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Anthracite Coal and the Beginnings of the Industrial Revolution in the United States*

¶ *Professor Chandler traces the rise and spread of the factory system in American industry, suggesting an explanation for the timing and the pattern of development of the industrial revolution in the United States.*

The factory, nearly all economic historians agree, was central to the process of nineteenth century industrialization. With its battery of machines, operated from a single source of power, its large permanent working force, whose tasks were subdivided and routinized, and whose livelihood depended solely on the wages received from carrying out these tasks, the factory was a new and different form of production. Since as long ago as Adam Smith, economists have been pointing out that careful subdivision of men and machines greatly expanded the output of a single production unit. And even before Karl Marx, others realized that the factory created a new life for workers in manufacturing. With the coming of the factory, working men became mere tenders of machines. They no longer owned the tools of their trades, and they were deprived of the satisfaction of traditional craft work. Crowded into new, large, industrial cities, these laborers no longer worked in close personal touch with the owners of small shops, mills, forges, or foundries. Instead, they reported to foremen, who in turn were directed by salaried factory managers. The latter were among the first of a managerial class that was to become so influential in the modern world. The factory, therefore, not only greatly expanded production, but also helped to create a new class of workers and of managers.

As important as the rise of the factory has been in the process

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of industrialization, and as much as its story in Europe has commanded the attention of economic historians, surprisingly little has been written on how, why, and when this basic economic institution developed in the United States. Many questions about the coming of the factory still remain unanswered. Why did factories, which had become significant in British manufacturing by the end of the eighteenth century, not become a major form of production, except in the textile industry, in the United States until the 1840's? And why did the early textile factories differ in many ways from those built during and after the 1840's? The earlier textile mills were powered by water, used machines made largely of wood, and had leather belting to transmit the water-produced energy to the machines. Their working force was almost entirely children and young women, recruited from nearby farms. After 1840, as the factory quickly appeared in other industries, it became increasingly powered by steam, used metal machinery, was manned by heads of families, and was located in the larger cities rather than in rural areas near water power sites. Why then was steam power so little used in the United States before the 1840's? Why was there so little metal machinery in the United States before that decade? Indeed, why until the 1840's were nearly all metal products – implements, tools, stoves, nails, plows, pots, pans, small arms – made in small shops, foundries, or mills, rather than being produced in volume in factories? Although the techniques of producing goods by the fabrication and assembling of interchangeable parts was well known early in the century, the only metal products to be made by this technique before the 1840's were guns made under government contract. This fact suggests another question: why did the output of American iron makers remain so small until the 1840's, and why did Americans cling so tenaciously to the ancient processes of making iron by charcoal and wood, rather than adopting modern techniques, using coal as fuel? Of all these questions, only the last has been given serious attention, and the thoughtful answers proposed by Louis C. Hunter and Peter Temin are still inadequate to explain the timing and the way in which the modern iron industry came to the United States.

Manufacturing in the Early 1830's

Before attempting to provide answers to these questions about the coming of steam and iron and the rise of the modern factory in the United States, the facts which gave rise to these questions

must be documented. The best place to begin is the detailed report on American manufactures made in 1832 to Louis McLane, the Secretary of the Treasury. This report, supplemented by census data, other government reports, and existing firm and industry studies, provides a useful profile of American manufacturing at the beginning of the 1830's.

The data in the McLane Report emphasize the fact that the large, impersonal factory was, in 1832, concentrated almost entirely in the textile industry.[1] Of the 106 manufacturing enterprises that listed assets of $100,000 or more, eighty-eight were textile companies (of these, ten were producers of wool fabrics, and two made both wool and cotton cloth). Twelve were iron makers, and the majority of these were still the ancient type of "iron plantation," where the mining of iron, the collecting of wood and making of charcoal, as well as the production of both cast iron and wrought iron was carried on in a single extensive rural location. (The assets of these firms were, then, as much in land and mines as in buildings and machinery.) The remaining six enterprises in the list included a nail and hoops, an axe, a glass, a paper, a flour, and a hydraulic equipment manufacturer. Of the thirty-six enterprises reporting 250 or more workers, thirty-one were textile factories, the remaining five included three iron works, the nail and hoops works, and the Collins Axe Factory.[2]

If a smaller amount of capital and a smaller number of workers are used to define a large manufacturing establishment, the pattern remains the same. Of the 143 firms having capital assets between $50,000 and $100,000, the greatest number were textile firms, with iron enterprises following in about the same proportion as those with assets of $100,000 or more. The enterprises in other industries included more nail-making firms, a producer of steam engines in Pittsburgh, a firearms maker in Connecticut, a gunpowder company and a flour mill in Delaware, and a saddlery in Pennsylvania. If one looks at the enterprises with fifty or more workers, which were not included in the other categories, the concentration remains in textiles, with ironworks second in number, but a good way behind.[3] There are a number of industries that list one or two enter-

[1] U.S. Congress, House of Representatives, Executive Document No. 308, *Documents Relative to Manufactures in the United States, Collected by the Secretary of Treasury* [Louis McLane], 22nd Cong., 1st Sess. (Washington, 1833). Hereafter cited as the *McLane Report*. The following generalizations are based on an analysis made of this report by Alfred D. Chandler III for all enterprises with assets of $50,000 or over. This analysis includes for each enterprise its name, location, product, source of power, legal form, fixed assets, working capital, number of employees, and date founded.

[2] The number of employees in the hydraulic equipment firm was only twenty.

[3] I am indebted to Robert Brugger for making this check for me.

prises hiring more than fifty men. But in only five industries were there as many as three enterprises with a working force of that size. These were: books and printing with seven, cordage with five, shipyards with five, buttons with three, combs with three, and glass with three. On the other hand, the McLane Report lists many hundreds of enterprises with assets of only a few thousand dollars, and employing at most ten or a dozen men.

The McLane Report is, of course, incomplete. It includes only ten states, all in the Northeast (plus a short and very incomplete statement in Ohio). Although the returns for some states, especially Maine, Massachusetts, Rhode Island, Pennsylvania, and Delaware are most detailed, those for others have gaps in capitalization, employment, and other data. Nevertheless, the information covers those states in which, as late as 1850, 75 per cent of all American manufacturing was concentrated.[4] Much of the data provided on individual enterprises are very detailed, giving a wealth of information on wages, sources of raw materials, locations of markets, types of power used, as well as assets, working capital, and employees. While historians can doubtless identify some other enterprises with assets of more than $50,000 and more than fifty employees, such new information can hardly alter the profile of American industry as outlined in the two large volumes of the McLane Report. Also, it seems safe to identify an enterprise with more than $50,000 invested in plant and equipment, and more than fifty workers, as a factory. An enterprise with less assets and less workers would have required only the rudimentary routinization and subdivision of labor, and would, in most cases, be managed by owners without the use of plant managers or even foremen. By 1832, then, the information in the McLane Report and, indeed, nearly all other available supplementary data, emphasize that the large, impersonal factory had become a dominant form of manufacturing only in textiles. While large enterprises existed in iron production, these firms were as much mining as manufacturing enterprises, and the number of men in each activity (mining, processing, and transportation) was relatively small.

Another fact that a review of the McLane Report underlines is that in 1832, American machinery was powered almost exclusively by water. If enterprises in the Pittsburgh area are excluded, only four of the 249 capitalized at $50,000 or more reported using steam power. Of these, three were recently constructed textile mills in

[4] Douglass C. North, *The Economic Growth of the United States, 1790–1860* (Englewood Cliffs, N.J., 1961), 159.

Rhode Island, and the fourth was the New England Glass Company in East Cambridge, Massachusetts.[5] In addition, a textile factory in Dedham, Massachusetts; one in Dover, New Hampshire; and a third in Oneida, New York, supplemented water power with steam. Of all the other enterprises with fifty or more workers, only one reported the use of steam, and that was a machine and iron works in New Britain, Connecticut, which employed just fifty men. Peter Temin, in his study of steam and water power, located as many as 100 steam engines in the McLane Report, but the great majority of these were small, often auxiliary, engines of low horsepower.[6] With the exception of Pittsburgh, more firms reported the use of wind and mule power than steam.

Pittsburgh is, however, a striking exception. There, of the enterprises listed with assets of $50,000 or more, there were four textile factories (one in nearby Beaver County), five iron works (one in Fayette County), a steam engine works, and a glass works, all of which relied wholly on steam for power.[7] In fact, nearly all enterprises in the Pittsburgh area listed in the Report used steam. A competent observer writing in 1828 estimated that the cost of operating a steam engine in England was two-fifths that of running one on the American seaboard. The difference was nearly all in the fuel costs. "While at Pittsburgh on the contrary, from the wonderful abundance of coal, steam power is actually available at about 3/4 of expenses required in England."[8] Even with its incompleteness, the McLane Report does effectively testify that American manufacturers, except for those in the Pittsburgh region, had not yet turned to steam as a source of power.

As striking as the failure of American manufacturers to use steam power was their continued reliance on imported iron. Before the high tariff of 1828 – the Tariff of Abominations – even Pennsylvania manufacturers relied on iron imports. An owner of a nail mill on the Delaware River, for example, reported in 1832 that his mill consumed annually "400 tons of wrought iron, mostly foreign; last three years about all American."[9] For New Englanders, the high

[5] The *McLane Report* lists two steam powered mills in operation, and a third at Newport about to commence operations (I, 966–67). Samuel Slater reported in 1832 that four textile mills used steam, and two more were under construction (I, 927). One of these four may have been the Eagle Mill, reported in 1838 to have had its engine in operation since 1831. U.S. Congress, House of Representatives, Executive Document No. 21, 25th Cong., 3rd Sess. (Washington, D.C., 1838), 81. Hereafter cited as the *Woodbury Report*.

[6] Peter Temin, "Steam and Water Power in the Early Nineteenth Century," *Journal of Economic History*, XXVI (June, 1966), 189.

[7] *McLane Report*, II, 242–255, 393, 461, 467. There was an iron works in Fayette County that used both water and steam power.

[8] Zachariah Allen, *The Science of Mechanics* (Providence, R.I., 1829), 351.

[9] Report of Henry Moore, *McLane Report*, II, 207, also 223–24.

tariff only increased the price of their materials, as they continued to obtain most of their iron abroad. Of the 166 blacksmiths in Maine who provided information in the McLane Report, 97 per cent (161) depended entirely on iron from abroad, and the 3 per cent who did use American iron used only small amounts.[10] In New Hampshire, Massachusetts, and Connecticut, blacksmiths and other small iron users did buy more American iron, relying on the few local sources such as the ore deposits in Franconia, New Hampshire, and Salisbury, Connecticut, as well as those in Pennsylvania. Nevertheless, of all the small manufacturers using iron, only a handful reported obtaining as much as 20 per cent of their needs in the United States. While many of the bigger general iron producers had begun to rely quite heavily on Pennsylvania iron, many of even the very largest of the New England iron users, including the nail and hoops works at Wareham, the nail, tack, and iron works at Bridgewater, and the Warner, Hunt axe company at Douglas (all in Massachusetts) and a large rolling mill in Norwich, Connecticut, still purchased up to 70 per cent of their requirements in Europe.[11] Again, Pittsburgh was the exception. It had the largest concentration of rolling mills (eight) and steam engine manufacturers (eight) in the United States and relied wholly on domestic iron.[12]

This lack of a source of good quality, inexpensive iron in the industrial areas east of the Alleghenies helps to account for the small output of metal goods and the lack of metal machinery in this country. Even in the one industry then using the factory form of production — textiles — machinery continued to be made largely of wood until the late 1830's.[13] Important, too, as Samuel Batchelder pointed out long ago, was the use of leather belting rather than iron gearing for transmitting power. In textile and other machinery, metals were used only where friction was constant, where a cutting edge was needed, or to strengthen areas of stress.

The lack of metal and metal machinery, as well as the small pro-

[10] I am indebted to Edwin Perkins for compiling these data on the 247 Massachusetts blacksmiths. Only one reported using over 30 per cent American iron.

[11] For these four companies, see the *McLane Report*, I, 410–11, 416–17, 510–11, 994. George S. Gibb, *The Saco-Lowell Shops* (Cambridge, Mass., 1950), 50, 82, notes that the early textile machinery making shops relied on British, Russian, and Swedish iron.

[12] *McLane Report*, II, 638. Carroll W. Pursell, Jr., *Early Stationary Steam Engines in America* (Washington, 1969), 61–66, 80–81.

[13] Gibb, *Saco-Lowell Shops*, 81, 107, 158, points out that there was little metalworking machinery used in the making of textile machinery until the 1840's. Craft workers continued to use the traditional hand tools, and the textile machine shops did not have their own foundries until the late 1830's. For leather belting see Gibb, *Saco-Lowell Shops*, 79–80; and George Rogers Taylor, ed., *Early Development of the American Cotton Textile Industry* (New York, 1969), xiv, 88. The best way to appreciate the lack of metal in early machines is to view the numerous specimens available at the Merrimack Valley Textile Museum in North Andover, Mass.

duction of iron, reflected the backward state of the technology of the American iron industry. In the United States, iron manufacturers were still producing small amounts by ancient techniques. As Peter Temin has pointed out in his outstanding study of the industry, "the American iron industry was in 1830 still operated almost exclusively on the basis of traditional technology, despite the very successful new technology in England." [14] In some areas, the major unit of production was still the iron plantation, where all the processes in the making of iron were combined. Such establishments were usually located in rural, isolated areas, with ample supplies of ore and wood, as well as water power. The output of the furnaces using charcoal remained small, producing at best twenty-five tons a week. Both the furnaces that made the pig iron and the forges that produced wrought iron were normally shut down during the cold of winter and the heat of summer. When new sources of ore were opened up after 1815, largely in central and western Pennsylvania, the furnaces moved to the ore beds, distant from feasible transportation, while the forges remained closer to transportation routes.[15]

As historians have been careful to point out, when Americans began to adopt the modern methods of making iron by the use of coal rather than charcoal, they took up these innovations in the reverse order of that in which the British had adopted them more than a generation earlier.[16] In the United States, coal was first used to reheat cast and wrought iron in rolling and nail mills, and in cupola and air furnaces, where the iron was manufactured into final products. Coal next replaced charcoal in the making of wrought iron from cast iron by the puddling and rolling processes. Instead of beating out the impurities in cast iron by large hammers in the forge, the pig iron was "boiled" and "puddled" for an extended period of time, and then the semi-molten metal was squeezed

[14] Temin, *Iron and Steel*, 15; Louis Hunter, "Heavy Industries Before 1860," in Harold F. Williamson, ed., *The Growth of the American Economy* (New York, 1951), 174.

[15] For example, of the three central Pennsylvania counties having the largest iron output (Center, Huntington, and Bedford), there were in 1832 in Center County five iron plantations operating forge and furnaces, four separate furnaces and two forges (one of which included a rolling mill, foundry, and wood screw factory). In Bedford, there were two plantations, one forge and two furnaces, while in Huntington, there was only one plantation, eleven separate forges and seven separate furnaces. In Fayette County, in the western part of the state, the pattern was similar to Huntington's. *McLane Report*, II, 638–642.

[16] This is most clearly spelled out in Louis C. Hunter, "The Influence of the Market Upon Techniques in the Iron Industry in Western Pennsylvania up to 1860," *Journal of Economic and Business History*, I (February, 1929), 266–281; for Temin's disagreement with Hunter on the reasons for the timing of these developments, see Peter Temin, "A New Look at Hunter's Hypothesis about the Ante-Bellum Iron Industry," *American Economic Review*, LIV (May, 1964), 344–351; and Fritz Redlich, *History of American Business Leaders: Men and Iron* (Ann Arbor, Mich., 1940), 71–76. Hereafter cited as Redlich, *Men and Iron*.

through rollers. Last of all, coal was used in the making of the cast pig iron from iron ore.

Louis C. Hunter, who wrote only about the industry west of the Alleghenies, saw the reason for the delay in adopting the new techniques and for the reverse progression in which they were adopted as the response to the demand for the product. The users of western iron, produced largely in the Pittsburgh area, were country blacksmiths who preferred the more workable wrought iron made of charcoal to the more brittle coal-produced product. Peter Temin disagrees, and shows that the use of coke from bituminous coal in the making of western iron was delayed until the late 1850's, because of the high sulfuric content of the coal in the great Pittsburgh seam. Such coke produced a low quality iron, which could not even compete with that made from anthracite when the latter began to be shipped across the mountains in the mid-1850's. However, Hunter, because of the focus of his studies, says nothing of the larger market for iron in the East, one which was as much industrial as agricultural, and one which, in the early 1830's, was still so dependent on Europe. While answering Hunter about the impact of the western market on production, Temin says relatively little on why and how American iron came to the eastern markets, and why the progression in the adoption of the new technology came in the way it did.

In the early 1830's, then, American iron was still being produced by charcoal. New England still relied on Europe for most of its iron supply, little metal was yet used in machinery, and steam was hardly employed at all as a source of power. This lag in the use of iron and steam appears to have held back high volume factory production in all industries except textiles. Then in the 1830's and 1840's, these patterns began to change quickly. A revolution in American ironmaking began in the 1830's with the use of coal in the making of wrought iron, and then in the 1840's in the production of cast iron with the adoption of the coal-using furnaces in eastern Pennsylvania. In the same decades, steam began for the first time to be used extensively in industrial production. Six years after the McLane Report, another government study indicated that in the states where in 1832 a hundred steam engines had been reported, over nine hundred were already in operation. Concurrent with the new use of steam and metal, the large enterprise spread rapidly. The factory came quickly to the metalworking industries. By the 1840's, shovels, saws, scythes, stoves, pots, pans, wire, plows, reapers, harvesters, as well as axes and nails, were being produced in factories. At the end of the decade, guns were being produced for non-

government markets by the fabrication and assembling of interchangeable parts. So, too, were reapers, clocks, scales, and sewing machines. In the 1840's, the production of glass and paper became concentrated in the factory, and sugar refineries, distilleries and breweries, plants making acids and other chemicals grew to factory size. In the late 1830's and early 1840's, large steam-driven factories revived the textile industry in southeastern New England. By the 1850's, the factory had come to the leather, cloth, and even woodworking industries. By then, the output and technology of American factory production was indeed so impressive that the British government began to send experts to study American industrial techniques.

The Importance of Coal

Why, then, were the basic techniques of a modern industrial economy so slow in coming to the United States, and why did they spread so rapidly in the late 1830's and the early 1840's? The term "delay" seems valid, because the technology of the generation of steam power, the methods of modern iron making and factory production in industries other than textiles had been widely used in Great Britain, and widely admired by Americans. Certainly the demand for factory goods existed and indeed was being met by the products of British factories.[17] The rapid expansion of population, its swift spread into the Mississippi Valley, particularly after 1815, and the growth of commercial centers to service the expanding agrarian economy provided the basis of this demand. In years after 1815, American merchants and shippers quickly created a national marketing and shipping network that assured manufacturers of regular delivery of goods hundreds and even thousands of miles to their ultimate consumers. The importance of this strong demand has been termed by Robert Fogel and Stanley Engerman the major factor in encouraging industrial expansion in the first half of the nineteenth century.[18] Why then, except for textiles, did Americans

[17] Hardware and metal were major importing businesses in the 1820's. Robert G. Albion, *The Rise of New York Port, 1815–1860* (New York, 1939), 66–70, outlines the development of this trade, while Elva Tooker, *Nathan Trotter, Philadelphia Merchant, 1787–1853* (Cambridge, Mass., 1955), fills in the details of how it was carried out. See especially Tooker's Chaps. IV–VIII. In fact, the importing of wrought iron and finished iron products was second only to textiles in value during the 1820's and 1830's; North, *Economic Growth of the United States*, 287; also George Rogers Taylor, *The Transportation Revolution* (New York, 1951), 449.

[18] Robert Zevin, "The Growth of Cotton Textile Production After 1815," and Robert W. Fogel and Stanley L. Engerman, "A Model for the Explanation of Industrial Expansion During the Nineteenth Century: With Application to the American Iron Industry," both in Robert W. Fogel and Stanley L. Engerman, *The Reinterpretation of American Economic History* (New York, 1971), 122–146, 148–162.

wait until the 1840's to meet this demand through large-scale factory production?

There do not appear to be any obvious changes in technology, the availability of capital, or government action in the mid-1830's that might account for the revolution in iron making, the rapid expansion of steam power, and the quick growth of the factory in many industries during the 1840's. The hot blast technique for the making of pig iron with hard coal, patented in Britain in 1828, was one major technological innovation, but this alone could hardly account for the coming of the factory, even in the iron industry. The railroad, the best known of the technological innovations of the era, had its major impact later, in the 1850's. The British investment of capital in the United States did increase in the early 1830's, but it was placed almost wholly in canals and the first railroads. Moreover, it stopped almost completely after 1837, shortly before the industrial expansion based on iron and steam began. That availability of funds was not a constraint to the manufacturers is suggested by the fact that the new rolling mills and the first of the new factories were financed in the late 1830's and early 1840's during one of the most severe depressions in American history. Nor do changes in the tariff account for the expansion of factory production. The Compromise Tariff of 1833 provided a general scaling down of all schedules to a 20 per cent ad valorum duty by 1842. For a generation, from 1833 until the outbreak of the Civil War, protective tariffs were operative for only four years, 1842–1846. Significantly, this period of low tariffs was the very one which saw the rapid spread of the factory and a swift expansion of the manufacturing sector of the American economy.[19]

One answer appears to be more obvious than changing availability of capital, new technology, or government action. The exception of Pittsburgh from the general pattern of American manufacturing in the early 1830's provides the clue. That answer is coal. In 1830, Pittsburgh was the only industrial center in the United States that had enough coal for both household and industrial purposes. Indeed, enough bituminous coal was mined from the great Pittsburgh strip to meet the city's needs and still send large amounts down the Ohio River. Nevertheless, the cost of transporting Pittsburgh coal east across the Alleghenies was prohibitive. Even after the completion of the Portage Railroad to carry canal traffic over the highest parts of the mountains between Pittsburgh

[19] Taylor, *Transportation Revolution*, 360–67, has an excellent brief summary of tariff legislation to 1860.

and Harrisburg, only the tiniest amounts of coal found their way east. Only after the completion of the Pennsylvania Railroad in 1853 did shipments begin. As Peter Temin has emphasized, "it was not feasible before the middle of the 1850's to transport large amounts of coal and iron across the mountains." [20]

For this reason, the region east of the mountains – the area in which American manufacturing was concentrated – relied until the late 1820's for its coal on small amounts brought from bituminous fields of the James River near Richmond, and from Great Britain and Nova Scotia. Philadelphia and other coastal cities had come to depend on imported coal early in the century. John Gilpin noted in January 1808: "There is brought to the city of Philadelphia nearly five hundred bushels per annum, a great part of which is from Europe." [21] The situation remained much the same until about 1825. Then in the late 1820's and early 1830's, the eastern part of the country suddenly acquired a domestic source of coal that provided it with high quality fuel for most of its industrial and household needs.

Two reasons explain why the great anthracite coal fields of Pennsylvania were not fully opened up until the early 1830's. One was the difficulty of access. The Virginia and the Pittsburgh seams were on rivers. The British and Nova Scotia fields were on the sea coast. Anthracite coal was found only in rugged, mountainous country, some thirty to a hundred miles from navigable water. As significant for the delay was that anthracite was a new type of coal,[22] its texture and burning qualities unknown to Americans and even to Europeans. "Stone Coal" had almost pure carbon content, ranging from 85 per cent to nearly 100 per cent. It burned with a tiny blue flame, producing intense heat and almost no smoke. It was so hard to ignite that many people, even those living in the anthracite area, believed that it could not be burned. At every step of the way, anthracite coal mine owners expended a great deal of technological and entrepreneurial energy and skill to find ways to make this fuel usable.

The first interest by outsiders in anthracite came during the War

[20] Temin, *Iron and Steel*, 62. U.S. Bureau of the Census, Eighth Census, III, *Manufactures of the United States in 1860* (Washington, 1865), clxvii–clxviii, points out that a few bushels of western coal reached the seaboard as early as 1828. However, even in the early 1860's, when railroad transportation across the mountains was fully developed, the shipment of bituminous coal from western Pennsylvania to the east, the Census reported, was "never large," with that of "Virginia and Nova Scotia underselling it in the eastern markets."

[21] Quoted in Howard N. Eavenson, *The First Century and a Quarter of the American Coal Industry* (Pittsburgh, 1942), 64–66.

[22] U.S. Census, *Manufactures in 1860*, cixx; Eleanor Morton, *Josiah White, Prince of Pioneers* (New York, 1946), 89; Redlich, *Men and Iron*, 71.

of 1812, when Philadelphia, New York, and Baltimore were cut off from their supplies of Liverpool and even Virginia coal. Philadelphia iron manufacturers, including two partners, Josiah White and Erskine Hazard, attempted, with some success, to use anthracite in their nail and wire works.[23] With the coming of peace, the immediate need for anthracite disappeared. However, White and Hazard, believing in its potential demand, purchased coal lands and began the construction of a canal to reach them. For much the same reasons, William Wurts and his brother Maurice, also of Philadelphia, bought coal land in the Lackawanna Valley and began planning for a canal to the Hudson River. Others somewhat further to the west began efforts to improve the Susquehanna as a waterway. In the meantime, the concentrated efforts of men owning coal lands in the Schuylkill area helped to assure the building of a canal between Reading and Philadelphia.

As important as providing transportation for the coal fields was the developing of a market. When White and Hazard sent their first shipment of 365 tons of anthracite to Philadelphia in 1820, they were unable to find customers for that half of the shipment not taken by local nail and iron works for the reheating of iron.[24] They and other coal field owners worked to adapt existing grates and furnaces so that they could be used with the slow burning coal, producing an intense heat, in both homes and industrial processes. They advertised and issued booklets on how to use anthracite, with testimonials from satisfied customers.[25] By the mid-1820's the new grates and furnaces had been fully developed.

The long burning, clean coal was proving cheaper to use, particularly in the larger cities like Philadelphia and New York, than wood, charcoal, or Virginia and foreign bituminous. The head of the Pennsylvania Hospital in Philadelphia reported in November 1825 that his average cost of heating and cooking with wood over a four year period had been almost $3,200. In the previous year, with the use of anthracite, costs had dropped to about $2,100. Metal manufacturers found that the cheaper anthracite also required less attention than charcoal or bituminous coal. A ton of anthracite could do

[23] Hudson Coal Company, *The Story of Anthracite* (New York, 1922), 36–41, 47–72; Morton, *White*, 89, 91–95; and Clifton K. Yearley, *Enterprise and Anthracite* (Baltimore, 1961), 23–28.

[24] U.S. Census, *Manufactures in 1860*, cixx; Morton, *White*, 131–134, 149–150; Walter R. Johnson, *Notes on the Use of Anthracite in the Manufacture of Iron* (Boston, 1841), 3; Hudson Coal Company, *Anthracite*, 93–95.

[25] In 1824, 1825, and 1827 the Lehigh Coal and Navigation Company had published in Philadelphia *Facts Illustrative of the Anthracite, or Lehigh Coal Found in the Great Mines at Mauch Chunk*. The figures on the savings at the Pennsylvania Hospital are from p. 17 of the 1827 edition. The quotation in this paragraph and other statements are from pp. 5–12, also 18–19.

the work of 200 bushels of charcoal. Anthracite had a cost advantage in cities like Philadelphia (and after 1830 in New York), when charcoal was at 6¢ to 8¢ a bushel and anthracite at $7.50 to $8.00 a ton. Moreover, its use cut down on labor costs. As to coal, one rolling mill operator reported that "there is a saving of about fifty per cent over Virginia coal;" others maintained that a bushel of anthracite brought the same results as two or even three of Virginia bituminous. Because of its lower cost, anthracite was adopted with astonishing rapidity by metalworking enterprises even in rural areas where charcoal could be had at 4¢ or 5¢ a bushel. For example, in 1832 the McLane Report noted that anthracite was the standard fuel used in almost 90 per cent of the furnaces and foundries in New York state.[26] By then it was beginning to be used by brass and copper workers as well as by brewers, distillers, and makers of acids and other chemicals for their heat-using processes. In the late 1820's it began to be used to fuel steam engines.

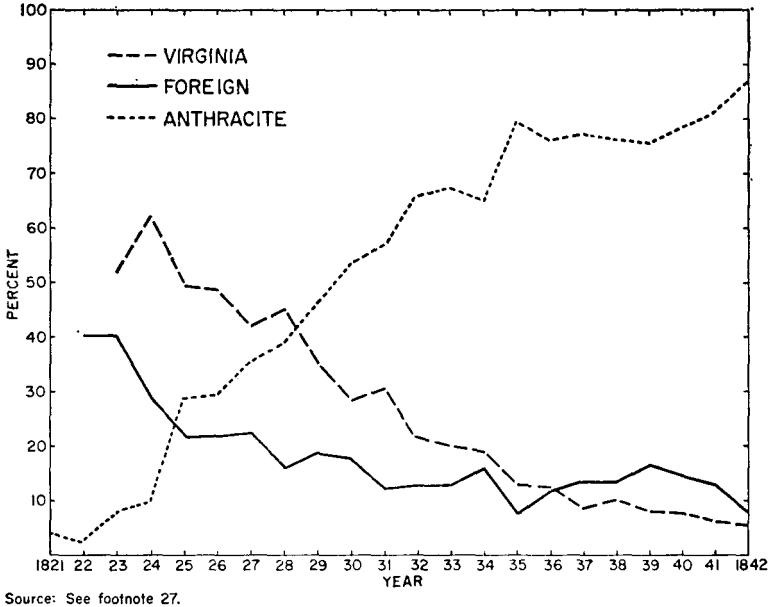
Once the urban householders and manufacturers realized the value of anthracite as a fuel, transportation costs remained the primary constraint on its use. Although the shipments from the anthracite fields grew in the 1820's, large-scale output did not occur until the early 1830's with the completion of the three major coal canals. In 1825, with the finishing of the initial work on the Lehigh Valley canal connecting Mauch Chunk to Easton, and the first section of the Schuylkill connecting Reading to Philadelphia, shipments to tidewater from the anthracite fields jumped from about 9,500 to almost 35,000 tons, a total that exceeded for the first time the imports of coal to the east coast from abroad (see Table I and Graph I).[27] The next big expansion of output came in 1829, with the completion of the Lehigh slackwater canal. (Prior to that, coal was carried to tidewater by means of artificial freshets.) In that same year, the Schuylkill was finished, and the Delaware and Hudson carried its first full loads of coal from the northern end of the fields to the Hudson River. The output of that year was 112,000 tons, which surpassed for the first time that of the James River. In

[26] *McLane Report*, II, 115–122.

[27] Richard P. Rothwell, "Coal Production of the United States," *Proceedings of the American Institute of Mechanical Engineers*, V (1876–1877), 378–79, is the source for the figures in Table I. Freeman Hunt, *Merchant's Magazine and Commercial Review*, VIII (1843), 548, also gives the information on Virginia and imported coal used here. The information on the opening of the three canals is from Chester L. Jones, *Economic History of the Anthracite-Tidewater Canals* (Philadelphia, 1908), 13–17, 26–27, 78, 128–29. For the Schuylkill, see also Henry V. Poor, *History of Railroads and Canals of the United States* (New York, 1860), 540. The supplementary canals – the Morris from Easton to New York harbor, the Delaware division of the Pennsylvania State Works from Easton to Philadelphia, and the Raritan, connecting Trenton and New York, were completed between 1830 and 1835; see Jones, *Anthracite Canals*, Chaps. III and VI. It should be stressed that Graph I represents only the U.S. coal consumption *east of the Allegheny Mountains*.

Graph I

PERCENTAGE OF U. S. COAL CONSUMPTION REPRESENTED BY VIRGINIA, FOREIGN AND ANTHRACITE COAL 1821-1842



Source: See footnote 27.

1832, the completion of extensive improvements on the Lehigh Valley, the widening of the Schuylkill and the full use of the Delaware and Hudson made possible a jump in output from 175,000 tons in 1830 to 364,000 tons in 1832. Five years later, the coal carried on these three canals reached 881,000 tons. By then, the anthracite canals shipped by far the largest share of coal consumed in the northeastern states east of the Alleghenies. In 1822 the anthracite shipped from the Pennsylvania fields to tidewater had amounted to only 2.5 per cent, and in 1826 to 29.5 per cent of the coal consumed in the major industrial area of the nation. It amounted to 65.2 per cent of the coal used in 1833; 75.5 per cent in 1839; and 86.5 per cent in 1842. At the same time, consumption of coal for household and industrial uses along the waterways before it reached tidewater increased rapidly. By 1837, the total output was almost 1,230,000 tons. After a slight decline, it rose from 1,127,000 tons in 1841 to 3,165,000 in 1849.

Much of the anthracite coal was shipped by canals and rivers to Philadelphia and New York and then re-exported to other coastal towns and cities. The New England market quickly became a

TABLE 1

PENNSYLVANIA ANTHRACITE COAL PRODUCTION TO 1849

(IN THOUSANDS OF TONS OF 2240 LBS.)

Year	Total			Increase or decrease	
	Shipments to tide	Consumption and sales at mines	Total Production	Amounts (in tons)	Per cent
Before 1820	——	18.0	18.0	——	——
1820	.4	1.6	2.0	——	——
1821	1.0	2.2	3.3	1.3	66.7
1822	2.2	2.7	4.9	1.7	50.9
1823	5.8	3.2	9.0	4.1	82.6
1824	9.5	4.1	13.6	4.6	51.2
1825	33.7	4.8	38.5	24.9	182.2
1826	48.1	6.7	54.8	16.3	42.4
1827	61.6	9.6	71.2	16.4	29.8
1828	77.4	14.5	91.9	20.7	29.2
1829	110.4	22.8	133.2	41.3	44.9
1830	173.7	35.9	209.6	76.4	57.4
1831	176.8	53.5	230.3	20.7	9.9
1832	368.8	79.4	448.2	217.9	94.6
1833	485.4	106.8	592.2	144.0	32.1
1834	376.6	80.2	456.9	-135.4	-22.9
1835	560.8	117.8	678.5	221.7	48.5
1836	684.1	141.6	825.7	147.2	21.7
1837	862.4	176.8	1,039.2	213.5	25.9
1838	725.7	147.3	873.0	-166.2	-16.0
1839	797.9	159.6	957.4	84.4	9.7
1840	841.6	166.6	1,008.2	50.8	5.3
1841	942.3	184.7	1,127.0	118.8	11.8
1842	1,076.6	209.9	1,286.6	159.6	14.2
1843	1,240.7	238.2	1,478.9	192.3	14.9
1844	1,596.4	303.3	1,899.7	420.8	28.5
1845	1,975.1	369.3	2,344.4	444.7	23.4
1846	2,284.7	422.7	2,707.3	362.9	15.5
1847	2,814.9	512.3	3,327.2	619.8	22.9
1848	3,027.7	545.0	3,572.7	245.5	7.9
1849	3,164.7	560.1	3,724.8	152.1	4.3

Source: See footnote 27.

major one and one that was developed largely by Philadelphians. As early as 1822, four vessels carried 181 tons to Boston; in 1825, 190 brought over 19,000 tons; by 1828, 464 carried about 46,000 tons.[28]

[28] Hunt's *Merchant's Magazine*, XVI (1847), 205. In 1842, Boston was importing 2,070 tons from Liverpool, 7,518 tons and 1,028 cauldrons from Newcastle, and close to 20,000 tons from Nova Scotia.

The big jump came in 1832, when the number of vessels in the trade rose from 563 in the previous year to 1,592 and from 56,000 tons carried to 158,000 tons. By 1836, the trade had again more than doubled, to 3,225 ships carrying 345,000 tons. And the Boston trade would continue to grow at a significant rate throughout the late 1830's and the decade of the 1840's.

The jump in output between 1830 and 1832 is of great significance for the industrializing of the Northeast. High quality coal now became available for both household heating and a variety of industrial purposes, at a price that was lower than wood, charcoal, and even the inferior, faster burning Virginia and British coal. Moreover, the price continued to drop except for the inflationary period of the mid-1830's. After 1830 the price of anthracite at Philadelphia fell from between $7.00 to $7.50 a ton (it had been from $8.50 to $10.00 a ton from 1822 to 1824) to below $6.00 a ton, and then from 1833 to 1835 to under $5.00 a ton (see Table 2). In the inflationary years of 1836 and 1837, it rose to between $6.00 and $8.00 a ton, dropping back in the spring of 1838 and then staying at about $5.00 until 1841. It rose slightly in that year but in 1842 dropped to below $4.00 and stayed at between $3.00 and $4.25 a ton until the mid-1850's.

From 1830 until 1850, except possibly for the two inflationary years, the price of the best Newcastle coal on the London Coal Exchange consistently listed higher than the price of anthracite in Philadelphia.[29] Nevertheless a small amount of British bituminous (normally well below 5 per cent of the coal consumed in the United States east of the Alleghenies) continued to be shipped to the eastern ports. This was for two reasons. First, English coal came in ballast. In addition, high quality cannel coal did find favor with householders at prices well above that of anthracite, while low grade bituminous (which sold somewhat above anthracite) had an industrial market of its own. It was used to supplement anthracite in lighting and regulating hard coal fires and in making coal gas, which was increasingly used to illuminate American cities.[30]

The opening of the anthracite fields thus provided the American Northeast with a constantly increasing supply of excellent coal at

[29] The prices were: 1830, 27s 6d; 1835, 20s 3d; 1840, 22s 9d; 1845, 17s 3d; and 1850, 13s 6d; or in dollars at a rate of $4.80 to a pound, $6.60, $4.86, $5.45, $4.04, and $3.24 respectively. George R. Porter, *The Progress of the Nation* (London, 1836–1843), 216.

[30] A useful table of amount and prices of foreign and Virginia bituminous and American anthracite shipped into Boston during the 1830's and 1840's is given in Richard C. Taylor, *Statistics of Coal* (Philadelphia, 1855), 458–59. By 1861, there were 420 coal gas works in the United States. U.S. Census, *Manufactures in 1860*, clxxiii; also Harold F. Williamson and Arnold R. Daum, *The American Petroleum Industry: The Age of Illumination, 1859–1899* (Evanston, Ill, 1959), 38–42.

TABLE 2
PRICE PER TON OF ANTHRACITE COAL IN PHILADELPHIA, 1829–1852

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1829	——	——	——	——	——	——	——	——	——	7.50	7.50	7.25	7.42
1830	7.25	7.25	6.00	5.75	5.75	5.75	5.75	5.75	5.75	5.75	——	——	6.08
1831	——	——	——	——	——	——	——	——	——	——	——	——	——
1832	——	——	——	——	——	——	——	——	——	——	——	——	——
1833	——	6.00	6.00	5.50	5.25	5.25	5.25	5.25	5.18	4.88	4.88	4.88	——
1834	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.59	4.84
1835	4.56	4.56	4.56	4.56	4.60	4.63	4.63	4.68	4.88	4.90	5.03	6.47	4.84
1836	7.70	7.44	7.31	6.58	5.38	5.50	5.50	6.19	6.41	6.50	7.13	8.05	6.64
1837	8.25	8.25	8.04	6.78	6.50	6.38	6.10	6.00	6.00	6.09	6.13	6.13	6.72
1838	6.13	5.91	5.28	5.25	5.16	5.13	5.13	5.13	5.10	5.00	5.00	5.00	5.27
1839	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
1840	5.00	5.00	5.00	5.00	5.00	4.63	4.63	4.63	4.66	4.95	5.06	5.34	4.91
1841	6.40	7.00	6.44	5.88	5.69	5.17	5.13	5.27	5.56	5.63	5.63	5.63	5.79
1842	5.63	5.56	5.06	4.38	4.03	3.88	3.83	3.60	3.56	3.51	3.56	3.56	4.18
1843	——	——	——	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
1844	3.50	3.33	3.10	3.02	3.00	3.03	3.13	3.21	3.26	3.26	3.27	3.26	3.20
1845	3.26	3.26	3.27	3.31	3.31	3.31	3.44	3.44	3.59	3.74	3.76	3.81	3.46
1846	3.81	3.75	3.72	3.84	3.87	3.97	4.00	3.94	3.96	3.88	4.00	4.00	3.90
1847	3.88	3.81	3.81	3.81	3.60	3.63	3.69	3.83	3.95	3.88	3.88	3.88	3.80
1848	3.90	3.90	3.58	4.44	3.37	3.29	3.33	3.56	3.46	3.41	3.29	3.36	3.50
1849	3.36	3.36	3.45	3.62	3.62	3.86	3.88	3.81	3.75	3.69	3.57	3.50	3.62
1850	3.50	3.50	3.40	3.31	3.25	3.25	3.25	3.25	4.25	4.25	4.25	4.25	3.64
1851	4.28	4.13	3.56	3.31	3.10	3.00	3.00	3.05	3.17	3.20	3.25	3.00	3.34
1852	3.18	3.47	3.40	3.44	3.44	3.45	3.45	3.50	3.56	3.56	3.56	3.50	3.46

Source: Samuel H. Daddow and Benjamin Bannan, *Coal, Iron, and Oil* (Pottsville, Pa., Benjamin Bannan, 1866), 781. The original table included this note about the prices of anthracite before 1829: "We find no reliable data on which to found an extension of the above chart further back than 1829; but may note the price of coal, at intervals, from the commencement of the anthracite trade. Anthracite coal was sold at Marieta, on the Susquehanna, for blacksmith purposes, at $8 and $9 per ton, from 1810 to 1814. In Philadelphia, the first Lehigh coal was sold to Messrs. White & Hazard in the spring of 1814 for $21 per ton; and in 1820 three hundred and sixty-five tons were sold for $8.50 per ton. From 1822 to 1824 the prices of Lehigh coal ranged from $8.40 to $10 per ton, and during 1826–27 the prices of Schuylkill coal ranged from $7 to $7.50 per ton."

decreasing prices. Given existing transportation methods, no other coal source was in a position to provide this massive increase at the same price. The annual output of the Pennsylvania fields rose from 210,000 tons in 1830 to 1,164,000 in 1837, to 1,900,000 in 1844 and to 3,327,000 in 1847. In the two decades between 1830 and 1850, the output of the Virginia fields stayed close to an annual average of 150,000 tons and that of Nova Scotia at 80,000 tons, of which a little over half was used in Canada.[31] The Maryland coal fields produced even less than Nova Scotia until the railroads reached them in the late 1840's. Only Great Britain, the world's leading coal producer, did have comparable supplies of coal available. To have met the American consumption of these years, however, Britain's exports to foreign countries would have had to double and in some years almost triple. These exports were 357,000 tons in 1830, 546,000 in 1835, 1,430,000 in 1844 and 2,400,000 in 1849.[32] Such exports would have had to come from either coal used in British domestic production or from the opening of new fields. In either case, the price of coal, already above that of anthracite, would have probably risen.

Of more importance, the marketing of this coal would have required British coal operators or shippers or American shippers to create an extensive shipping and marketing network similar to that built by the Pennsylvanians for the distribution of anthracite to the American Northeast. Such a trade would have required several hundred ships since coal was too bulky to send on normal trading ships except in ballast. A trans-Atlantic coal trade would have demanded an ocean going collier fleet of the kind that only came later in the century in the era of steam and iron ships. In the 1820's and 1830's there was no obvious incentive for British coal operators or British and American shippers to produce such a drastic innovation in ocean going transportation. The great increase in the consumption of coal in the 1830's did not come because there was a sudden new demand for it. American householders, merchants, and manufacturers, it must be stressed again, were not looking for new supplies of cheap fuel; consumption rose because the anthracite operators of eastern Pennsylvania first developed hearths and furnaces for the use of their product, built the canals to get the coal to tidewater, and then encouraged their neighbors to transport and sell anthracite coal to the potential markets of the Northeast.

[31] The annual output for Virginia, Nova Scotia, and Maryland fields is given in Eavenson, *American Coal Industry*, 443, 476, and 500 respectively.
[32] Porter, *Progress of the Nation*, 217.

Impact on the Iron Industry

The sudden availability of inexpensive anthracite coal during the 1830's had a profound effect on the output, technology, location, and organization of several major American industries. First, it provided the fuel that modernized the American iron industry east of the Alleghenies and shifted its location from the isolated hills of central Pennsylvania to the waterways in the eastern part of the state. This large new output provided manufacturers on the eastern seaboard with iron at prices lower than they had ever paid before. The new availability of iron and of coal (both for the reheating of metal and steam power) encouraged large-scale manufacturing of iron products for the first time, and so brought the factory to the iron working as well as the iron making industries. In so doing, the production units moved out of country and village sites and into the larger towns. The availability of fuel for both steam power and manufacturing processes that required heat encouraged the growth of the large urban establishments in glass and paper and other industries. Steam also revived the textile industry in southeastern New England and hastened the growth of new textile factory towns along the coast. Moreover, the great expansion of coal mining and the separation of iron mining from iron manufacturing that accompanied the development of the coal-using furnaces marked the beginning of the modern coal and iron mining establishments in the United States. The coming of large-scale mining and the rapid spread of the factory in turn hastened the rise of a new working class and a new managerial class in American industry.

The most immediate effects of anthracite on American industry were the changes that it brought in iron manufacturing. The very first market for anthracite was the manufacturers of simple iron products like wire and nails, who used the coal to reheat wrought iron bars. Also, by the 1820's most blacksmiths were already beginning to use coal rather than wood in their work. As has been pointed out, anthracite rapidly replaced both wood (charcoal) and bituminous as the normal fuel. Not only was it more economical than the faster burning bituminous, but it did not have sulfuric and other fumes to contaminate the iron being processed. By the time of the compilation of the McLane Report in 1832, 116 air and cupola furnaces were listed for the state of New York. Only eleven of these relied on wood and charcoal alone.[33] Of the remaining 105, only five consumed more bituminous than anthracite; all of the other 100

[33] *McLane Report*, II, 115–122.

that consumed primarily anthracite also used some wood and bituminous coal. By 1832, Lehigh and other anthracite coals were being used in New England ironworks, and the same pattern that had come in New York was developing there. Only in rural areas far from water transportation and close to large local supplies of wood did processors of wrought iron stick to charcoal as a fuel.

The use of anthracite to refine wrought iron from cast pig iron was technically a greater challenge than the mere reheating of wrought iron. This was because the iron had to be heated for a much greater period of time, so impurities in coal more easily contaminated the molten iron. Therefore, because of high sulfuric content of Pittsburgh's bituminous coal, 80 per cent of the iron used in rolling mills in Pittsburgh was made from wrought iron blooms, which were produced by the country forges, shipped to Pittsburgh, and there merely reheated before being rolled into bar iron, shapes, and nails.[34] The difficulty in using the new anthracite coal to make wrought iron by the puddling and rolling process came in igniting the coal and controlling the heat in the reverberatory furnace. However, the obvious reduction in costs already demonstrated in the replacement of coal for charcoal in the reheating of wrought iron provided the incentive for innovation. The making of wrought iron required a great deal more fuel, some 350 to 400 more bushels of charcoal per ton than the reheating of the wrought iron. The savings would be comparable.[35] From the late 1820's on, coal operators and iron manufacturers in Pennsylvania experimented with ways to use their coal in the puddling and rolling process.[36]

By 1834 success was being reported. By 1841, Walter R. Johnson, a Philadelphia scientist, had noted that boiling and puddling of anthracite had become an accepted form of making wrought iron.[37] Success in the East apparently hastened the development of improved furnaces in the West, for in 1844, a Pittsburgh paper noted that "the method of puddling iron is now in so general use and brought to such perfection" that its quality approaches the best wrought iron made by forges.[38] And the savings were indeed sub-

[34] Hunter, "The Influence of the Market," 247–49, 250–51.

[35] E. G. Danielsson, *Antegkningar on Novva America Fri-Staters Jerntillverking samt handel met Jern-oeh stålvaror* (Stockholm, 1845), 72.

[36] Hazard's *Register of Philadelphia*, XIV (December, 1834), 414–15. I am indebted to Diane Lindstrom for this citation.

[37] Johnson, *Notes on Anthracite*, 3–4, 11–13.

[38] Quoted in Hunter, "Influence of the Market," 253. For percentages of rolled iron made from cast pig and from wrought blooms see p. 247. *Report of a Committee to the Iron and Coal Association of the State of Pennsylvania* (Philadelphia, 1846), 8, 13, has reports from thirty-two rolling mills listed in the Census of 1840; eight are in Pittsburgh, seven in the central part of the state, and eleven in the southeast. It also lists fourteen more anthracite rolling mills completed between 1840 and 1845, all in the southeastern part of the state.

stantial. A Swedish expert on iron making reported in 1845 that wrought iron puddled and rolled in New Jersey could be made for $47 a ton (and still cheaper in Pennsylvania) while Pennsylvania-forged wrought iron cost $69 to produce. The major difference came in the price of fuel. The anthracite needed at the first place cost only $3.25 a ton, while the charcoal at the second cost $17.50.[39] By 1850, 85 per cent of the rolled wrought iron in Pittsburgh was made directly from cast iron pigs rather than wrought iron blooms. By 1849, 80 per cent of Pennsylvania's wrought iron was made in rolling mills.[40]

The use of coal instead of wood in the production of wrought iron initiated a major relocation in the American iron industry and a fundamental change in the nature of the iron making enterprise. Before the mid-1830's, iron production was concentrated on the eastern slopes of the Alleghenies, in the center of Pennsylvania (especially in isolated Centre and Huntington Counties), while the furnaces and forges of Fayette and Venengo Counties supplied Pittsburgh rolling mills and other metalworking shops with their materials.[41] In the West, Pittsburgh by 1850 had taken over the production of wrought iron, while in the East, the new rolling mills were built on the canals and improved waterways at Norristown, Allentown, Reading, Phoenixville, Pottsville, Wilkesbarre, and Montour, as well as in Philadelphia and Chester and Wilmington. These mills, almost all powered by steam, employed a much larger working force than the older, water-driven forges. By 1849 the average number of workers in the eastern Pennsylvania rolling mills was 65, and that in the western Pennsylvania ones almost twice as many.[42] With the coming of the modern rolling mill, the factory in the sense of the large, subdivided, routinized, continuously operating unit manned by a large working force first became a major unit of production in the metalworking industries.

The adoption of coal in the initial step of the process of iron making – that of converting iron ore into cast iron in the blast furnace – quickly followed its use in the making of wrought iron. As

[39] Danielsson, *Antegkningar*, 9–10, 72–73. According to Danielsson, anthracite sold from $3.25 to $5.00 a ton and charcoal on the average sold at 5¢ a bushel, ranging from 3¢ in the forests of upper New York to 7½¢ on the Hudson River near New York City.

[40] Temin, *Iron and Steel*, 100.

[41] *McLane Report*, II, 637–645; *Report of a Committee to the Iron and Coal Association*, 8,13 shows the location of the rolling mills in 1845.

[42] Temin, *Iron and Steel*, 86, and Frederick Overman, *The Manufacture of Iron in all its Branches* (Philadelphia, 1850), 460, indicate the universality of the use of steam power instead of water where coal was used in the making of iron by 1849. *Report of a Committee to the Iron and Coal Association*, 13, records the increased output of the new anthracite rolling mills.

was not true for the rolling process, this innovation was carried out entirely in eastern Pennsylvania. Bituminous coal did not become used extensively in the United States in the production of pig iron until just before the outbreak of the Civil War. As in the case of the eastern rolling mills, it was the coal mine operators, not the ironmasters, who sought out the necessary technological innovations. The managers of the Lehigh Coal and Navigation Company and other smaller companies, especially in the Schuylkill area, began to experiment with the use of anthracite in furnaces almost as soon as they did with its use in puddling and rolling mills.[43] The technical problems were more complex and the savings less. The making of a ton of pig required from 150 to 240 bushels of charcoal rather than the 350 to 400 needed to forge a ton of wrought iron.

At first, attempts were made to adopt the existing cold blast techniques used with bituminous. Then attention was turned to the "hot blast" method patented in Britain in 1828 in response to a similar challenge – the possibility of using the hard "black band ironstone" or "splint" coal of Scotland in the making of iron.[44] In 1836 an American, Frederick W. Geissenhainer tested a similar process, which he had patented earlier. That same year a Welshman, George Crane, patented a comparable invention for the use of Welsh anthracite. (On the American's death in 1838 Crane took over his patents.) By May 1837 Erskine Hazard had sent a representative from his Lehigh Valley Coal and Navigation Company to observe Crane's process at work. The two groups quickly formed the Lehigh Crane Company to exploit the technique in the United States. With a large shipment of equipment Crane sent his best foreman, David Thomas, to set up a large furnace near Allentown. By the time the Lehigh Valley furnace came into blast in July 1840, five other furnaces had begun or were about to come into operation, using variations of the Crane process.[45] Because the Lehigh group had Thomas and his tested machinery, theirs was the first commercial success. By 1845 twenty-eight such anthracite furnaces were in

[43] Johnson, *Notes on Anthracite*, 13–14, 24–26.

[44] J. Carr and W. Taplin, *History of the British Steel Industry* (Cambridge, Mass., 1962), 8. The story of the coming of the hot blast in the United States can be followed in James M. Swank, *History of the Manufacture of Iron in all Ages* (Philadelphia, 1892), 267–270; Johnson, *Notes on Anthracite*, 12–13; Temin, *Iron and Steel*, 58–62; Redlich, *Men and Iron*, 71–73; Morton, *White*, 212–15; also, *The Annual Report of the Lehigh Coal Company for 1840*. Significantly, James B. Neilson, the inventor of the hot blast, was a man whose career was in coal, not iron. He began work in a colliery and was for thirty years engineer and manager of the Glasgow Coal Gas Works, *Dictionary of National Biography* (London, 1921–1922), XIV, 179–181.

[45] These furnaces are described in detail in Johnson, *Notes on Anthracite*, as are all but two of the fifteen furnaces that had gone into operation before his book was published in the fall of 1841.

operation, and eight more building; by 1849 there were over sixty in eastern Pennsylvania; by 1853, 121.[46]

The initial innovation and later adoption of the hot blast furnace was, then, a direct response first in Scotland and then in Wales and Pennsylvania to the cost cutting possibilities of using hard coal to make pig iron; it is an excellent case of an induced innovation, and those adapting it to anthracite were coal operators rather than iron makers. If the anthracite coal fields had not been opened in the late 1820's and 1830's, there would have been no incentive to bring the hot-blast method to the United States at least until the Civil War. Even then it might not have been widely used, for the savings permitted when soft coal was the fuel were much less than with hard coal.

The rapid growth of the new pig iron producing capacity completed the relocation of the iron industry in the East, and with it increased the separation of the mining of iron from its processing. The anthracite furnaces in the Wyoming region in northeastern Pennsylvania on the Susquehanna (including those in Scranton, Wilkes-Barre, and Danville), and those in the Lehigh and Schuylkill areas soon replaced the charcoal using furnaces of the central counties as the major producers east of the Alleghenies. These eastern Pennsylvania works had both massive supplies of inexpensive coal and easy access to the markets of the Northeast.[47] Not only did $3.50 worth of anthracite produce as much pig iron as $7.50 worth of charcoal, but, as the Swedish expert reported, the cost of transporting iron from eastern Pennsylvania was about $1 a ton to New York and Philadelphia and $3 to $4 to more distant markets, while that sent from central Pennsylvania to the eastern markets was $5 to $8 a ton, even though it came all the way by water.[48] The new furnaces, whose blasts, bellows, and other machinery were powered by steam, were larger than the old charcoal ones, with a much greater output, and bigger working force, and also a much higher initial capital cost. By 1849, the Pennsylvania anthracite furnaces had an average working force of eighty persons, and an average capital of $83,000.[49] A single anthracite furnace was then often larger in

[46] *Report of a Committee to the Iron and Coal Association*, 13; U.S. Census, *Manufactures in 1860*, clxxli; Overman, *Manufacture of Iron*, 179.

[47] As indicated in Table 1, the rapid increase in the coal used at the mines and not shipped to tidewater in the Wyoming section after 1840, and in the Schuylkill region after 1842, and the Lehigh Valley areas after 1843, illustrates the growth of both iron smelting and refining in those regions.

[48] Danielsson, *Antegkningar*, 15–16, 70–71.

[49] Temin, *Iron and Steel*, 87–90.

terms of assets and working force than an old iron plantation, with its ore beds, forests, furnaces, and forges.

The new capacity of the anthracite furnaces played an important part in the great increase in the production of American iron during the 1840's. While estimates vary, the consensus puts that increase at from about 230,000 tons of pig iron in 1842, to a peak of about 760,000 tons in 1847.[50] Production then declined steadily to a low of 413,000 tons in 1851 with the dumping of British iron in the United States during the depression of the late 1840's and early 1850's and only returned to this high output again later in the 1850's. Imports of the British iron rose from 90,000 tons in 1846 to 416,000 in 1850 and then to a high of 619,000 tons in 1853, after which they declined during the rest of that decade. The importance of anthracite to the expansion of the 1840's is suggested by the first statistics available on the output of the different types of iron. In 1854, out of a total of 657,000 tons produced, 303,000 tons were made from anthracite, 306,000 from charcoal, and 49,000 from coke.

While precise information on prices paid for the different types and grades of iron is difficult to come by, it seems certain that the development of the production of iron by anthracite coal provided American manufacturers in the industrial Northeast an extensive source of high grade domestic iron at prices which were, during most of the critical decade of the 1840's, appreciably lower than both domestic charcoal-produced, and imported coal-produced iron. By 1844 anthracite was the cheapest iron ever made in America. According to the Swedish iron expert who examined many iron making establishments in that year, anthracite pig was made in Pennsylvania for $12 a ton and charcoal pig for $16 a ton. The first was purchased for $22 by rolling mills in New Jersey and the second for $25 by nearby wrought iron producers in Pennsylvania.[51] Fuel was a critical factor in the cost differential. The cost of coal to produce a ton of the first was $3.00 (one-quarter of total cost); that of charcoal to produce a ton of the second was $7.50 (or just under half the total cost). Iron making was clearly a fuel intensive industry.

British iron did not sell more cheaply until the end of the 1840's.

[50] See Stanley Engerman, "The American Tariff, British Exports and American Iron Production, 1840–1860," in Donald N. McCloskey, ed., *Essays on a Mature Economy: Britain after 1840* (London, 1971), 15. See also Temin, *Iron and Steel*, 264–66.

[51] Danielsson, *Antegkningar*, 71–73. Danielsson points to one place in western Massachusetts close to the source of iron where pig could be made for $14. At Salisbury, Connecticut, New England's largest local source, charcoal pig was made for $23 and sold for $28. The retail price of charcoal pig in Philadelphia as listed by Temin for 1844 was for No. 1 Foundry Pig, $25.75 and for No. 1 Charcoal Foundry Pig, $28.25; *Iron and Steel*, 283. Danielsson's prices may have been for 1843 rather than 1844.

During most of that decade, the demand for iron in Britain rose and imports from Britain dropped off. Because of strong demand, the price of high grade Scotch pig iron did not fall sharply even with the spread of the cost-cutting hot blast technique. During the 1830's the price of Scotch pig at Glasgow never fell below 90 shillings a ton (or below $21.50), and went as high as 135 shillings. For three years in the early 1840's it dropped to slightly below 60 shillings, rising to 67s. 3d. in 1846 and 65s. 4d. in 1847 (or about $15 a ton).[52] During the years between 1841 and 1847, American imports of British iron dropped to below 100,000 tons. After 1847 demand fell sharply in Britain, and prices dropped to as low as 40 shillings a ton (or $10), and exports to the United States rose sharply.[53] However, between 1842 and 1847, the American consumption of iron had tripled, and the greatest share of this new consumption was of iron produced by Pennsylvania anthracite coal.

Spread of the Factory

In this way, then, the opening of the anthracite fields in the early 1830's provided American manufacturers in the industrial Northeast of the 1840's with their first extensive supplies of inexpensive iron. As important, the new coal gave that same region an inexpensive fuel to use in other manufacturing processes which required heat. It further provided steam power at a cost that was equivalent to that in Britain or Pittsburgh before 1830. The industries most dramatically transformed by the availability of the new fuel were those that converted the new supplies of cast and wrought iron into finished products. The impact on glass, paper, and other fuel intensive industries was almost as significant. The factory quickly appeared in all those industries. Even in the industries that did not use heat in manufacturing (such as textiles), the availability of coal for steam brought an increase in output, and a growth of factories in new locations. These changes all took place in the late 1830's and during the decade of the 1840's.

A report to Treasury Secretary Levi Woodbury on steam engines in the United States was published in 1838, and it indicated the sizeable increase in the use of steam power in the Northeast in the six years following the compilation of the McLane Report. Of the

[52] B. R. Mitchell and Phyllis Deane, *Abstract of British Historical Statistics* (Cambridge, 1962), 493, and Porter, *Progress of the Nation*, 246.

[53] While the Tariff of 1844 did substantially increase the price of imports until 1848, Engerman stresses that "the market-induced changes in British prices . . . had a greater impact on the transatlantic iron market than did legislative changes in the American tariff." Engerman, "The American Tariff," 22.

1,616 stationary steam engines listed in the Woodbury Report of 1838, some 930 were located in the ten northeastern states covered by the McLane Report.[54] The remaining 686 in the other nineteen states were used almost wholly for processing major crops, including sugar, rice, flour, and cotton, as well as the sawing of lumber. Of these states, Louisiana alone had 274 engines to power its sugar mills. These engines burned wood, still readily available in agricultural areas. In the Northeast, anthracite coal became the usual fuel for steam engines, the greatest growth coming in Pennsylvania (which had 383 stationary steam engines in 1838) and Massachusetts (which had 165). In Boston alone there were 114 steam engines in 1838. Only sixteen of these were more than five years old. By contrast, of the 130 engines in Pittsburgh, forty-seven of them were more than five years old, and seven of these more than ten.[55] Middletown, Connecticut, on the Connecticut River, had ten engines, all of which were less than five years old, and Providence had seventeen, the oldest of which was built in 1831.[56] By the end of the 1830's, anthracite coal was making possible the swift adoption of the basic modern source of power at the same time it was assuring the adoption of modern processes of iron making.

In the following decade, the producers of finished iron goods used the new source of power for their machines, ample fuel for their manufacturing processes, and the new supplies of iron to transform quickly their products and processes. Prior to the 1830's, most metalworking establishments produced a broad line of products, and those few that had specialized were still very small shops. In the villages and small towns, the blacksmith remained the traditional jack-of-all trades. The McLane Report indicates that only in southern New England — Massachusetts, Connecticut, and the coastal areas of New Hampshire — had metal workers begun to specialize in the production for distant markets of implements and edged tools, including hoes, axes, rakes, hammers, saws, chisels, shovels, scythes, gun barrels, and cast iron plows. Those shops employed only a handful of men, were usually located in small villages, relied on water power, and sold their goods to the south and east via Boston, and then through the national distributing network which had been

[54] Pursell, *Early Stationary Steam Engines*, 73; *Woodbury Report*, 379. Virginia, long a coal-using state, followed Massachusetts in number, with 124 engines.

[55] For Boston, see the *Woodbury Report*, 41–44; for Pittsburgh, 191–95; for Middletown, 82; for Providence, 88. The *McLane Report* listed nine stationary steam engines in and about Boston; *Niles Weekly*, XLV (November 30, 1833), 217 (cited in Pursell, *Early Stationary Steam Engines*, 83) lists eighty-three in Pittsburgh for the same year. Pursell has an excellent account of the increasing use of steam power in the Northeast in this period, pp. 83–89.

[56] The engine installed by Samuel Slater (see footnote 64) in 1828 had been replaced.

created after 1815. In the towns and cities a single large ironworks made all sorts of goods – engines, machinery, ordnance, water wheels, presses, nails, and all sorts of iron shapes and forms. Where specialization in urban metalworking had occurred first, in the making of nails and screws and then later in the production of stoves, tools, and hardware for building ships and houses, the shops remained small.

Before 1830 the best-known volume producers of metal goods were the makers of guns for the federal government. In New England, there were, before 1830, only two large private contractors – Eli Whitney and his son, who employed from fifty to eighty men in their New Haven works; and Simeon North, at Middletown, who had a working force of about sixty men. The government's Springfield Armory was one of the very largest metalworking factories in the nation, with a force averaging 250 workers.[57] Outside New England, only the Harper's Ferry Arsenal, and possibly John and James Henry of Lancaster County, Pennsylvania, operated large arms-making factories. Of other establishments employing over fifty workers which made finished metal products by large-scale subdivided, specialized production, the McLane Report lists two axe factories – the Collins Axe Works, at Collinsville, Connecticut, with an impressive force of 300 workers, and the Warner Hunt and Company axe makers of Douglas, Massachusetts, with fifty-seven workers.[58] Collins began its expansion from a small shop in 1829–1830 when it began to use Lehigh coal as fuel to reheat iron. This also appears to be true of the Douglas enterprise, which by 1832 was relying on Lackawanna coal. Again, Pittsburgh was the exception, having in the early 1830's several large specialized establishments making plows, stoves, and hardware, as well as steam engines.

During the 1830's volume production in the metalworking in-

[57] The *McLane Report*, I, 1030–31, consolidated the three Middletown, Connecticut, armories (Nathan Starr, R. & J. Johnson, and Simeon North) into one listing, with ninety workers and total capital assets of $105,000. In 1822, North had a capitalization of $75,000, and sixty workers, while the Johnsons and Starr employed thirty and fifteen workers apiece. Each listed assets of $30,000. Only two other New England contractors and three from other areas are identified by Felicia J. Deyrup in her "Armsmakers of the Connecticut Valley," *Smith College Studies in History* (Northampton, Mass., 1948), 43–46, 48, 220–21.

[58] *McLane Report*, I, 994–95, 510–11, 1038. Some of Collins' workers may have been at this time working at home under a putting out system. "The Collins Company, 1826–1867: Reminiscences of Samuel Watkinson Collins," a typescript in the Manuscripts Division, Baker Library, Harvard University, has good information on that firm. According to the *McLane Report*, Warner Hunt and Company in 1832 purchased 900 tons of Lackawanna coal at $8,100 and obtained only $600 worth of charcoal. Its iron still came wholly from Europe (at a cost of $29,890), as did the Collins Company's iron. After 1846 Collins began using "Pennsylvania iron;" see "Collins Company," 2, 25. For Pittsburgh, see the *McLane Report*, II, 638–39, and Nathan Rosenberg, ed., *The American System of Manufactures: The Report of the Committee on the Machinery of the United States, 1855, and the Special Report of George Wallis and Joseph Whitworth, 1854* (Edinburgh, 1969), 112–144.

dustry expanded slowly. For example, Oliver Ames and Sons, which had made shovels since the Revolution, began after 1835 operating three establishments in southern Massachusetts, producing a total of forty dozen shovels a day. At these units, the work became so subdivided that twenty different men worked on a single shovel. By 1844, Ames' business was worth about $200,000.[59] In the 1830's Philo Remington began to specialize in the making of gun barrels in his shop near Utica, New York, and in 1839 he began to use steam driven machinery. N. P. Ames, of Springfield, Massachusetts, opened his shop in 1830 to make textile machinery and expanded during the decade into the production of cannon, swords, and a variety of machinery. But these enterprises were still pioneers and exceptions to the general rule.

Then, in the 1840's, with the great expansion of domestic iron output and the drop in the prices of both coal and iron, the factory in the iron-shaping industry came with a rush.[60] Most obvious was the growth of the makers of standardized products. A well-documented example is that of Peter Cooper, owner of a furnace and rolling mill in New York City who decided to join with Abram Hewitt to build in Trenton in 1845, first a large wire mill and then mills for rails and other railroad iron. In the next two years several similar large rail-making enterprises began operations, all but two of which relied wholly on anthracite coal and iron. At the same time, factories appeared for the making of railway wheels, locomotives, steam engines, and marine engines; in the making of stoves, household furnaces, and safes produced largely from cast iron; and in the

[59] For the Ames Shovel Company, see U.S. Census, *Manufactures in 1860*, ccxiii; and Allan Johnson, ed., *Dictionary of American Biography* (New York, 1946), I, 253–54. See also U.S. Census, *Manufactures in 1860*, clxxiv. For Philo Remington, see Alden Hatch, *Remington Arms in American History* (New York, 1956), 28–42. For Nathan P. Ames and his brother James T. Ames, see Johnson, ed., *Dictionary of American Biography*, I, 243, 250.

[60] For example, in 1845 the cost of making wrought charcoal iron at Salisbury, Connecticut was $82 a ton compared to a cost of $47 a ton of anthracite rolled wrought iron in New Jersey. The cost of the fuel for the first (with charcoal at 5¢ a bushel) was $20 a ton, and of the second (with coal at $3.25 a ton) was $3.25 per ton. (Labor costs were higher at Salisbury [$20.50 per ton as compared to $15.00], probably because of the longer time involved in making charcoal wrought iron.) Because Salisbury was some distance from tidewater and the New Jersey mill was on tidewater, the transportation costs from New Jersey to many New England ports was approximately the same; Danielsson, *Antegkningar*, 16, 71–73. The rapid growth of large-scale factory production in wire and rail manufacturing is best indicated in Allan Nevins, *Abram S. Hewitt, with Some Account of Peter Cooper* (New York, 1935), 71–72, 83–93; Temin, *Iron and Steel*, 117–18. For its growth in other ironworking industries, see Rosenberg, ed., *The American System of Manufactures*, especially 100–118, 129–144, 262–270, 278–79, 334–37 and 341; U.S. Census, *Manufactures in 1860*, ccix–ccxiii, clxxxvi–cxcvi; James Wickham Roe, *English and American Tool Builders* (New Haven, Conn., 1916), 281–291; Hatch, *Remington Arms*, 48–50, 54–69; Harold F. Williamson, *Winchester: The Gun That Won the West* (New York, 1952), 6–11; William T. Hutchinson, *Cyrus Hall McCormick* (New York, 1935), I, Ch. 13; and Charles E. Goodrich, "Story of the Washburn and Moen Manufacturing Company, 1831–1899," a typescript (written in 1935) available in the Washburn & Moen Papers, Manuscript Division, Baker Library, Harvard University.

production of large agricultural equipment requiring iron, including harvesters, reapers, and plows. Older manufacturers who had been relying on high grade, imported iron began to turn to the American product. For example, Ichobod Washburn, a specialized wire maker in Worcester, in 1846 expanded his small shop, built a rolling mill, and began for the first time to use American iron. Even the makers of axes, scythes, saws, and hoes supplemented their quality imported iron with the American product as they moved into factory production. Locks, scales, and other goods besides guns began to be produced through the fabrication and assembly of interchangeable metal parts in factories rather than small shops. Small arms began to be made for the first time in volume for the non-military market. New men and firms – Colt, Remington, Sharps, Lawrence & Robbins, and the forerunners of Winchester arms – replaced the old government contractors as leaders in the industry. All built their new and large factories in the late 1840's and the early 1850's.

The rapid rise of large metalworking enterprises led in turn to the beginnings of the specialized machine tool industry. Prior to the mid 1830's there were few specialized machine shops, and those that existed were enterprises (like the Lowell Locks and Canals and N. P. Ames) still associated with textile companies. In the 1840's, enterprises making tools for a large number of industries became concentrated in Hartford, Springfield, Providence, and Philadelphia. Because of these new demands, the late 1840's and 1850's constituted one of the most significant periods of innovation in the development of American machine tools.

Besides bringing the factory to the ironworking industries, the new availability of coal as fuel and metal for machinery encouraged the adoption of the new form of production in the paper and glass industries. The making of glass had similarities to the production of iron.[61] High heat was needed to melt the sand, soda, and lime in furnaces, and steam power was used to move the machinery which after the 1830's replaced hand blowing and cutting to draw, mold, press, and shape the molten glass. The first large glass works, those in Cambridge and Sandwich, Massachusetts, and in Pittsburgh, were already using coal fuel and steam power by 1832. By 1855, the glass industry had become concentrated in Boston, Pittsburgh, and Jersey City, relying in those centers wholly on coal as a fuel for both heat and power.

[61] Rosenberg, *American System of Manufactures*, 287–290; and Warren C. Scoville, "The Growth of the American Glass Industry to 1880," *Journal of Political Economy*, LII (September, 1944), 197–99; Victor S. Clark, *History of Manufactures in the United States* (New York, 1929), I, 417; Pursell, *Early Stationary Steam Engines*, 83.

In the paper industry, heat was also used in the process of production, and this may help explain why manufacturers using the new machine processes preferred steam to water power. In 1830, nearly all the paper made in the United States was produced by hand, although some small machines were used in one or two parts of the process.[62] The first automated Fourdiner machine was brought to Springfield, Massachusetts, from Great Britain in 1825. By 1829, six machines were in operation in Massachusetts and three in one Delaware firm. During the 1830's, these machines came to be manufactured at Windham, Connecticut, and Worcester, Massachusetts. By 1860, hand papermaking had all but disappeared. The Census reported that by that date "automatic machinery was used in all but two paper mills." The Fourdiner process was in fact a complex series of machines (rather than a single machine) that carried out both the converting of raw material into pulp and prepared pulp into paper. From the very start, these machines were powered by steam. The very first one at Springfield (a water power center) was powered by twelve steam engines and employed well over 100 workers. Steam was used to heat the cylinders that pressed the pulp into paper, and also in the drying process. Because of the economies of scale permitted by machine production in both glass and paper (for example, the Fourdiner machine was estimated to do the work of thirty hands), large establishments became commonplace. The figures in the Census for 1840 indicate that paper and glass had, with textiles and iron, the largest average size of establishments in the United States. Cotton textiles averaged sixty workers per establishment, glass twenty-eight, iron nineteen, and paper eleven.[63] By 1850 these figures had risen to ninety-two workers per establishment for cotton, sixty for iron rolling mills, fifty-one for iron furnaces, and sixty-two for glass. In paper the average remained fifteen, for although large factories had appeared, particularly in urban centers, a small shop using local supplies and one set of machines could meet local demands. The pattern in paper was, then, similar to that in wool.

In addition to encouraging the rise of the large, steam powered

[62] U.S. Census, *Manufactures in 1860*, cxxvi–cxxvii; *McLane Report*, II, 817.

[63] The average capitalization for these industries was: cotton textiles, $48,000; glass, $35,000; paper, $16,000; iron, $12,800; U.S. Census, *Compendium of the Sixth Census* (Washington, 1841), 358–363. The figures for 1850 are from *A Digest of the Statistics of Manufactures According to the Returns of the Seventh Census*, in U.S. Senate, Exec. Doc. No. 39, 35th Cong., 2nd Sess., 138–140. The only other industry with available figures from the Census of 1840 which had an average of ten or more workers per establishment was the still unmechanized rope and twine industry, which had an average of eleven workers per unit. While twine is given in the 1850 compilation, there are no figures on cordage.

factory in glass and paper, the availability of anthracite hastened its coming in other industries requiring heat in the processes of manufacturing. This was particularly evident in baking, sugar refining, the brewing of malt liquors and the distilling of spirits, but also in the processing of earthenware, plated ware, chemicals, and India rubber products. These large new establishments became concentrated in the major eastern cities where fuel, markets, and labor were most readily available. An excellent example is sugar refining. The first large factory in 1832 in New York and another in Boston in 1834 both used anthracite for fuel in distillation and for steam power. Then in the late 1840's and 1850's, the factory quickly came to dominate sugar production.[64]

For textiles, the coming of anthracite in the early 1830's had a direct, though less fundamental impact on the industry. Heat, of course, was not needed in the process of cloth making but was used in printing and dyeing. By 1835 two Lowell mills with printing and dyeing auxiliaries were using 7,000 tons of anthracite annually. On the other hand, the availability of metal did encourage the building of improved metal machines. It was, however, in making possible the generation of steam power on a large scale in New England that anthracite had its major effect on the textile industry.

The Woodbury Report documents the first use of steam in the New England textile factories. While an occasional steam engine was used in textile mills as early as the war of 1812, the use of steam as a major source of power began only in 1828, when Samuel Slater decided to compete with the large water power mills of Lowell and other New England river towns, by building the first large steam driven factory in Providence. From the start, Slater relied on Pennsylvania anthracite coal for fuel. Other Rhode Island manufacturers soon began to follow Slater's lead. Where there had only been three steam textile mills in operation in Rhode Island in 1832, there were twenty-nine by 1838.[65] By then, steam powered textile factories had appeared at Stonington, Taunton, and Newton, as well as Fall River and Newburyport. Factories on the fall lines of smaller rivers, such as those at Exeter and Dover in New Hampshire, and even the very first one, the Boston Manufacturing Company at

[64] For sugar, see Alfred S. Eichner, *The Emergence of Oligopoly* (Baltimore, 1969), 31–34; Pursell, *Early Stationary Steam Engines*, 85; *McLane Report*, I, 951; for the use of anthracite at Lowell see Christopher Roberts, *The Middlesex Canal, 1793–1860* (Cambridge, Mass., 1938), Appendix H.

[65] *Woodbury Report*, 85, 88–89 for Rhode Island; 35, 48, 52, 57, 70 for other coastal towns; 160–63, 165, 210–11, for Philadelphia and Baltimore. See also George R. Taylor, ed., *The Early Development of the American Cotton Textile Industry*; and citations for footnote 5.

Waltham on the Charles, had, by 1838 introduced steam power. And by that time a number of steam driven mills had been built in Philadelphia and Baltimore.

The effect of steam on the textile industry was twofold. First, it permitted the older Rhode Island mills to expand their productive facilities substantially and to compete effectively with the large integrated mills on the major rivers. The southern New England spinning mills had been slow in adding power looms in large part because of their limited water power. In any case the Blackstone and other small streams did not have sufficient flow to power the output of a Lowell or a Manchester. Second, the availability of fuel for steam permitted the building of new large mills in many New England coastal cities. As Peter Temin has documented, the initial cost of building a steam powered mill was much less than that involved in installing complex hydraulic systems on the largest rivers.[66] These new factories, placed in cities where coal was delivered by water, were closer to supplies of raw materials and markets and of some significance to an increasingly important new labor supply, the immigrant.

The new availability of coal and iron had less of an impact on other major industries. In the nonferrous metal industries – copper, brass, and pewter – metal did not require extended high heating in the rolling process. Relatively little heat was needed even in annealing cold metal that had become brittle. Until well after the Civil War, therefore, much of the copper and brass manufacturing industry (concentrated in Connecticut and particularly in the Naugatuck Valley) continued to rely more on water power and wood than on steam and coal in the making of buttons, pins, hooks, plates, and other small products made by stamps and presses. Even so, in the production of brass clocks and locks by the fabrication and assembling of interchangeable parts, steam powered factories appeared in the 1840's in Bridgeport and New Haven.[67] On the other hand, the smelting of copper did require heat, and from the start the furnaces in Baltimore and other seaport towns used coal for both heating and power in the making of copper ingots.

In the leather, wood, and clothing industries, the impact of coal and iron had even less significance than it had for the nonferrous metals. In these industries the factory rarely came before the 1850's.

[66] Temin, "Water and Steam Power," 196–98.

[67] William B. Lathrop, *The Brass Industry in the United States* (Mt. Carmel, Conn., 1926), Ch. IV; Rosenberg, *American System of Manufacturers*, 277–79, 338–348; Chauncey Jerome, *History of the American Clock Business for the Past Sixty Years* (New Haven, Conn., 1860); *McLane Report*, I, 734, 828, lists only small shops making brass clocks in 1832.

By then the laying down of the railroad network, the resulting changes in transportation, and the surge of population in the West were probably more significant than the availability of steam power and metal machinery for the growth of the factory in these industries. Metal machinery, such as that devised by Thomas Blanchard and others in the 1830's and 1840's was, however, important in expanding production in woodworking, as were variations of the sewing machine developed in the 1850's in the leather, shoe, and clothing trades.[68] As early as the Woodbury Report, steam was being used in furniture and carriage making works in New Haven and Bridgeport, and in making floors in Philadelphia.[69] In lumbering and flour milling, steam appears to have had little major importance until after the Civil War.

Yet as the industries most central to the industrializing process – iron, iron working, textiles, glass, paper and those involving refining and distilling processes – used fuel intensively in manufacturing processes, the coming of anthracite did bring the factory and concentrated the new form of production in the large towns and cities of the most industrial section of the nation. In addition, the opening of the anthracite fields first brought to American mining the pattern of modern enterprise (a counterpart to the factory) with its large number of wage earners and its new class of managers. Before these fields came into production, the only extensive specialized mining carried on in the United States was in the scattered lead mines along the Mississippi in Illinois, Iowa, and Wisconsin, and in the Virginia and Pittsburgh bituminous coal fields. While there were a handful of mines in each of these regions manned by a working force of more than twenty men, the largest share of the mining was carried on by small operators employing a handful of men and a few hundred dollars in capital and using primitive methods. Many operators and their workers still continued to work their farms. This was also true in the southern anthracite region. As Chester Lloyd Jones, the historian of the anthracite canals, has pointed out: "The working of coal as then carried on did not differ in amount of capital from farming; indeed, many of the operators were or had been farmers."[70] On the other hand, the middle and northern anthracite fields were exploited by the country's first large mining enterprises, the biggest and best known being the Lehigh Valley Coal and Navigation Company and the Delaware and Hud-

[68] U.S. Census, *Manufactures in 1860*, lxiii–lxv, lxxi; Rosenberg, *American System of Manufactures*, 343–47, 385; U.S. Census, *Manufactures in 1860*, clx–clxxviii.
[69] *Woodbury Report*, 41–44, 65–66, 159, 161. See also footnote 73.
[70] Jones, *Anthracite Canals*, 131.

son Canal Company. By 1823, the former had been capitalized at $500,000; by 1827, at $1,000,000; and by 1837, $1,600,000.[71] The latter began with a capital of $1,000,000 in 1825. While much of these sums were used to build the canals necessary to get the coal to market, both companies owned large tracts of coal lands, railroads (among the very first in the country), and large numbers of boats and barges to ship coal to tidewater.[72] They began to use advanced techniques for deep, below water level mining, using steam engines to pump out water. They hired a large number of workers, recruited experienced miners from Britain, and had many managers. Because of their extensive investment, they even laid long term plans for the development of their resources.

The adoption of anthracite as fuel in the making of iron also transformed iron mining. The old iron plantation quickly disappeared. For a time furnace owners were able to locate where coal and iron was to be found in the same spot. As these locations became scarce, the furnaces stayed with the coal, and the iron had to be shipped in. New iron fields were opened in Pennsylvania, and in the 1850's, large iron ore deposits began to be mined in the Upper Peninsula of Michigan, the ore being shipped by rail and water to Pennsylvania.[73] (The increased need for copper and brass led in the 1840's to the opening of the first large copper mines in the United States in the same area of Michigan.) In these ways, then, the revolution in the making of iron, set off by the opening of the anthracite fields, marked the coming of large operating units in American mining as well as in American manufacturing.

Wider Impact of Coal, Steam, and Iron

The sudden availability of coal, and with it domestic iron and steam power, had an impact on the larger economy. It must have been at least partly responsible for the rapid growth of the manufacturing sector in the 1840's. Robert Gallman has noted that during the decade 1839–1849, the manufacturing sector's contribution to

[71] Yearley, *Enterprise and Anthracite*, 23–26, 57–64, 74–75, 108–115, 165–66. The extensiveness of the wide range of activities carried on by these two companies is emphasized by their annual reports, available in the Corporation Records Division, Baker Library, Harvard University.

[72] After the great flood in 1840, the capitalization of the Lehigh Company was increased to $6,000,000; Jones, *Anthracite Canals*, 23. See also 13–17, 81–85.

[73] Temin, *Iron and Steel*, 91–93. However, the U.S. Census, *Manufactures in 1860*, clxxxvii, suggests that mining outside of Pennsylvania was still small in 1860. The other two major extractive industries were salt and stone quarrying. The former required more equipment and larger enterprises. Stone quarrying could be carried on in small units. Salt, because it involved pumping of water, required a larger investment, and the pumps were usually powered by steam. U.S. Census, *Manufactures in 1860*, cxcvii–ccl.

national output grew from 17 per cent to 30 per cent, while agriculture's share dropped from 72 per cent to 60 per cent.[74] This was the most rapid rate of expansion of the manufacturing sector in any decade of the nineteenth century. In that same decade of the 1840's, Gallman found that the decennial rate of growth in value added was 152 per cent in manufacturing and 138 per cent in mining, again the largest rates of change for the nineteenth century for those sectors, and for manufacturing, the largest increase of any sector in any decade.[75] In value per worker added, the rate of increase was, for the same decade, 36 per cent. The only decade that was higher in the century was that ending in 1880, when the rate was 46 per cent.[76] Gallman's data, then, indicate that the decade of the 1840's marks the beginning of the rapid industrialization of the country. Since the nation's industry was concentrated in the northeastern states east of the Alleghenies, it does not seem too farfetched to suggest that by providing this region with a new energy source – the same source that made possible industrial growth in Britain and continental Europe – the opening of the anthracite fields helped to initiate the unprecedented growth of the manufacturing sector in the 1840's.

The growth of manufacturing may in turn have had an impact on the growth of the economy in terms of per capita income and gross national product. Douglass North, George Rogers Taylor, Raymond Goldsmith, William Parker, and Franklee Whartenby all believe that there was little change in per capita income in the United States until the 1830's, and that it then began to rise substantially.[77] Gallman has pointed out that the two periods with the greatest rise in gross national product in American history were the decades 1834–1843 and 1944–1955, when "GNP increased at an exceptionally high rate of 42% per decade – a rate perhaps never equalled elsewhere for any such extended period."[78] On the other hand, Paul

[74] Robert E. Gallman, "Commodity Output, 1839–1899," in Conference on Research on . . . Income and Wealth, *Trends in the American Economy in the Nineteenth Century* (Princeton, N.J., 1960), 26. Gallman begins his study in 1839. Since most economists believe there was some growth in the manufacturing sector before 1830, it is hard to believe that sectoral shares could have grown at a greater rate than 13 per cent in any earlier decade.

[75] Gallman, "Commodity Output," 28. Except for one variant of construction, which read 143 in the decade ending in 1854, the rate of change for mining in the decade of the 1840's was also larger than any other sector in any other decade.

[76] Gallman, "Commodity Output," 31.

[77] These views and the sources in which they are stated are listed in Paul David, "The Growth of Real Product in the United States before 1840: New Evidence, Controlled Conjectures," *Journal of Economic History*, XXVII (June, 1967), 151–57.

[78] Robert Gallman, "Gross National Product in the United States, 1834–1909," in Conference on Research on Income and Wealth, *Output, Employment and Productivity in the United States After 1800* (New York, 1966), 23. The reader hardly needs to be reminded that Walt W. Rostow identified the 1840's as the decade of the "take-off" of the American economy.

David, in presenting his estimates of gross national and gross domestic product before 1840, argues that "it appears more reasonable to maintain that no significant acceleration in the secular trend in real GNP per capita occurred within the period of our national history that preceded the Civil War." [79] He suggests that "structural transformation associated with rapid industrialization" takes a relatively long time to be felt throughout the entire economy. While a historian would certainly agree with this last statement, the data so far provided by economists appear to indicate an acceleration of GNP after the mid-1830's.

Less debatable is the proposition that the two decades between 1835 and 1855 witnessed the beginnings of volume production by individual enterprises in many American manufacturing and mining industries, and that the opening of the anthracite coal fields was directly related to this critically important institutional change.

The sharpness of this institutional transition can be best illustrated by comparing the profile of American manufacturing presented by the McLane Report in 1832 with that described by official British experts who visited the country in 1854 and 1855. It will be recalled that in 1832 manufacturers, except for those in cotton textiles, were still operators of small shops or mills, or they were men who put out goods to households for manufacture. Their activities were clustered in small towns and villages, and in the case of iron production, in the countryside, far from any town. The machines they used, while often ingenious in their operation, were small, flimsy, and made largely of wood. They were powered by water from small streams. Ice, drought, and floods often stopped the productions of goods, in much the same way as these natural forces hampered transportation. Workers in the mills and shops continued to farm on the side, as did the household and putting out workers. All these laborers received as much of their pay in produce and kind as they did in cash. Their way of life and their attitudes and values were still close to those of their neighbors, who continued to be full-time farmers. Even in the textile industry, the only one in which the modern factory appeared, machinery was made of wood and the working force consisted largely of farm girls.

American industry in the early 1850's presented a very different picture. Already, the excellence of its mass-produced products had won applause at Great Britain's Crystal Palace Exposition of 1851.

[79] David, "Growth of Real Product," 156; the next quotation is from p. 195. Gallman's answer to David seems convincing. See Robert Gallman, "The Statistical Approach: Fundamental Concepts as Applied to History," in George R. Taylor and Lucius F. Ellsworth, eds., *Approaches to American Economic History* (Charlottesville, Va., 1971), 65–86.

So impressed was the Parliament of the world's leading industrial nation that it sent in 1854 an official commission to study and report on American manufacturing.[80] The commission's report, supplemented by those of two of its members and that of another investigation a year later, gives a detailed picture of American industry in the early 1850's. Those reports describe an advanced industrial economy. They speak of factories of 500 to 700 workers in many different industries. They describe in detail the mass production of metal goods through the fabrication and assembling of interchangeable parts – a technique which, by the time of the Crystal Palace Exposition, had been dubbed "the American system of manufacturing." While they visited older textile centers like Lowell, Lawrence, Manchester, and Chicopee Falls, where water power was still a prime mover, they also describe factories in the coastal cities and interior towns such as Boston, Worcester, Providence, Taunton, Fall River, New Haven, Middletown, Buffalo, Utica, New York City, Jersey City, Baltimore, Philadelphia, and of course, Pittsburgh. And in these cities, water power was limited and often non-existent. The armories and machine shops they saw in Springfield and Hartford had, by this time, turned from water to steam. By the early 1850's, then, American manufacturing had begun to move out of the shop and mill and into the factory. Its setting had become urban rather than rural. Large, steam driven factories were unaffected by summer drought and spring freshets. The workers in these new factories were no longer farm girls, but men, heads of families, who had moved permanently to the city from the countryside of the United States and increasingly from the farms of Ireland, England, and Germany. These men no longer had any connection with the land. For them, the factory wages had become the sole source of income, and they were paid almost wholly in cash. These workers were no longer part of a small personal organization using simple machinery or relying on traditional tools handled in traditional ways. The metal machines they tended were large, complex, and costly, needing specialists for their repair and maintenance. Tasks in the factories were far more routinized and subdivided than in the shops and small mills; the relations with the owners had become distant and totally

[80] Besides Rosenberg's introduction to *American System of Manufactures*, see D. L. Burns, "The Genesis of American Engineering Competition, 1850–1870," *Economic History Review*, II (1930–1933), 292–311. The returns of the Census of 1850 emphasized that manufacturing was no longer the handmaiden to agriculture that it had been before 1830. The processing of agricultural products was no longer manufacturers' major task. The list of the twelve largest industries by capital assets in 1850 suggests the growing industrial nature of manufacturing. These industries, ranked by size, were: cotton textiles, flour and grain, iron (including nails), lumber, tanning, wool textiles, machinery, clothing, coal mining, cabinet ware, and paper. "Statistics of Manufacturers according to the Seventh Census," 137–142.

impersonal. The workers in these factories were, by the 1850's, as they had not been in the 1830's, members of a proletariat in the Marxist sense. This had also become true of the workers in the new large coal and iron mines, and on the new railroads where steam and iron had been applied to transportation.

The subdivision of labor within the new manufacturing and mining and transportation enterprises not only created a new class of permanent machine tenders and users, but also required for the first time in the United States a new class of managers. Only in the Army and Navy, and on southern plantations, were men hired to spend their full time in directing the work of others. In the shops, mills, small mines and transportation companies that characterized the economy in 1830, the owners were managers. They worked closely with their small laboring force. They recruited, trained and supervised workers themselves, and allocated duties personally on a day-to-day basis. And they kept only the simplest of accounts. The coming of the factory and large mines and railroads, by bringing a subdivision of labor, ended this highly personal management. Size and subdivision raised brand new problems of coordinating and planning the work of many men; of recruiting, training, and paying a large working force; of accounting for capital funds as well as working capital for materials and wage rolls. Not surprisingly, then, the 1840's and 1850's saw the very beginnings of systematic internal organization and cost accounting in American industry. These years mark the genesis of modern management in America.

It must be stressed, however, that the decades of the 1840's and 1850's witnessed only the beginning of modern industry and transportation, only the beginnings of a modern labor force, and only the beginnings of modern management in the United States. The small shop and mill, craft work, and water power remained a basic part of the industrial scene for the rest of the nineteenth century.[81] Yet, the factory did come to dominate manufacturing, almost as quickly as

[81] As late as 1869, only 29.7 per cent of total power (steam and water) used in New England was generated by steam. This was because water remained in that area an inexpensive form of power, particularly for small mills and shops usually producing for local markets, especially for lumber, wood, flour, paper, and fulling mills. Water power remained, of course, significant in textiles where heavy investment had been made before the coming of cheap coal. By 1869 the industries in the United States as a whole in which more than 50 per cent of the power was still generated by water were: food, textiles, and pulp, paper and allied products. Those where more than 70 per cent of the power was generated by steam were: metal; fabricated metal products (69.6 per cent); machinery; transportation equipment; stone, glass and clay; rubber products; products of coal and petroleum; tobacco; apparel; and printing and publishing. In all but the last two, heat was used in the process of manufacturing. These data are from Allen H. Fenichel, "Growth and Diffusion of Power in Manufacturing, 1838–1919," in National Bureau of Economic Research, *Output, Employment and Productivity in the United States After 1800* (New York, 1966), tables B–12 and B–13.

the railroad took over domestic transportation. By the 1880's, the Census reported that four-fifths of the 3,000,000 American workers in mechanical industries worked in factories.[82] And these factories became increasingly concentrated in the great cities. In the twentieth century, this type of urban industrial life came to dominate American society. Its beginnings, therefore, are of legitimate concern to the historian. If the rapid spread of the factory (and to a lesser extent the large mining enterprise) in many industries marks the beginnings of American industrial society, then its first growth seems to have been precipitated by the opening of the Pennsylvania coal fields in the late 1820's and early 1830's.

It should be further emphasized that while anthracite helped to determine the timing and the process of accelerated growth and institutional change in American manufacturing and mining, its impact was short-run, not long-run. The modern iron, iron working, glass, paper, sugar and other fuel intensive industries, as well as modern coal and iron mining industries surely would have come to the United States if the anthracite fields of Pennsylvania had not existed or if they had not been opened in the late 1820's. Cheap iron would have come from Britain after 1848, although it would have had relatively little impact if inexpensive fuel had not been available for its further processing. However, once the railroads had crossed the Alleghenies in the mid-1850's, there would have been coal and iron enough to provide the fuel and metal necessary to build an industrial America. Thus the opening of the anthracite fields probably had little impact on long-term American economic growth. It is most unlikely that gross national product in 1900 or even in 1880 would have been very different if the Northeast had waited a quarter of a century or more before it had available a massive supply of inexpensive coal. Nor indeed would the basic institutional arrangements in the economy have been much different if the factory had not come to any industry except textiles before the outbreak of the Civil War.

But if the opening of the anthracite fields had little effect on the long-term growth of the United States or the long-run shape of American institutions, it had a major impact on American economic history. Without anthracite coal, the economic developments of the 1830's and 1840's would have been very different. The history of the iron making, iron working, textile, mining, and other industries would not have been the same. Nor would the economic history of many American states and cities have been the same. Industrial

[82] U.S. Census, Tenth Census, II, *Manufactures* (Washington, 1883), 548.

location and industrial output would have been different, and interregional and international trade would have followed different lines. Precisely what these differences might have been suggest a fascinating but hardly fruitful intellectual exercise.

Far more useful would be a detailed analysis along the lines of the somewhat impressionistic one sketched here, based as it is on only readily available printed material. A study on the effects of anthracite coal comparable to Albert Fishlow's examination of the impact of the railroads on the ante-bellum economy would provide much new information and many new insights into the beginnings of industrial America. However, until such a study is made, I propose the hypothesis that the opening of the anthracite coal fields in Pennsylvania greatly influenced the timing and the process of the coming of the large, subdivided business enterprise in American manufacturing and mining. The hypothesis is based on the assumption that the rapid westward expansion of population, the growth of commercial centers to service the agrarian economy, as well as the building of an effective marketing and transportation network in the years after 1815 provided a demand that could be met by large-scale enterprise in this country. In fact, after 1815, British factories were already meeting this demand. The constraint to the growth of the factory in America was basically the relative costliness of fuel which in turn increased the cost of metals, of power, and of the over-all process of manufacturing. The constraint began to be lifted when entrepreneurs perceived a market for anthracite, developed the technology for its use, built the canals for its transportation to tidewater, and encouraged others to fashion a transportation and marketing network to distribute the coal in the Northeast. The availability of coal permitted the rapid adoption of steam power in eastern towns and cities. In addition, the coal operators, by adopting the hot blast techniques devised in Britain to meet the same technical problems of using hard coal in the making of iron, were responsible for providing Americans with their first volume supply of inexpensive iron. On the basis of the fuel, iron, and power thus generated by the opening of the anthracite fields, manufacturers could lower costs and undersell British imports and, of more importance, undersell the small local manufacturers scattered throughout the nation's largely rural areas. The provision of cheap anthracite coal and iron thus permitted American manufacturers to meet the growing demand, which was being intensified by expanding population and improved transportation. They met the demand through the rapid adoption of the factory. With the coming of the factory in the

1840's, the new working and managerial classes appeared for the first time. Because inexpensive sources of coal and iron would have become available in the late 1850's, these developments had little effect on American economic growth; however, they greatly influenced the course of American economic history.