG IRON PRODUCTION SMELTED WITH DIFFERENT FUELS, SELECTED YEARS, 1854-1905

Year	Bituminous Coal and Coke	Anthracite	Charcoal
1854	7.4	46.1	46.5
1855	8.0	48.7	43.3
1860	13.3	56.5	30.3
1865	20.4	51.5	28.2
1870	30.6	49.9	19.6
1875	41.8	40.1	18.1
1880	45.4	42.1	12.5
1885	59.1	32.1	8.8
1890	69.4	23.8	6.8
1895	84.2	13.4	2.4
1900	85.0	12.2	2.8
1905	91.2	7.3	1.5

Source: *The Mineral Industry, Its Statistics, Technology and Trade*, ed., R. P. Rothwell, Vol. I, New York, 1892, p. 278; and Fleming, *A Report to the Bituminous Coal Association*, 1908, p. 44.

TABLE A-3

CONSUMPTION AND VALUE OF FUEL WOOD AND CHARCOAL, 1879

Consumer	Cords (millions)	Value Per Cord (dollars)	Bituminous Coal Equivalent (million net tons)[a]	Value of Coal Per Ton at Mine (dollars)
Fuel wood				
Domestic	140.54	2.18	112.43	
Railroads	1.97	2.60	1.58	
Steamboats	0.79	2.30	0.63	
Precious metals	0.36	8.03	0.29	
Other mining	0.27	2.52	0.21	
Brick and tile	1.16	3.44	0.93	
Salt	0.54	0.23	0.43	
Wool	0.16	2.69	0.13	
Total (or average)	145.78	2.21	116.62	1.25
	Net Tons (thousands)	**Value Per Net Ton (dollars)**	**Bituminous Coal Equivalent (thousand net tons)[b]**	**Value of Coke Per Ton of F.O.B. Oven (dollars)**
Charcoal				
Domestic (20 largest cities)	43.19	12.07	66.60	
Iron industry	695.92	6.79	1,073.17	
Precious metals	0.98	30.00	1.51	
Total (or average)	740.09	7.13	1,141.28	1.95

Source: Fuel wood and charcoal, *Tenth Census, 1879-80*, Vol. IX, *Report on the Forests of the United States*, p. 489. Average value of bituminous coal, *Tenth Census*, Vol. XV, *Mining Industries of the United States*, p. xxviii. Average value of coke, *Tenth Census*, Vol. X, *Report on the Manufacture of Coke*, p. 12.

Note: The above cited Census *Report on the Forests of the United States* gives the value of a cord of fuel wood for each state, ranging from $1.21 in North Carolina to $7.16 in the Dakotas. The number of persons using wood as domestic fuel is estimated at 32,375,074, about two-thirds of the total population. This indicates an annual per capita consumption of some 4 1/3 cords for wood users, a figure which does not seem unreasonable compared with additional—though scanty—information for that period. However, the reported value per cord—$2.18 for the country as a whole—implies an expenditure for domestic fuel of more than $9 per person and several times as much for a family. This is out of proportion with the estimates of average per capita income during that period. It must be assumed that the reported value per cord was a retail price which was not paid by all users.

[a]Converted at the rate of 1 cord of fuel wood equals 0.8 net tons of bituminous coal.

[b]Converted at the rate of 1 net ton of charcoal equals 0.976 tons of coke; the production of 1 ton of coke required 1.58 tons of bituminous coal during the Census year 1879-80.

TABLE A-5

REPORTED AND ADJUSTED EMPLOYMENT IN BITUMINOUS COAL MINING
BY MAJOR COAL-PRODUCING STATES,
SELECTED YEARS, 1839-1918
(number of persons)

Census and Calendar Years	Pennsylvania	West Virginia[a]	Ohio	Kentucky	Illinois	Other States	Total
1839-40	1,798	995	434	213	152	242	3,834
1840	2,710	714	322	560	331	890	5,527
1849-50	n.a.	1,044	1,187	453	n.a.	n.a.	n.a.
1850	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	9,370
1859-60	4,651	1,190	1,678	757	1,430	1,642	11,348
1860	8,141	918	2,452	347	1,685	2,439	15,982
1869-70	16,851	1,140	7,567	714	6,301	9,160	41,733
1870	17,802	1,655	7,901	1,190	6,508	9,275	44,331
1879-80	33,248	4,497	16,331	2,826	16,301	35,811	109,014
1880	39,295	5,504	21,906	3,632	17,337	41,354	129,028
1890	61,333	12,236	20,576	5,259	28,574	64,226	192,204
1900	92,692	29,163	27,628	9,680	39,101	106,711	304,975
1910	175,403	68,663	46,641	20,316	72,645	171,865	555,533
1918	174,306	89,530	48,450	39,342	85,965	177,712	615,305

Source: 1890-1918: Geological Survey, *Mineral Resources of the United States*, various issues; 1840, 1860-80: the Census ratio of employment to output was multiplied by Eavenson's output estimate to get employment for each of the five states listed separately and for other states as a group. In 1840, 28 bushels = 1 long ton, according to Eavenson *(The First Century)*.

State estimates for 1850 would be unreliable. Total employment and the shares of bituminous coal and anthracite are not very solid, either, as is evident from the description of the estimate that follows.

Bituminous coal, 1850 *(E/O)*, for four main states (Pennsylvania, Virginia, Ohio, and Kentucky) was derived by interpolation between 1840 and 1860.

Anthracite, 1860 *(E/O)*, was at the same level as in 1840 (3.10). The Census gives employment for the four states for both bituminous coal and anthracite (see the *1850 Census*, pp. lxxix, 193, 272, 861, and 623), so that a correction factor, λ, which implies that forces peculiar to 1850 acted on *E/O* for both anthracite and bituminous coal:

NOTES TO TABLE A-5 (concluded)

Total coal employment in 1850 (*1860 Census*, p. clxxii)

$$= \frac{15{,}118}{2.51(1960) + 4.7(348) + 3.10(4{,}138)} = 0.78.$$

Bituminous coal output for four states in 1850 was estimated by applying their percentage share (0.85, interpolated between 1840 and 1860) to 1850 *Census* bituminous coal production.

Adjusted 4 state bit. coal employment $= \lambda$ Bit. $(E/O)_{50}$ (Eavenson bit. coal output of 5 states) = 0.78 (2.51) (3,189) = 6,250.

$_{os}(E/O)_{50}$ for other states estimated by interpolation (4.7).

Other states bit. coal employment $= \lambda_{os}(E/O)_{50}$ (Eavenson other states production) = 0.79 (4.7)(840) = 3,120.

Total bituminous coal employment = 6,250 + 3,120 = 9,370.

Anthracite employment $= \lambda$ anthr. $(E/O)_{50}$ (Eavenson anthr. output) =

0.79 (3.10)(4,327) = 10,600.

[a] Including Virginia during 1839-60.

TABLE A-6

UNITED STATES ANTHRACITE COAL MINING EMPLOYMENT, SELECTED YEARS, 1840-1918
(number of persons)

	Census	Adjusted[a]
1840	2,977	3,490
1850	--	10,600
1860	25,138	34,021
1870	53,096	60,402
1880	70,748	70,748
1890		126,000
1900		144,206
1910		169,497
1918		147,121

[a] 1840-80: Census employment times the ratio of Eavenson to Census output. But for 1850, see source to Table A-5. 1890-1918: Geological Survey, *Mineral Resources of the United States*, various issues. The data refer to production and development workers.

COMMENT

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This paper is a straightforward use of the adjustments of coal production data derived by Eavenson as applied to Census data for the period 1839 through 1890. Subsequent to that period, the data require but minor adjustment. For a half-century period of substantial underreporting of coal mining by the Census, all figures on employment and income from coal mining are adjusted accordingly. The author points out that there exists no comprehensive, detailed economic history of the coal mining industry for that period; and, therefore, no comprehensive set of economic data for the period is available beyond the careful production data work of Eavenson. An even smaller amount of data has been assembled for transportation costs of coal and amounts shipped by different routes and modes, despite the fact that transportation facilities were crucial in the development of energy for industry and that dramatic reductions in transportation costs permitted very large increases in coal production.

There is a trend in the ratio of cost of materials to value of shipments computed from Table 6 where there was a steady rise from 12.5 per cent in 1849-50 to 20 per cent for anthracite in the 1889-90 Census, but a slight decline for bituminous from 12.5 to 9.3 per cent. This interesting statistic apparently reflects the growing difficulty in operating anthracite mines during that period and the corresponding ease in expanding bituminous coal production at new sites in thick, flat, nondeep seams.

Information on average days operated per year in different states can be developed to some extent from Census data on capacity utilization which ostensibly assume 300-day normal years. The coal industry suffered from overexpansion from the earliest date of its development. That is, ease of entry has been so great that there always has been too much coal mining capacity in that large portions of it usually could not be operated profitably. This should be a sobering historical comment to those who have almost as chronically attempted to solve the problems of the coal mining industry.

The author emphasizes the fact that it would take a number of man-years to organize and evaluate the large amount of archives and other research materials on the coal industry which would be necessary to bring price and cost data into a condition of refinement comparable to that for coal mining production by Eavenson. Of course, not all these data would lend themselves to the development of annual data in Census

detail as Eavenson developed production data. The author is to be thanked for clarifying the analysis of the impact of coal mining on national income. Coal was the major sector of the mining industry after 1860, but her tables remind us that coal mining was a very modest fraction of all national income generated, while at the same time it was a large industry from the late nineteenth century through World War II.

Several interesting features emerge from the Eliasberg summary of Census data on coal mining. The first is the surprisingly slow growth of coal to a consumption role dominating wood despite very great apparent price advantages. This contrasts sharply with the European experience and is no doubt due to the fact that market success for coal had to await a greater degree of urbanization and transport development (because real prices in rural areas were still much lower for wood, collected and prepared by farmers in the winter when they had no other crop to sell). Another remarkable feature of coal mining is the early and almost unchanging regional dominance pattern with five states as the leading producers, decade after decade. That stability was in contrast with the shifts in metal mining dominance during the period and occurred despite the fact that transportation costs were relatively high for coal compared with many other products. International trade in coal was small during the entire period because the greater relative productivity of U.S. than of European coal mining had not yet been realized. In fact, the growth of output per person employed was much smaller for coal than for almost any other U.S. industrial sector. The Eliasberg data also indicate that the shift after 1850 from anthracite to bituminous coal use depended to a large extent on the use of coal in steel production; that is, the substitution of coke for anthracite.

Harold J. Barnett, Washington University

Vera Eliasberg has made a useful contribution to the statistical economic history of the United States in the nineteenth century. It is attractively presented and interesting to read.

Among her major points are an allegation of extraordinarily high energy consumption per capita in 1850 and a level trend from at least 1850 to 1885. I suspect the possibility of error in both of these. I do not know that she is wrong—indeed I think the probability is high that she will satisfactorily answer my questions and doubts. But my responsibility to her in the minor role of discussant is to state them.

Mrs. Eliasberg writes following Table 8: "By the middle of the nineteenth century the total energy consumption of the United States economy was already huge in absolute terms, as can be seen in Table 1. Apparently

it was larger in per capita terms than that of any other country, including the industrially more advanced such as Great Britain. Even when the mechanical energy derived from wind, water power, and work animals is disregarded and only fuel materials are considered, per capita use around 1850 was the rough equivalent of four tons of bituminous coal per year. Nine-tenths of this (measured in btu content), however, consisted of wood burned at the rate of about four cords per person per year, while only one-third of a ton of coal per year per person was being used."

Her description of the availability of virgin forests and their clearing to provide farm lands establishes that wood was plentiful. Wood would be used with a rather free hand, having regard for the cost and effort of cutting, trimming, hauling, sawing, splitting, and handling; the size of homes to be heated; and so on. But why the equivalent of "four tons" of coal per year? I suspect from the paper that the keystone is an 1880 Census volume on forests, which alleged a per capita wood use of about 2.2 tons of coal equivalent. This, when added to the estimated 1.6 tons of coal consumed, yields a figure approximately equal to the 3.9 tons per capita which Mrs. Eliasberg presented for 1850 (Table 9). Do I presume correctly that the 1880 Census per capita figure of wood fuel and total fuel is taken as valid? If so:

1. How does Mrs. Eliasberg view the competence of the group which prepared the particular Census volume in question, *The Forests of the U.S. in Their Economic Aspects*? How was the Census of home use conducted? To what extent was it a survey based on a sensible questionnaire and yielding objective data by state and county, which can be reviewed, and to what extent was it a subjective estimate by professional foresters?

2. The Census figure of wood consumption in homes using wood is the equivalent of about twenty tons of coal per year for a family of six. As Mrs. Eliasberg points out, this yields a very large fuel expense bill (about $50 per year, when valued at the Census unit price) relative to annual family income of the period. And fireplace or stove wood was not free—to the extent that it was not purchased in the market. Twenty-five cords of wood per year (twenty tons of coal equivalent) represent a very considerable labor outlay for the family, in converting living trees into an economic good, and provide an extraordinary amount of heat in found a small home.

Let me now assume that the forest Census figures for 1880 are, however, found to be very satisfactory. Then I have these questions:

1. Mrs. Eliasberg's figures on annual per capita fuel consumption for the preceding thirty years are virtually identical with the 1880 figure.

Did the author project the 1880 figure backward to 1850 at a constant level? If so, what is the basis for the assumption that the increased energy required for increase in GNP per capita from 1850 to 1880 was approximately offset by improved energy efficiency?

2. Can Mrs. Eliasberg reconcile her *level* annual per capita consumption of almost four tons of coal equivalent during the period 1850–85 with the Eavenson study (which she refers to in this paper and quotes in *Energy in the American Economy*[1])? Eavenson, using data reported by Marcus Bull in 1827, found annual fuel consumption in Philadelphia in 1826-27 to total about 150,000 tons of coal equivalent. For the Philadelphia population, then about 75,000, this is an annual consumption for all purposes of about two tons of coal equivalent per capita.

I close with a very brief comment concerning coal output, value of output, and employment. Mrs. Eliasberg has adopted Eavenson's output figures, which are upward revisions of Census data for the period 1840 to 1890. Then, on the assumption that Census coal values and employment were similarly understated, she has raised these figures in proportion to the output increase. From the method of the Eavenson revisions, however, the new output figures may still be seriously underestimated, as Eavenson points out (see quotation from Eavenson in Mrs. Eliasberg's discussion of Table 5). And, therefore, the value and employment figures may be too low. I anticipate that further combing of historical records and review of the implications of improved nineteenth century national statistics of labor force, GNP, and activity in important coal-consuming sectors will ultimately permit further improvement in the coal data.

[1] By Schurr *et al.*, p. 51.

Power and Machines