Organization, Structure, and Growth of the Pennsylvania Iron Industry, 1780-1850

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The persistence of traditional technologies in the face of the adoption of new ones has become a fruitful area of study (see for example, [3, pp. 372-98; and 7, pp. 444-51]). The two most commonly given reasons for such persistence are (1) the dictates of custom and (2) the cost and opportunity structure of a particular industry. Both are persuasive arguments, especially when applied together, and go a long way toward explaining why so much of the Industrial Revolution can be said to have been a matter of industrial evolution (this point is alluded to in [3, pp. 449]). Much the same may be said of the persistence of traditional forms of business organization in the United States during the first half of the 19th century.

An examination of the Pennsylvania iron industry during the 100 years from 1750 to 1850 suggests that, rapid as may have been the pace of technological change within the industry, the traditional forms of business organization, common in the 18th century -- that is, the firm owned by an individual or by a share partnership -- not only persisted well into the 19th century, but continued to play a significant, perhaps the most important, role within the industry in almost all its branches and in virtually every part of the state. Moreover, firms organized along these traditional lines, as opposed to the then recently rehabilitated but long disreputable joint stock companies, were not only not resistant to technological change but were often among the first firms to adopt innovations.

This point assumes a special significance when we consider that the adoption of technological innovations by industrial firms during the first half of the 19th century is generally thought to have been associated with the appearance of increasing numbers of newer, more formal, and complex forms of business organization, that is, the joint stock company and the state-chartered corporation. These more sophisticated entities, so the argument goes, were necessary for the technological transformation of industry because they provided the most suitable means for raising the large amounts of capital required to finance production with the new technolo-

gies.[1] A related assumption about the role of these more advanced forms of organization is that, by virtue of their embrace of more advanced technologies and accounting methods, they necessarily enjoyed higher levels of labor productivity (and factor productivity generally) than did firms owned by individuals or partnerships [10, pp. 113]. A considerable body of evidence exists against which we can test these assumptions and also arrive at a clearer understanding of the relationship between organizational change and technological change or, in broader terms, between business organization and economic development.[2]

By 1750, ironmaking was firmly established in Pennsylvania and concentrated in about a half dozen counties well within a 100 miles of Philadelphia. The output of the province's furnaces and forges -- pig and bar iron, respectively -- was produced using falling water as a source of power and charcoal as a fuel. The typical furnace or forge was owned by an individual, a pattern of business organization that would persist throughout the 18th century and into the 19th [1, Appendix A].

By 1849, the last year for which reliable comprehensive data exist prior to the advent of the Bessemer process and the Civil War, the iron industry was quite different from that of a century earlier. The industry of 1849 operated in most parts of the state with four concentrations of activity: one in the anthracite coal fields; another in the southeastern counties; a third in the centrally located Juniata Valley; and the fourth in the western counties with commercial ties to Pittsburgh.[3] Not only was the industry more geographically dispersed in 1850, but it was also more diverse in terms of its technology and markets.

These profound differences, however, tend to obscure the considerable continuity which characterized the development of the Pennsylvania iron industry, especially with respect to forms of business organization. For example, on the most aggregate level of analysis -- that is, with no distinction made among the various types of furnaces, forges, and other facilities -- those owned by individuals represented a bit more than two-thirds of 146 facilities in the 18th century; about half of 110 in 1830; and 43 percent of 495 installations in 1849. For the same periods, joint stock companies accounted for 18 percent, 25 percent, and 28 percent, respectively, while partnerships were represented in almost the same proportions as were companies.[4] These figures, however, require some explanation.

As is so often the case with statistical findings, the accuracy of these figures suffers to the extent that the sources from which they spring are incomplete. This is not a particularly serious problem with respect to the results for the 18th century and for 1849. The 1830 figures, however, drawn from the *McLane Report* of 1832 [6] faithfully reflect the *Report's* most glaring imperfection concerning the Pennsylvania iron industry: very few

firms in the eastern part of the state cooperated with the Treasury Department's questionnaire on which the *Report* was based, thereby lending undue weight to the industry in the west.[5] Most of the state's forges and many of its furnaces, owned by individuals, were located in the southeastern counties which made no return. Consequently, the percentage figures for 1830 considerably understate the strength of individually owned firms and, similarly, overstate the importance of joint stock companies and partnerships [See the Appendix, Table 1]. This is not to say that the 1830 data are without value; rather that we should take more than a grain of salt to digest them.

With that caveat in mind, I can proceed with an examination of the assumptions which underlie the conventional view of the role of the joint stock company and chartered corporation in American industrialization prior to the Civil War. If these more formal, more advanced forms of business organization were more significant than other forms in facilitating American industrialization, then we should expect to find that (1) they were at the technological cutting edge of the iron industry; (2) they operated with greater efficiency than did firms owned by individuals and partnerships, for example, with a higher rate of labor productivity; and (3) their higher levels of capitalization reflected their use of advanced technology and operation on a large scale. Analysis of the evidence reveals that only the third criterion is satisfactorily met -- and then only in part.

Before determining whether companies and corporations were in the forefront of technological innovation, we must first recognize which of the various types of furnaces and other installations such as forges and rolling mills were more technologically advanced than others [10, pp. 51-106]. Of the furnaces, the cold blast charcoal type was the oldest, operating at relatively low temperatures and using the traditional fuel. More advanced by virtue of the heating of the blast by waste gases was the hot blast charcoal furnace which operated at higher temperatures and with greater fuel efficiency [10, pp. 59]. Of the remaining, still more advanced types of furnaces in operation by 1850 in Pennsylvania -- those fueled with anthracite coal, those with the bituminous, and those using coke -- only the anthracite furnaces operated in sufficient numbers to make them significant.[6]

A similar clear-out technological hierarchy is more difficult to construct for the other types of production facilities -- forges, ironworks, and rolling mills -- because they frequently bore little or no similarity to one another. A fairly sound rule of thumb, however, is that forges were generally less advanced in design and older than rolling mills, Ironworks present a unique problem in that these were often compound facilities -- that is, ones consisting of a furnace and a forge. It was therefore possible for an ironworks to have consisted of a fairly advanced fur-

nace and a forge of antiquated design and even of considerable vintage.

During the 18th century, a period of remarkable technological stability within the Pennsylvania iron industry, the relationship between organizational form and level of technology was of less moment than in the following half-century. Even so, the 18th century figures suggest that except for a strong interest in furnaces. companies played an insignificant role in the iron industry's more specialized branches, that is, forges, rolling mills, naileries, and slitting mills.

The data for 1830 confuse rather than clarify matters because, as already mentioned, they are heavily biased in favor of western facilities, and are also incomplete. The inherent shortcomings of the 1830 data notwithstanding, the figures indicate that companies then played an important, but by no means the predominant, role in the iron industry, accounting for about 25 percent of all facilities and from 30 to 32 percent of total output, measured in either tons or dollars.[7] These shares and those of firms owned by partnerships were virtually identical, the latter having accounted for about one-fourth of all firms and from 31 to 35 percent of total output [6, pp. 638-44].

For firms in 1849, the relationship between form of business organization and level of technological advancement is quite clear. Even without disaggregating beyond the three major classes of facilities then in operation -- furnaces, forges, and rolling mills -- it is apparent that for the state as a whole, companies accounted for about the same proportions of furnaces and forges in 1849 as in the 18th century: 31 percent of the furnaces and 12 percent of the forges in 1849 compared with 33 percent and 10 percent, respectively, during the period 1716-1800.

A different picture emerges, however, if we distinguish among cold blast and hot blast charcoal furnaces and anthracite furnaces. When this is done, it is apparent that as we move up the technological hierarchy the company form of organization assumes an increasingly important role. This ostensibly strong relationship between technological and organizational levels perhaps suggests that companies were more receptive to technological innovation than were firms owned by individuals or partnerships. A more plausible explanation has to do with the respective scales at which each organizational form operated. Thus, as we move up the technological hierarchy for furnaces, we also move to higher levels of output per furnace and, significantly, higher levels of capitalization as well. For example, the average cold blast furnace was capitalized at $35,658 and the average hot blast furnace at $40,924. The mean capitalization of anthracite furnace was $56,509.[8]

Although capitalization figures for individual firms were not included in the 1849 compilation, output levels were listed and these indicate that although scale of operation consistently in-

creased with the level of technological sophistication, the same was not true with respect to the level or organization within a particular furnace type. Thus, only in the case of cold blast furnaces did mean annual output increase consistently with increases in organizational complexity. These variations notwithstanding, it is apparent that the company form of organization became more important within the pig iron sector of the industry with each step up the technological hierarchy.

The company form of organization was also extensively involved with rolling mills in 1849, accounting for about 41 percent of all such installations, compared with 50 percent of those listed in the more unreliable 1830 compilation, and none of the 13 rolling mills included in the 18th century list. The role of companies in the ownership of rolling mills is even more pronounced in a regional breakdown of the 1849 data. Companies owned 74 percent of the 23 rolling mills in western Pennsylvania but only 25 percent of the 56 mills in the east.

This curious regional distribution of business organization reflects primarily the fundamental influence of the market and, more specifically, regional differences in the structure of demand for iron products. In both east and west Pennsylvania, rolling mills turned out a variety of products including both generic and specific goods (see Appendix). A decomposition of the output of rolling mills with respect to form of business organization reveals a pronounced relationship between the two. Of 51 eastern Pennsylvania rolling mills for which complete data exist, 11 of the 16 mills owned by individuals produced almost exclusively boiler and flue iron whereas mills owned by partnerships and companies produced rods, bar iron, nails, plate and sheet metal, and rails. The differences in the levels of labor intensity and fuel consumption help to explain the distribution. Boiler and flue iron, the major products of rolling mills owned by individuals, required less fuel and fewer workers per ton of output than did the products turned out in mills owned by partnerships, but especially by companies (see Appendix). Moreover, the mills which produced them were generally capitalized at a level considerably below that of mills owned by either partnerships or companies. Thus, rolling mills inteded for the production of boiler and flue iron operated on a scale that was sufficiently small so as to be within the reach of individual capitalists and too small to have required the formation of partnerships or companies [9, pp. 48]. This explains the near absence of rolling mills owned by individuals in the western part of the state where little boiler or flue iron was produced in rolling mills, the supply of these products coming from foundries.[9]

Rolling mills owned by partnerships and companies accounted for most of the iron produced statewide in such facilities -- 33,569 and 68,731 tons, respectively, of a total of 108,358 tons.

The balance of 6,058 tons came from mills owned by individuals. But here again, the product type explains much of the disparity. Boiler iron and flue iron were products often turned out in relatively small lots for sale in small lots [9, pp. 42]. Bar iron, rod iron, nails, and particularly rails were products made in large quantities, especially by companies. The differences in scale among the forms of organization are even more evident in a comparison of mean output levels: 356 tons for mills owned by individuals; 1,243 tons for partnerships; and 2,217 tons for companies. An important point, however, should be borne in mind: rolling mills owned by partnerships and those owned by companies which made the same products -- including rails -- operated on a similar scale and, as will be shown later, with comparable efficiency. Once again, a regional pattern clearly existed.

In western Pennsylvania, company-owned mills produced the lion's share of output -- 80 percent -- but suffered slightly in a comparison of mean output levels with mills owned by partnerships. The situation in the east, however, was quite different. There, mills owned by companies accounted for about 48 percent of the output as opposed to a 43 percent share for partnerships. Moreover, company mills produced a mean output of 1,858 tons; mills owned by partnerships turned out only 1,012 tons. These differences are readily understood when we recall the distinctly regional character of the product mix already discussed: in the east, the output of rolling mills was far more heterogeneous than in the west. The mean output levels and shares of total output of mills owned by partnerships and those owned by companies simply reflected this heterogeneity.

Although a technological hierarchy defined according to process type is useful in determining the relative importance of various forms of business organization, it is not comprehensive. The development of the furnace from charcoal cold blast to hot blast to anthracite blast was a gradual process which, in the case of the shift from cold to hot charcoal blast types, involved a significant number of conversions of furnaces initially built as cold blast installations into hot blast ones. All told, 25 cold blast furnaces built before 1830 were converted to the hot blast mode between 1830 and 1849 and of these, 9 were owned by individuals, 8 by partnerships, and 7 by companies, indicating that although companies were active in upgrading their production plants they were hardly alone in doing so.[10]

Still another consideration in constructing a technological hierarchy for the iron industry is the type of power used -- water or steam -- by specific kinds of facilities, as well as the regional and organizational patterns of power use. Here again, the data for 1830 are not all that we could wish them to be, but they nevertheless permit some useful, if only rough, comparisons with later, better documented periods. For example, of 96 facil-

ities of all types active in 1830, about 30 percent were powered by either steam alone or a combination of steam and water, depending upon the season [6, pp. 638-44]. By 1849, the proportion of all facilities using steampower had increased to 34 percent [2, tables].

The shift to steam appears to have been even more pronounced if we examine power use with respect to organizational form in 1830 and 1849. Fifty-one percent of all facilities operated by companies in the latter year used steam, compared with only 31 percent in 1830. The proportion of steam-powered facilities owned by individuals barely changed over the 20-year interval while that of partnership-owned works using steampower curiously declined from 42 percent to 37 percent. In this instance, the imperfections in the 1830 data are probably responsible for the anomalous behavior of the figures. These same imperfections, especially the western bias of the data, no doubt overemphasize the importance of steampower in the iron industry of 1830. A relative dearth of accessible waterpower sites in the west had early made steam an attractive, almost essential, source of power for ironmaking. The iron industry in the east, by contrast, had long exploited that region's abundant waterpower sites and consequently, to the extent that eastern ironworks are inadequately represented in the 1830 data, the role of steampower in the industry is exaggerated.

Despite the shortcomings of the 1830 data, the picture conveyed is at least consistent with what we might expect of the industry: that is, the incidence of steampower increased as technological sophistication increased. A similar strong relationship between steampower usage and level of technology is evident from the data for 1849, although at this point, predictably enough, the matter of regional variation in the distribution of steampower intrudes and assumes considerable importance.

With the exception of the anthracite furnaces, all but one of which were in the east, the use of steam in the east never approached the levels achieved in the west, where roughly 45 percent of the cold and hot blast charcoal furnaces were steampowered. The regional disparity was even greater with regard to rolling mills. Fifty percent of the 56 eastern mills used steam compared with 96 percent of the 23 mills in the west. Moreover, the use of steampower by the various organization forms in each region varied greatly. For example, although firms owned by individuals accounted for 18 percent of the steampowered rolling mills in the east, the corresponding figure in the west was only 5 percent. Similarly, partnerships and companies in the east owned 43 percent and 39 percent, respectively, of the mills powered by steam. Western rolling mills owned by partnerships and companies represented about one-fourth and three-fourths, respectively, of the steampowered mills. Much of this regional variation in the re-

lationship between business organization and the use of steampower no doubt arose from the distinct regional differences in the availability of waterpower sites and in the scale of operations, the latter having had much to do with the product mixes of rolling mills in each region.

The importance of the company's role in the adoption of new technology, including the use of steampower and the construction of larger furnaces of more advanced design, is hardly clear-cut. The weight of the evidence warrants giving the company an important but only a supporting role in the technological transformation of the Pennsylvania iron industry prior to 1850. Companies were seldom first in the adoption of a new production process; nor. for that matter, did companies embrace steampower before firms owned by individuals or partnerships, except in the western rolling mills which were almost all company-owned facilities.

Moreover, companies generally did not erect furnaces, regardless of type, with annual capacities larger than those built by individuals or partnerships. The exceptions were, of course, the anthracite blast furnaces which had an average capacity much larger than that of either cold blast or hot blast charcoal furnaces. For example, 33 anthracite furnaces had been erected or were near completion by 1846 [5, pp. 131]. Of these, 11, with a mean capacity of 3,050 tons were owned by individuals; 10 with a mean capacity of 2,950 tons were owned by partnerships; and 12 having a 3,646-ton mean capacity were owned by companies. Although the company-owned furnaces were, on average, 20 percent larger than the furnaces owned by individuals and partnerships, this was due entirely to the fact that two company-owned furnaces were behemoths with a 13,000-ton capacity between them, or an average capacity of 6,500 tons. The next largest furnace size was 5,000 tons and one of this size, owned by an individual, was already built; the only other one, then under construction, was owned by a company.

Charcoal furnace sizes varied virtually not at all with respect to form of business organization. The average capacity of 66 furnaces built between 1840 and 1846 was 1,048 tons and ranged from 1,060 tons for those built by individuals down to 1,033 tons for those owned by companies [5, pp. 129-30]. The same near uniformity of furnace size, regardless of organizational form, is evident from an examination of the data for 57 cold blast and 64 hot blast charcoal furnaces built between 1736 and 1849 [2, tables].

The unexceptional role of the company form of organization in the adoption of technological innovations was matched by its failure to operate its facilities at higher levels of efficiency -- measured in terms of labor productivity and fuel consumption rates -- than those achieved by firms owned by individuals and partnerships. An examination of the annual output (in tons) and

number of workers employed in 1842 at each of 67 furnaces in eastern Pennsylvania reveals that, although the shares of the total number of furnaces and total output of 70,075 tons were fairly evenly distributed among the three organizational forms, the average furnace owned by an individual employed fewer workers, produced more, and achieved a higher rate of output per worker -- 20.5 tons -- than did the average furnace owned by partnerships or companies [5, p. 125].

Unlike the output of the furnaces, measured here only in tons of pig iron, forges made two distinct products -- bar iron and boiler plate -- and 10 of the 42 eastern forges operating in 1842 made both. Thus, no single figure for output per worker can possibly be an accurate measure of the performance of the average forge, or even of the average forge owned by each form of business organization. Instead, measures of output per worker must reflect the type of product made at each forge.

At the aggregate level of analysis, a breakdown of mean output per worker by organizational form suggests that forges owned by individuals were substantially less productive than those owned by partnerships -- 9.7 tons compared with 11.1 tons -- and that both were grossly inferior to company-owned forges which achieved a mean output per worker of 23.8 tons. These results are quite misleading and an examination of forge production data, disaggregated according to product and type of firm, leads to the almost opposite conclusion.

As already noted, three major product groupings constituted the output in 1842 of these 42 forges. Forges apparently specialized in one or two of these groupings according to their respective forms of organization and, therefore, probably according to scale as well. Thus, we find that about half the forges owned by individuals produced only bar iron and the other half made boiler plate almost exclusively. Similarly, almost all forges owned by partnerships and companies produced more bar iron than anything else. A comparison of the mean output per worker within each product grouping for forges of each organizational type reveals that, of 23 forges making only bar iron, those owned by partnerships achieved the highest rate (18.5 tons), followed by the 15.7 tons for companies, and 13.3 tons for forges owned by individuals. Forges owned by partnerships were also more efficient, on average, than those owned by individuals in the making of boiler plate, a product not made at all by companies. Finally, of the 10 forges which turned out both bar iron and boiler plate, little difference in output rates distinguished one type of firm from the others.

Many of the foregoing points concerning forges were made with respect to rolling mills and led to virtually the same conclusion: installations owned by companies were generally less efficient than those owned by partnerships and individuals. The obvious question, then, is: why were the firms with the most advanced form

organization often less efficient in the operation of facilities at all levels of technology? One obvious possibility to be rejected almost out of hand is that the company form of organization suffered from the crippling effects of a bureaucratic structure. As should be apparent, most of these companies were not very large and fewer than 20 of the companies active between 1800 and 1850 were chartered corporations.[11] Moreover, all three types of firms made use of hired ironmasters, managers, and foreman.[12] With the exception of the few incorporated companies, many of which after 1830 had allied coal and railroad interests, little backward integration of advanced operations occurred within the iron industry [9, pp.40]. Thus, of the 350 firms listed in the 1849 compilation, only 20, or less than 6 percent, owned one or more furnaces and a rolling mill and of these 20, 9 were companies, 8 were partnerships, and 3 were firms owned by individuals.[13]

In view of the demonstrably small size and modest levels of capitalization of all firms of whatever organizational type, the explanation for the lackluster performance of company-owned facilities must lie elsewhere. The proximate cause of the companies' poor showing was their inability to push their facilities to their operating limits -- that is, to realize the economies of scale that many of the technological innovations had made possible. Because the company-owned facilities of most types were generally the most heavily capitalized and also were somewhat larger than those owned by partnerships or individuals, their fixed costs were comparatively high. Moreover, variable-cost inputs such as labor at some types of facilities were not very susceptible to manipulation within specific product groupings. Thus, at rolling mills which made bar and rod iron -- specialties of company-owned mills -- output per worker was almost completely inelastic with respect to changes in the size of the labor force [2, tables]. Boiler and flue-iron mills which commonly were owned by individuals, on the other hand, enjoyed a fairly elastic inverse relationship between the two.

Ultimately, the market's level of demand for iron products probably was the greatest single influence on the performance of all iron firms, company-owned and others alike. The differences in the effect of the level of demand on the three types of firms arose from their different scales of operation. Because ironmaking was still a labor-intensive activity in all its processes and the capital equipment required a rather large number of workers to produce any output at all, the larger, company-owned facilities suffered acutely when they ran at levels substantially below their capacities. At such times, fixed-cost and normally variable-cost factors of production frustrated attempts to realize greater efficiency. The available advanced technology, adopted by firms of all organizational types, carried with it the potential for realizing increasing returns to scale. Aggregate demand for iron prod-

ucts, however, was still insufficiently developed in 1850 to enable these firms to realize the full benefits of this technology. The aggressive pursuit and adoption on a large scale of the new, more potent processes by companies no doubt represented an important endowment of technology for that time after the Civil War when advanced technology and advanced forms of business organization combined to revolutionize the American iron industry. Attempts to join the two before 1850, however, were premature and, for the most part, unimpressive in their results. More impressive was the significant transformation of the iron industry in Pennsylvania during the first half of the 19th century brought about through the combination of traditional forms of business organization with new technologies.

APPENDIX

Table 1

FORMS OF BUSINESS ORGANIZATION OF PRODUCTION FACILITIES, 1716-1849
(% Composition)[a]

Facility Tape	1716-1800			1830			1849		
	Individual	Partnership	Company	Individual	Partnership	Company	Individual	Partnership	Company
Furnace	51	16	33	58	15	27	40	29	31
Forge	81	9	10	46	27	27	61	27	12
Ironworks	62	8	31	60	33	7	--	--	--
Rolling mill	69	31	0	17	33	50	24	35	41
Other	67	11	22	52	26	23	--	--	--
Total	68	13	18	49	25	25	43	29	28

Source: See text.
[a]Totals may not equal 100 percent due to rounding.

Table 2

REGIONAL DIFFERENTIATION OF PRODUCTION FACILITIES AND FORMS OF BUSINESS ORGANIZATION, 1849 (% Composition)*

Facility Type	East %			West %			Total %		
	Individual	Partnership	Company	Individual	Partnership	Company	Individual	Partnership	Company
Cbcf[a]	60	19	21	39	34	27	48	28	24
Hbcf[b]	44	25	31	28	33	39	40	27	33
Abf[c]	25	30	45	0	0	100	24	30	46
Forge	62	27	11	33	33	33	61	27	12
Rolling Mill	34	41	25	4	22	74	24	35	41
Total	68	28	24	30	33	37	43	29	28

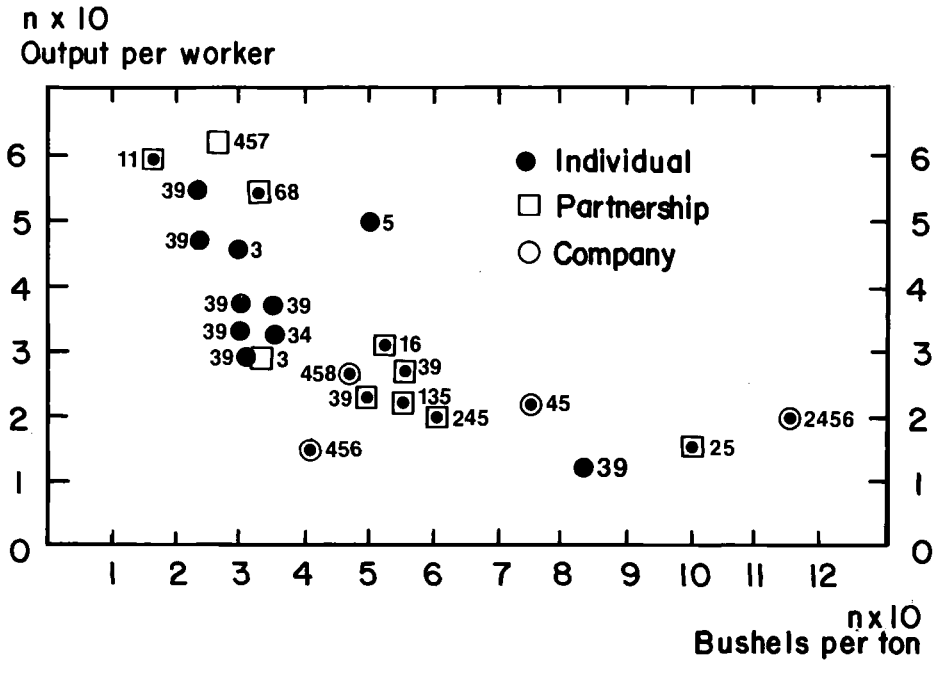
Source: See text.
*Totals may not equal 100 percent due to rounding.
[a]Cold blast charcoal furnace.
[b]Hot blast charcoal furnace.
[c]Anthracite blast furnace.

Table 3

DISTRIBUTION OF ROLLING MILL PRODUCTS BY BUSINESS ORGANIZATION IN EAST AND WEST PENNSYLVANIA, 1849

Number	Product	East			West		
		Individual	Partnership	Company	Individual	Partnership	Company
1	Sheet iron	2	2	1	1	3	15
2	Nails	1	4	2	1	3	14
3	Boiler iron	11	8	2	0	2	11
4	Rod iron	2	6	7	1	3	16
5	Bar iron	5	11	7	1	4	14
6	Plate	0	3	2	1	1	4
7	Axles	0	0	0	0	0	2
8	Wire	0	1	0	0	0	0
9	Flue iron	8	5	4	0	0	0
10	Spring steel	0	2	1	0	0	0
11	Steel	1	0	0	0	1	0
12	Rails	1	2	4	0	1	0

BITUMINOUS ROLLING MILLS IN EASTERN PENNSYLVANIA, 1849: OUTPUT PER WORKER (TONS) BY BUSHELS OF COAL PER TON OF OUTPUT, IDENTIFIED BY PRODUCT OR PRODUCT MIX[a] AND BY OWNERSHIP OF MILL



Source: see text. [a]Product numbers in Table 3 identify product or product mix.

NOTES

* I gratefully acknowledge the assistance of Wardell Jones, Robert A. Becker, and Daniel J. Wilson.

1. Peter Temin addresses a facet of this argument in his discussion of the integrated rolling mill before the Civil War. See [10, pp. 106-14, especially 113].

2. Eighteenth century data are drawn largely from [1, pp. 171-76]. The 1830 data are contained in [6] (hereafter referred to as the *McLane Report*). Data for 1842 are printed in [5, pp. 124-36]. The 1849 data are contained in [2, tables following pp. 69-72].

3. [2, tables following 69-72]. Peter Temin [10, p. 60] divided the state into three parts: "the East, the Juniata Valley ..., and the remainder of the West..."

4. See Note 2 for sources.

5. Responses to the questionnaire were often hostile in tone, expressing "an universal objection to several of the queries proposed by the department." Document 13, No. 2, "Report of Andrew M. Prevost to the Commissioners (Mathew Carey and Clement C. Biddle)," in [6, p. 197].

6. Only seven bituminous hot blast furnaces and four coke hot blast furnaces were among the 294 furnaces of all types covered in the ironmasters' report of 1849.

7. [6, Doc. 14, No. 323, Abstract, 638-44]. Twenty-eight companies accounted for 14,912 tons and $1,173,222 of a total output for all firms of 50,529 tons and $3,634,439.

8. For capitalization levels of different types of production facilities, see [2, "Statement, showing the number and condition of each sort of Iron Works, and the capital ivested in the Land and Buildings in each County in Eastern Pennsylvania, in the year 1850" and a similar statement for western Pennsylvania, tables following pp. 69-72]. A useful caveat concerning early capitalization figures, such as those given in [6] is offered in [9, p. 49].

9. [9, pp. 47-48; and 5, p. 126]. Of the 8 rolling mills listed in the latter, only 2 made any boiler iron. According to the returns contained in [6, pp. 638-44], only one rolling mill in Pennsylvania made any boiler iron in 1830.

10. [2, 72 n]. The numbers of hot blast charcoal furnaces owned by individuals, partnerships and companies are derived from the tables following pp 69-72. One furnace was owned by a bank.

11. See [8]. These contain the special charters of incorporation issued by the state to petitioners.

12. See, for example, the manuscript records of Speedwell Forge, Mary Anne Forge, and Colebrook Furnace, in [4].

13. An additional 35 firms, or 10 percent of the total number, owned both furnaces and forges. Of these 35, 21 were owned

by individuals; 9 by partnerships; and 5 by companies. The combined total of "integrated firms" (the use of the term in this context is Temin's own), therefore, is 55, or about 16 percent of the 350 firms. This is close to the 20 percent figure cited by Temin, [10, p. 94] for 1820 and 1857.

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