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Economies of Scope in U.S. Manufacturing Industries 1850-1880: An Empirical and Quantitative Analysis

I. INTRODUCTION

This paper concerns the measurement and quantification of the relationship between railroadization in the United States in the mid-19th century and the subsequent evolution of the modern, large-scale, corporate form of industrial business organization marked by significant economies of scope, efficiencies in production that tend to be captured by larger, more integrated firms capable of joint production and distribution of many different, but interrelated products, as described in various writings by Alfred Chandler. Focusing on American industry as it developed from 1850-1880 using data uniquely suited to empirical analysis of economies of scope, we aim to determine whether the growth of the American railroad network, as Chandler contended, expanded markets and augmented the American financial sector such that the result was a more concentrated, large-scale mode of industrial organization characterized by extensive and increasing economies of scope in sync with the growth of its extensive railroad system.

This paper is a digest of a larger work that also attempted to measure and quantify the relationship between railroadization and economies of scale in American manufacturing industries. It was Chandler's contention that the greater impact of the railroads on the American industrial landscape of the late 19th century was a pivotal factor contributing to its usurpation of Britain as the world's industrial and scientific leader at about that time. In his 1994 book, *Scale and Scope: The Dynamics of Industrial Capitalism*,[1] he argues that economies of scale and scope were an essential feature crucial for success in the large-scale, capital-intensive science-based industries of the late nineteenth century such as electricity, and that part of the reason Britain failed to develop substantial industrial structure of this type was a lesser impact of the railroads on its continued industrial development around the middle of the 19th century.[2] Because Britain

[1] Chandler, Alfred D. *Scale and Scope: The Dynamics of Industrial Capitalism*. Cambridge: Harvard University Press, 1994.

[2] Economies of scale figure prominently in electrical industries, particularly in electric power distribution, where it has been observed that larger utilities serving an extensive network of customers are able to transmit power at a lower cost per kilowatt-hour than utilities serving a smaller network of subscribers. Economies of scope figure prominently in electrical technology due to the tremendous interdependence of the various components of the industry. Standardization of current, voltage and frequency characteristics is essential to ensure that machinery and appliances are manufactured so as to be compatible with the form of power supply in use, and vice versa. Larger electrical firms capable of branching out and producing a diverse array of products have an advantage in this respect in their ability to market a working system of compatible apparatus to consumers. In examining the research of many historians of industrial technology, there was a consensus that the British electrical industries in the late nineteenth century were, on the whole, smaller scale than their American and German counterparts, with a greater assortment of voltages, frequencies and currents in use, and it has been argued that this factor contributed to the less rapid development of this technology in Britain. Besides Chandler's analyses, there is an extensive literature surrounding Britain's decline as the industrial leader in the 19th century, and the relationship between its early start and its weakness in the more modern industrial sectors that formed the background for this study. Much of it concerns the legacy of its early start and its implications on the size and scale of its industry, and can be found in general economic histories such as David S. Landes' *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*. London: Cambridge University Press, 1969, and *The Wealth and Poverty of Nations: Why Some are so Rich and Some so Poor.* New York: W. W. Norton, 1998. See also H. J. Habakkuk's *American and British*

industrialized before the transportation and communication revolution of the mid-19th century—that is, the coming of the steamship, telegraph, cable, and most of all, the railroads--it did not respond as vigorously to the opportunities for expansion of markets that the railroads bequeathed to other countries; the United States and Germany in particular. Since the United States and Germany were undergoing their initial industrialization at the time these transportation innovations were being made, they were able to build their initial industrial structure in a manner more suitable for effective exploitation of the opportunities for economies of scale these innovations created, and, by implication and association, scope as well. While Britain's older, smaller-scale, pre-existing industrial structure could perhaps have, with extensive investment and modification, expanded in a similar manner, its opportunity to do so was circumscribed by the fact that the railroads in Britain did little more than cement its pre-existing commercial channels that had been established under the age-old transportation methods provided by animal, wind and current. These trading channels were too restrictive to maintain a level of throughput necessary to achieve the scale and

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Technology in the Nineteenth Century: The Search for Labour-saving Inventions. Cambridge: Cambridge University Press, 1962, and Sidney Pollard's *The Development of the British Economy, 1914-1950*. London: E. Arnold, 1962 and *Britain's Prime and Britain's Decline: The British Economy 1870-1914.* London and New York: E. Arnold, 1989.

The interdependent nature of electrical technology, and its characteristics that favor large integrated systems receive emphasis in many of these studies; a discussion that is continued in depth by Nathan Rosenberg in *Technology and American Economic Growth*. New York: Harper & Row, 1972 and, with David C. Mowery, *Technology and the Pursuit of Economic Growth*. Cambridge and New York: Cambridge University Press, 1989 and *Paths of Innovation: Technological Change in 20th Century America*. Cambridge and New York: Cambridge University Press, 1998. This discussion is developed in further detail as part of a comprehensive historical analysis of the electrical industries by Thomas P. Hughes in *Networks of Power: Electrification in Western Society, 1880-1930*. Baltimore: Johns Hopkins University Press, 1983. Hughes was an indispensable source for the background of this study because it consists, to a large degree, of a comparison of the development and growth of American, German and British electrical industries in the 19th and early 20th century.

Britain's meanderings in a miasma of small-scale electrical firms and a maze of competing systems in this era is given extensive treatment in Hughes and the general histories cited above, and especially in business histories of the electrical industries. See Byatt, I. C. R., *The British Electrical Industry, 1875-1914: The Economic Returns to a New Technology*. Oxford: Oxford University press, 1979; Ballin, H. H. *The Organisation of Electricity Supply in Great Britain*. London: Electrical Press, Ltd., 1946; Hannah, Leslie. *Electricity Before Nationalisation: A Study of the Development of the Electricity Supply Industry in Britain to 1948*. London: Macmillan,1979, and Hall, Peter and Paschal Preston. *The Carrier Wave: New Information Technology and the Geography of Innovation 1846-2003*. London and Boston: Unwin Hyman, 1988.

For a theoretical discussion of the economic issues surrounding adoption of standards in interdependent technological systems, see Scitovsky, Tibor. "Two Concepts of External Economies." In *Papers on Welfare and Growth* by Tibor Scitovsky. Stanford: Stanford University Press, 1964; Kindleberger, C. P. "Standards as Public, Collective and Private Goods." *Kyklos*, Vol. 36, 1983; Berg, S. V. "The Production of Compatibility: Technical Standards as Collective Goods." *Kyklos*, Vol. 42, 1989; Farrell, J., and G. Saloner. "Standardization, Compatibility and Innovation." *Rand Journal of Economics*, Vol. 16, No. 1, Spring, 1985, and three articles by M. L. Katz and C. Shapiro: "Network Externalities, Competition, and Compatibility." *American Economic Review*, Vol. 75, No. 3, June, 1985, "Technology Adoption in the Presence of Network Externalities." *Journal of Political Economy*, Vol. 94, No. 4, 1986, and "Systems Competition and Network Effects." *Journal of Economic Perspectives*, Vol. 8, No. 2, Spring, 1994, in which it can be seen that the problem of the need for compatibility in complex systems can often assume a dimension of market failure that points to the need for coordination and planned investment, which favors large integrated firms with significant economies of scale and scope in order to better expedite the diffusion of an interdependent technology.

For a discussion of these topics specifically pertaining to the German electrical industries, see Brady, R. A. *The Rationalization Movement in German Industry: A Study in the Evolution of Economic Planning*. New York: H. Fertig, 1974.

scope economies inherent in the new technologies. Consequently, Britain's early start at industrialization condemned its industry to a scale too small for efficiency in the modern industrial sectors such as electricity, and by "efficiency", it is implied, all the scope advantages of integrated production.

Furthermore, because the American and German initial industrializations occurred in tandem with the building of their railroads, the organizational and structural revolutions associated with the railroads were at the core of their industrialization process from its inception. All of the requisite tools and apparatus for the building and maintenance of other large-scale, capital intensive industry, including the necessary financial mechanisms, arose along with the railroads, and were instrumental in their subsequent rapid industrialization based on the modern production technologies. The massive capital needs of the German and American railroads, too great for the lone entrepreneur to muster, called for the evolution of incorporated joint-stock enterprise owned by numerous scattered shareholders. Thus, the essential structural parameters for success in the modern industries such as electricity were established and formed the bedrock of American and German industry. In Britain, a smaller scale mode of industrial organization based on individual proprietorships, partnerships, and family-owned firms that had sufficed for the earlier iron-, coal-, and steam-based production technologies of the "First Industrial Revolution" of the 18th century was firmer in the saddle at the time the railroads began to stimulate organizational changes there. Furthermore, due to the smaller and more compact nature of the British railroad network, its capital requirements were modest in comparison to the German and American networks, therefore capable of being financed by more traditional, local mechanisms. Consequently, the railroads in Britain stimulated far less organizational and structural change in British industry, which may have created disadvantages in later years when efficiency and competitiveness called for enterprise of the mammoth corporate variety.[3]

Two fundamental assumptions underlie Chandler's analysis: the railroad is correlated with, firstly, an expansion of markets and secondly, a more concentrated, large-scale mode of industrial organization characterized by extensive recourse to outside sources of finance. Therefore, in order to determine whether a smaller and more compact railroad network in Britain was responsible for its economy's failure to develop such characteristics, and whether that failure, in turn, can explain any of its electrical failings, it is necessary to determine the nature and extent of this correlation. For if this relationship is weak, it casts doubt upon Chandler's theories as acceptable or plausible explanations for the failure of British industry to achieve the necessary scale and scope advantages crucial for success in many of the science-based industries of the "Second Industrial Revolution" that emerged in the late 19th century, that included not only the electrical industries, but also chemicals and technology centered around the internal combustion engine.

For instance, it would be necessary to determine if the above correlation is one which holds in general, across a broad spectrum of industries, or merely within the railroad itself and a few closely related industries. It is possible, for instance, that Britain did experience some widening of markets as a result of the railroads, and it learned about the organizational and financial methods necessary in constructing large scale capital intensive enterprise, yet many segments of its industry remained small scale for internal reasons unrelated to market size or lack of appropriate financial apparatus. Conversely, if Britain was able to build its relatively smaller, but still vast railroad network with traditional local means of finance, it is a puzzle as to why it would be unable to build other large-scale industry using similar methods. If it were found that Germany and the United States had also constructed their even vaster railroad networks without extensive recourse to outside capital, it would serve to show that claims of the railroads as having been the catalyst to the modern industrial corporate structure of enterprise have been greatly exaggerated. All such

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[3] While these are broad themes that are developed and supported throughout *Scale and Scope*, some key sections that emphasize these points can be found on pp. 12, 54-58, 62-63, 89, 235-42, 249-55, 266-68, 281-86, 291-94, 397, 410-19, 497-502, 595-96.

above evidence constitutes weakening of the empirical chain between the railroads and the evolution of the apparatus of large scale corporate enterprise, and would serve to discredit any hypotheses linking lesser impact of the railroads on Britain's economy with less industry of this type, and any backwardness in its modern sectors lack of such industry may have produced.

In this larger study, we attempted to determine the nature and extent of this correlation between the railroads and economies of scale and scope by focusing on American industry in the mid-to-late nineteenth century. Chandler's idea that the railroads were a great impetus to market expansion and the emergence of a highly concentrated, large-scale mode of industrial organization characterized by extensive recourse to outside sources of finance, and that these, in turn, promoted economies of scale and scope implies a correlative cause-and-effect hypothesis that has never been subjected to rigorous empirical analysis using data. This thesis attempts to remedy that deficiency with an empirical methodology that tests Chandler's hypothesis in its rudimentary form with regards to American industry in the mid-to-late 19th century, and a comparison of the development and growth of the American, British and German railroad networks in order to determine if Chandler's claim that the American industrialization of the mid-to-late nineteenth century was particularly heavily impacted by the railroads has any validity.

II. DEVELOPMENT AND PHASES OF GROWTH OF THE AMERICAN, BRITISH AND GERMAN RAILROAD NETWORKS: THE CHANDLER HYPOTHESIS EXAMINED

In the second and third chapters, we conducted a comparison of the development and growth of the American, British and German railroad networks in order to determine if Chandler's claims that British industrialization of the mid-to-late nineteenth century was less heavily impacted by the railroads has any validity, and also to see if the American and German railroad systems were in fact constructed using more extensive recourse to outside sources of finance. It was found through a side-by-side analysis of the timing of effects of the railroads on the industrial development of these countries with data concerning the development of the railroads themselves that Chandler's claims that British industrialization of the mid-to-late nineteenth century was less heavily impacted by the railroads must be viewed with a certain degree of skepticism. While a side-by-side comparison of railroad mileage phases data for the three countries to the revealed history concerning their industrial development essentially corresponded to and supported Chandler's claims that a greater expansion of the railroad systems of the United States and Germany at mid-century and resultant vastness thereof with respect to Britain had occurred by the 1870's, and may have been instrumental in expanding markets, our analysis did not produce any concrete evidence that this was a paramount factor contributing to a more concentrated industrial sector that was intensive in the new science-based technologies of the Second Industrial Revolution, or that these forces were set in motion by the 1870's as was Chandler's contention. In comparing and interpreting rates of railroad physical capital accumulation of the three countries, while we did observe more rapid capital growth and accumulation in the German and American railroad systems than in Britain during the time leading up to the 1870's, sharp spikes in the British capital flow data in the 1840's and 1860's, in combination with the revealed history detailing the strong dependence of its railroad system on coal, the strong dependence of its own, the American, and Continental railroad systems on its iron industry; not to mention its far greater railroad mileage per square mile of national territory, left us with an indicator of the possibility that the railroads may have had a far greater impact on the British industrial development at mid-century than Chandler gave them credit for. That is because he focused on market-expanding properties, and ignored the factor input demand effects of the railroads on manufacturing industries.

A further examination of the role of financial intermediaries in the growth of the railroad systems of the three countries also produced skepticism about Chandler's claim that the American and German railroad systems were constructed using more extensive recourse to outside sources of finance than the British, and its ramifications for industrial development in the latter decades of the 19th century. An in-depth survey of the existing body of literature surrounding the financing of the British railroad system[4] indicated that Britain's railroads may have also been heavily financed by outside capital, and that this financing did have a dramatic impact on its capital markets, as evidenced by the development of a national market for railroad shares as having occurred by the 1840's. Our principal empirical analysis of comparative financial intermediation effects from the railroads consisting of the stock of railroad financial capital data for the United States and Britain for 1830-1914 that were normalized by being measured relative to G.N.P. showed Britain in a strong lead all the way until the 1870's, which suggests that railroad finance played a stronger role in the British economy at least until the 1870's, and points to a stronger impact of the railroads on financial intermediation facilities in Britain than in the United States all the way until the 1870's.

Britain may have thus experienced a significant impact of the railroads on its industrial landscape that was different in character from the American, and financial augmentation from the railroads that was just as, if not greater than that of the United States. Why this did not translate into rapid economic growth centered on the science-based technologies of the Second Industrial Revolution at the end of the 19th century is another question; but it is not at all clear from the evidence uncovered in this section that the answer is a lesser impact of the railroads on its industrial development.

In the following chapters, we focused on American industry as it developed from 1850-1880 using data uniquely suited to empirical analysis of economies of scale and scope in order to determine whether the growth of the American railroad network did, in fact, expand markets and augment the American financial sector such that the result was a more concentrated, large-scale mode of industrial organization characterized by extensive and increasing economies of scale and scope in sync with the growth of its extensive railroad system. Lack of appropriate data precluded a similar analysis for British and German industry as they developed during this period, and for American industry after 1880 until well into the 20th century. However, the period of 1850-80 our data cover is sufficient for a test of this hypothesis as it concerned economies of scale and scope of American industry because it was Chandler's belief that the great American railroad boom of the middle of the 19th century was the catalyst to the market expansion and financial augmentation that brought this large-scale mode of industrial organization characterized by

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[4] See Gourvish, T.R. *Railways and the British Economy, 1830-1914* (London, 1980); ----------. *Mark Huish and the London and North Western Railway: A Study of Management* (Leicester,1972); Reed, M.C. "Railways and the Growth of the Capital Market," in M.C. Reed, (Ed.), *Railways in the Victorian Economy* (New York: Augustus M. Kelley Publishers, 1968); ----------. *Investment in Railways in Britain, 1820-1844: A Study in the Development of the Capital Market* (London: Oxford University Press, 1975); Bagwell, Philip S. *The Transport Revolution from 1770*. London, Batsford (1974); Hawke, G. R. *Railways and Economic Growth in England and Wales, 1840-1870*. Clarendon Press, (Oxford, 1970); Thomas, W. A. *The Provincial Stock Exchanges* (London: Frank Cass and Co. Ltd., 1973); S.A. Broadbridge, "The Sources of Railway Share Capital" in M.C. Reed, (Ed.), *Railways in the Victorian Economy* (New York: Augustus M. Kelley Publishers, 1968); ----------. *Studies in Railway Expansion and the Capital Market in England: 1825-1873*. (London: Frank Cass and Co. Ltd., 1970); Cottrell, P. L. *Industrial Finance, 1830-1914: The Finance and Organization of English Manufacturing Industry* (London and New York: Methuen & Co. Ltd., 1979); Tilly, Richard. "Germany 1815-1870" in Rondo E. Cameron, ed., *Banking in the Early Stages of Industrialization: A Study in Comparative Economic History* (New York, 1967); ----------. "Financing Industrial Enterprise in Great Britain and Germany in the Nineteenth Century: Testing Grounds for Marxist and Schumpeterian Theories?" in H. J. Wagner and J. W. Drukker, eds., *The Economic Law of Motion of Modern Society: A Marx-Keynes-Schumpeter Centennial* (Cambridge, Eng., 1986), Ch. 9.

extensive economies of scale and scope into existence by about 1870.[5] The empirical analyses that followed consisted of quantitative estimates of the degree of economies of scale and scope achieved in various American manufacturing industries over successive time periods within this period starting from the beginning of when these effects were purported to have begun until 1870, which was identified as the benchmark period in which to expect to see the lagged effects of these transportation improvements upon industrial size and performance, and on until 1880 by which time they ought to have been in full bloom. We were thereby able to produce quantitative measures of the degree of economies of scale and scope in various industries in order to see if this theory of a lagged, correlative cause-and-effect relationship between the growth of the railroads and economies of scale and scope has any empirical validity; something that previous analyses of the impact of the railroads on industrial size and performance in the 19th century do not contain.

Since the electrical and chemical industries were in their infancy at the time of the rapid take-off of the railroads, there is little or no earlier-on growth of these industries in 1850 or 1860 that their growth in 1870 or 1880 can be compared to. Consequently, our study has been confined to industries that were in full-fledged existence in 1850 for which sequential growth in association with the railroads for the full period from the beginning of the impact of the railroads to the final period can be ascertained.

III. ECONOMIES OF SCALE

The fourth chapter introduced these industries, described the data used in the analyses, introduced the measure of economies of scale achieved by various industries at any given time used in our analysis, and discussed its empirical results in an attempt to determine whether they confirm or contradict the beliefs of Chandler as to which industries experienced these rising scale advantages that were said to have occurred over this period, and when they occurred. The methodology used in this scale analysis is derived from the survivor technique, a method pioneered in its application to measurement of scale economies by George Stigler, William Shepherd and Leonard Weiss among others, [6] that seeks to identify the size classes of firms or plants that not only survived the rigors of market competition, but also succeeded in increasing their share of total industry value-added. An increasing share of industry value-added held over time by the larger size class or classes of firms or plants in an industry serves as empirical evidence in support of the idea that larger firms or plants have gained a competitive advantage over their smaller counterparts by acquiring greater market share over time, thus economies of scale. [7]

This particular scale analysis can be viewed as a continuation of that begun by Jeremy Atack, whose 1985 article “Industrial Structure and the Emergence of the Modern Industrial Corporation”[8], the first systematic attempt to address the core of Chandler’s thesis with quantitative evidence, used a variation of the survivor technique to test Chandler’s key argument that the modern business corporation evolved by taking advantage of continuous production technologies and the opportunities afforded by the railroad and

[5] Chandler, pp. 26, 53, 281-82.

[6] Stigler, G. J. “Economics of Scale” *Journal of Law and Economics*, 1:5-71 (1958); Shepherd, William G. “What Does the Survivor Technique Show about Economies of Scale?” *Southern Economic Journal*, Vol. 34, No. 1 (Jul., 1967), 113-122; Leonard W. Weiss. “The Survival Technique and the Extent of Suboptimal Capacity” *The Journal of Political Economy*, Vol. 72, No. 3 (Jun., 1964), 246-261.

[7] Atack, Jeremy. “Industrial Structure and the Emergence of the Modern Industrial Corporation” *Explorations in Economic History* 22, 29-52 (1985), pp. 36-38.

[8] Ibid.

declining transport costs to market a high volume of production nationwide by measuring the extent to which the average plant at the end of the 19th century (when most of the developments discussed by Chandler had taken place) differed in size from plants that survived the Civil War decade, that is, prior to such changes. Atack measured economies of scale in United States manufacturing industries from 1870-1900 by determining the entire range of size class (size measured in terms of value-added per plant) that increased its share of industry value-added from 1850-70 for 24 industries. This size class is termed "optimal", or of "minimum efficient scale" (MES) in these analyses. Then he computed the total share of industry value-added held by plants in that size class, and expressed it as a percentage of total industry value-added. [9] Then he took the lower and upper bounds of those size classes that were determined to be optimal in 1870, and divided total industry value-added in both 1870 and 1900 out by those individual value-added sizes which produced the number of "potentially" optimal plants that industry value-added could sustain, using this 1870 survivorship size class as the standard of optimality. [10]

Then he compared this number of potentially optimal plants to the actual number of plants in each industry at each date. The higher the ratio of potentially optimal plants to the actual number of plants, the greater the indication that many establishments had achieved an efficient scale, and the more economies of scale there were in that industry. If there were more potentially optimal plants than actually existed in an industry, that would mean that a handful of plants are producing a large portion of industry output, and they are well above the MES. Whereas, if there were far fewer potentially optimal plants than actually existed in an industry, that would mean that industry output is divided out amongst many, many plants, few of which are operating at this efficient scale. A rising ratio of potentially optimal plants to actual number of plants can be construed to indicate increasing size of enterprise that is consistent with a widening of market opportunities permitted by cheaper transportation and the existence of economies of scale that could be both internal and external. [11]

Then he used these results to test the Chandler hypothesis that it was in the industries that experienced the greatest impact of transportation improvements and the most rapid technological progress over 1870-1900 that the most economies of scale were found in. He categorized various industries by these criteria (see Table 1 and commentary below), and found that those who had the most impact of transportation improvements and the most rapid technological progress also had the highest ratios of potentially optimal plants to total plants as computed in the previous section. These industries were meat packing, flour milling, malt liquor, leather tanning, and pig iron. He also found a rise of the ratio of potentially optimal plants to the actual number of plants from 1870-1900 in all but one of these 24 industries. [12]

While this test does not provide us with a quantitative measure of the degree of economies of scale, it is noteworthy in terms of what its results tell us about industrial growth from 1870-1900, and the degree to which Atack's results confirm the Chandlerian hypothesis. It was Chandler's thesis that the modern

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[9] Ibid., pp. 39-42.

[10] Presumably Atack did not compute a new survivorship class as it emerged from 1870 to 1900 with which to divide out 1900's industry value-added by because the data set he used for this study, the Bateman-Weiss and Atack-Bateman Samples from the Manuscript Censuses of Manufactures, 1850-1880, do not contain individual plant-level data for 1900 that would be necessary to determine a new survivorship class for 1900. For more information, see Atack, Jeremy and Fred Bateman. "Nineteenth-Century U.S. Industrial Development through the Eyes of the Census of Manufactures: A New Resource for Historical Research." *Historical Methods*, Fall 1999, Vol. 32, No. 4: 177-88, pp. 177, 179. This article is also available on line and downloadable at http://www.vanderbilt.edu/Econ/faculty/Atack/atackj.htm.

[11] Atack, pp. 42-47.

[12] Ibid., p. 47.

business enterprise, as exemplified by American Tobacco, Carnegie Steel, and Armour and Company, emerged as a response to the combined forces of continuous production process technology and the transportation revolution of declining railroad freight rates. The effects of this revolution in transportation and production technology on the scale of enterprise, according to Chandler, were seen most visibly in the production of tobacco and grain products and in the furnace and foundry and distilling and refining industries. Atack's results here must be regarded as an empirical validation of the Chandlerian thesis. [13]

In this study, we do provide a quantitative measure of the degree of economies of scale that is derived from survivor estimates that is also termed "Minimum Efficient Scale" (MES), but is defined a little more precisely as the minimum plant *size* (in valued added) *within* the minimum size class range that increased its total percentage of industry value added over a designated time period. By determining MES in this manner over successive time periods spanning the late nineteenth century, we obtain a quantifiable measure of the degree of economies of scale achieved in various American manufacturing industries because if the minimum size that a firm needed to be in order to be competitive in its respective industry rose over time, that serves as an indicator that increasing size is something associated with a plant's ability to survive and compete in this industry, thus presence of economies of scale. An increasing MES over time in a given industry thereby serves as an indicator of increasing economies of scale as having been achieved over time in that industry. This methodology is derived from Leonard Weiss's 1964 study that used the survivor technique to measure growth in economies of scale in American manufacturing industries in the 20th century. Weiss identified MES in 5 industries—automobiles, steel, petroleum refining, flour and cement--in the United States from 1924 to 1961. He measured optimal size in terms of plant output per year, or day; actual plant capacity in units of goods, not value-added.[14] Then he divided this whole time expanse into sections; 1924-29, 1929-34, etc. and identified the MES for each period, and found that it increased over time. In other words, the minimum size that a firm needed to be in order to be competitive in its respective industry rose over time. This seems to be a good indication of much unexploited economies of scale in each industry, and increasing exploitation of it over time. If average plant size is not only rising over time, *and* the minimum size a plant needs to achieve in order to be competitive and survive in the industry is also rising, it certainly shows that increasing size is something associated with a plant's ability to survive and compete in this industry. [15]

In this fourth chapter, we applied the same methodology Weiss used to the data Atack used [16] for the industries Atack analyzed that are presented below in Table 1.

[13] Ibid., pp. 47-49.
[14] Weiss does not say how he selected these size classes, except that he did it so that at least several plants would ordinarily fall within each class (see p. 248). He seems to have derived his methodology from J. S. Bain, *Barriers to New Competition* (Cambridge, Mass.: Harvard University Press, 1956), where perhaps these size classes are delineated. See Weiss, footnotes, pp. 247, 249.
[15] Weiss, pp. 247-50, Table 1.
[16] These data, which are entitled the Bateman-Weiss and Atack-Bateman Samples from the Manuscript Censuses of Manufactures, 1850-1880, are presented in a common format with uniform integrated coding to facilitate their use, and are available through the Inter-university Consortium for Political and Social Research (ICPSR) at the University of Michigan (http://www.icpsr.umich.edu/index.html) and at http://www.vanderbilt.edu/Econ/faculty/Atack/atackj.htm.

Table 1
Technological Change, Transportation, and the Adjustment
To 1870 Optimal Plant Sizes, 1900

	Pace of Technological Progress	
Impact of Transportation	High	Low
High	Meat packing Flour milling Malt liquor Leather tanning Pig iron	Sawmills and planing mills Millwork Wood furniture Bricks Gray iron foundaries Sheet metal
Low	Distilled liquor Tobacco manufacture Clothing Boots and shoes	Bread and baked goods Cotton textiles Wool textiles Millinery Printing and publishing Saddlery and harness Farm machinery Wagons and carriages

In his industry selection, Atack categorized industries by the degree of impact of transportation improvements and pace of technological improvements in a table in his 1985 article that I have here reproduced in this text as Table 1. [17] In the left hand column of Table 1 are listed the industries that Chandler said were the great industries that experienced these great impacts of the decline in transport costs and technological advance that led to these large-scale production methods. They are also, by Atack's study, the group of industries that had the highest ratios of potentially optimal plants to total plants as computed in the previous section of that article, which was an indicator of great scale economies as having been achieved over 1870-1900. Within that left hand column, there are some industries that, according to Nelson's study on the great merger movement at the end of the century [18] experienced a great impact of transportation improvements, and those that did not. It is an interesting fact that those that did not have a great transportation impact, those in the lower left cell in Table 1, had a slightly smaller ratio of potentially optimal plants to total plants.

There is a second column of industries Atack surveyed in the right hand column that do not coincide with those purported by Chandler to have experienced great growth due to continuous production technology and the transportation revolution. Atack's results show that for these industries, the margin of the lower difference in ratio of potentially optimal plants to total plants for these industries as compared with those in the left hand column is substantial, which is a basic confirmation of the Chandler theory that whatever the great impact of technology or declining transport costs on this group of industries was, it was not significant. It

[17] Atack, Table 4, p. 48.
[18] Nelson, R. *Merger Movements in American Industry 1895-1956.* Princeton, N.J.: Princeton Univ. Press for the NBER, 1959, pp. 158, 159, Table C-3.

is for that reason that I also tested these industries and compared the results to the left hand column industries to see if my results confirm the Chandler theory; a test that comprised a major portion of the fifth chapter of this larger study, which takes a closer look at these results, their data, and the grouping of industries together in the data. For now however, it is worthy of noting that Atack found that the upper right cell that contains industries that had a low pace of technological progress but a high impact of transportation had a greater average ratio of potentially optimal plants to total plants than the cell that contains industries had both a low pace of technological progress *and* a low impact of transportation. That does support the Chandler hypothesis that the transport improvements had an impact of sort, even if the industries did not experience a great amount of technological change.

Since the data set contained only data from 1850-80, the first period for which a MES could be ascertained was the group of plants that increased their share of industry value added over 1850-60. That was followed in the empirical results by MES as it emerged from 1860-70, and finally, from 1870-80; 3 periods in total. Following Atack's practice, MES was computed in value added in constant 1860 dollars rounded, [19] and all plants in each industrial category in each year were grouped by size of value added according to the following schema: $0-249; $250-499; $500-999; $1000-1999; $2000-3999; $4000-7999; $8000-15,999; $16,000-31,999; $32,000-63,999; $64,000-127,999; $128,000-255,999; $256,000 and over. The MES range was determined by identifying the smallest size class of plant that increased its share of total industry value added over each period delineated in the columns, and the MES of plant was determined by the smallest size of plant value-added within that class that increased its share of total industry valued-added over the period. [20]

The first component of the empirical analysis of Chapter Four endeavored to determine if all of the left column industries had a rising MES over 1850-80 (the period the availability of the appropriate data confines our study to), and in particular, to compare the results of the upper left to the lower left cell industries that purportedly did not receive as great an impact from the transportation improvements of the era. My results for these left column industries that Chandler said were the great industries that experienced the greatest impact of the decline in transport costs and technological advance that led to large-scale production methods did not display great scale economies by 1880; the time by which, if Chandler's theory were correct, they ought to have. In our results that measured and quantified economies of scale through the method of MES, the general pattern of the industries surveyed was relatively great economies of scale as having been achieved by 1860, followed by a pronounced dip at 1870, and only modest increases by 1880 that do not regain their 1860 levels. This phenomenon was ubiquitous, and applied to both the industries of the upper and lower cells equally. In fact, the industry whose results were the worst for the Chandler hypothesis, Meat, was one of the industries in the upper cell that designated the high technology/high transportation category. Meat was the only industry among those surveyed whose MES for 1880 was actually lower than its 1870 level.

While the dips of 1870 made sense in the context of the Civil War aftermath shock that was shown to have disrupted and retarded capital formation for a long time after the war due to

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[19] Value-added were adjusted by the rise or fall in the wholesale price indices for the United States in Mitchell, Brian R. *International Historical Statistics: the Americas, 1750-2000*, 5th ed. Palgrave Macmillan, New York, 2003, p. 702.

[20] Atack, pp. 41-42.

the crowding out effects of heavy government borrowing to finance the war,[21] there was no rational explanation for the extremely low MES's observed at 1880 in the context of Chandler's hypothesis. If 1870 is the benchmark period in which to begin to expect to see the effects of transportation improvements upon scale economies in American industry, then 1880 is certainly a liberal allowance in terms of time to expect to see the effects of the railroads upon market expansion and financial intermediation to have been taking place; post-war resumption of investment and capital accumulation notwithstanding.

These results compelled me to take a closer look at our data and to conduct deeper analyses in order to determine the root cause of these anomalous 1880 results. In the following Chapter Five, it was revealed that flaws in the 1880 data for some industries may have been responsible for these anomalous results,[22] and also the fact that many of the industrial categories analyzed were more broadly defined industry conglomerations encompassing a wider range of products than the corresponding industries in the Atack article. By looking at sample sizes and range distributions in order to see if there was a correlation between flawed data and lower-than-expected MES for 1880, Chapter Five conducted more thorough analyses of these data sets. For those industries found to contain flawed 1880 data, Chapter Five also reported the results of analyses performed using whatever superior data were available and, where possible, conducted disaggregated industry analyses based on finer product group distinctions in order to see how our results differed. Chapter Five also conducted MES analyses of the new group of fresh industries thus far unanalyzed in the right hand column of Table 1 in order to see if the Chandler hypothesis that these industry groups were less strongly

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[21] See Gallman, Robert. "Commodity Output 1839-1899." In National Bureau of Economic Research, *Trends in the American Economy in the 19th Century*, Studies in Income and Wealth, vol. 24. Princeton: Princeton University Press, 1960: 13-67; Engerman, Stanley. "The Economic Impact of the Civil War." *Explorations in Economic History* 3 (1966): 176-99; Williamson, Jeffrey. "Watersheds and Turning Points: Conjectures on the Long Term Impact of Civil War Financing." *Journal of Economic History* 34 (1974): 631-61; James, John A. "Public Debt Management Policy and Nineteenth-Century American Economic Growth." *Explorations in Economic History* 21 (1984): 192-217; Beard, Charles, and Mary Beard. *The Rise of American Civilization.* New Edition, Two Volumes in One, Revised and Enlarged. New York: Macmillan, 1934; Hacker, Louis. *The Triumph of American Capitalism.* New York: Columbia University Press, 1940; Kessel, Reuben, and Armen Alchian. "Real Wages in the North during the Civil War: Mitchell's Data Reinterpreted." *Journal of Law and Economics 2* (1959): 95-113. Reprinted in *The Reinterpretation of American Economic History*, ed. Robert W. Fogel and Stanley L. Engerman. New York: Harper & Row, 1971: 459-69; Mitchell, Wesley. "The Greenbacks and the Cost of the Civil War." Reprinted in Ralph Andreano, ed. *The Economic Impact of the Civil War.* Cambridge, Mass.: Shenkman, 1962: 66-78; DeCanio, Stephen, and Joel Mokyr. "Inflation and the Wage Lag during the American Civil War." *Explorations in Economic History* 14 (1977): 311-36.

[22] Atack and Bateman's article on the Census samples reveals that for the 1880 census, special experts on the industry in question were assigned to collect data on specific industries. These industries included iron and steel, cotton, woolens and worsteds, silk, beer, liquor, glass, coke, mining and drilling. Unfortunately, despite exhaustive investigation, no one has been able to locate all of the returns taken by the aforementioned experts. Thus many firms from these separately canvassed industries that appear in the 1880 samples are enumeration mistakes and were not generally tabulated from the regular returns by the Census Office, although they aren't missing in their entirety. See Atack, Jeremy and Fred Bateman. "Nineteenth-Century U.S. Industrial Development through the Eyes of the Census of Manufactures: A New Resource for Historical Research." *Historical Methods*, Fall 1999, Vol. 32, No. 4: 177-88, pp. 180, 185. This article is also available on line and downloadable at http://www.vanderbilt.edu/Econ/faculty/Atack/atackj.htm.

impacted by the technological and transportation improvements of the era is correct, and also to inspect and disaggregate the data sets of these industries in turn, in order to determine what these industries' data characteristics and their MES results have to tell us about how faulty data may have affected the results of the left column industries.

In Chapter Five, it was found that even when the industries that Chandler said were the great industries that experienced the greatest impact of the decline in transport costs and technological advance that led to large-scale production methods were re-tested using superior data in place of that which was found to be flawed, or split into finer product group distinctions so as to cleanse and distill a product group of a flawed component, there were little scale economies achieved by 1880; the time by which, if Chandler's theory were correct, there ought to have been. In our results that measured and quantified economies of scale through the method of MES, the general pattern of the industries surveyed continued to be relatively great economies of scale as having been achieved by 1860, followed by a pronounced dip at 1870, and only modest increases by 1880 that often did not regain their 1860 levels. Even after substitution and purging of the flawed data from the study to the best of our ability, these eight principal industries[23] were only evenly split between those whose MES rose in 1880 over their 1860 levels and those who declined. The similar examination of the Table 1 right column industries that Chandler believed were less strongly impacted by the technological and transportation improvements of the era for the sake of comparison yielded results that were no better or worse than the left column ones. In Chapter Five, we reached the conclusion that faulty and misconglomerated data alone cannot account for these anomalous results, and that a reassessment of the Chandler hypothesis consisting of further industry data analyses may be desired to further our knowledge and understanding of the true trends of efficiency and size of firms wrought by the railroads in the late nineteenth century.

IV. ECONOMIES OF SCOPE: DATA AND METHODOLOGY

In Chapter Six of this larger work that forms the principal basis of this exposition, we introduced the measure of economies of scope achieved by a given multi-product industry at any given time used in our analysis that is derived from that employed by Friedlaender, Winston and Wang in their 1983 analysis of the structure of costs, technology, and productivity

[23] Due to the fact that Distilled Liquor and Malt Liquor were grouped together in the data under the same Standard Industrial Classification (SIC) code, and for 1880 (a period that Atack did not take into account in his study), there were no fields in the data set corresponding to individual final product codes, quantities or value, there was no basis upon which to disaggregate these plants into primarily malt liquor- or distilled liquor-producing plants. Since a separate analysis for 1880 was impossible, Distilled Liquor and Malt Liquor were combined into one industrial class called simply "Beverages" in this analysis. Otherwise, there would have been nine principal industries as shown in the left column of Table 1, not eight.

For more information on the SIC codes, see U.S. Office of Management and Budget, *Standard Industrial Classification Manual*, (GPO, 1987), Dun & Bradstreet Information Resources, 1989 and the site http://www.osha.gov/pls/imis/sicsearch.html, the exact page of the site of the U.S. Department of Labor Occupational Safety & Health Administration that allows the user to search the 1987 version SIC manual by keyword.

in the U.S. automobile industry.[24] Friedlaender, Winston and Wang's methodology as applied to a given multi-product industry in my model (taking footwear as a hypothetical example), consists of estimating a cost function for the entire industry at a given time, and applying the following definition:

$$S_c = \frac{[C(Y_s) + C(Y_b) + C(Y_{sl})] - C(Y_N)}{C(Y_N)} \qquad (1)$$

where (lower-case) *s* denotes output of shoes, *b* denotes output of boots, *sl* denotes output of slippers, and *N* denotes the collective output bundle.

Thus defined, *Sc* measures the economies of scope of the entire footwear industry by computing the individual costs of producing *each* product independently that the given industry produced. Then by subtracting the total combined costs of producing that bundle of goods jointly, and dividing that difference by the total combined costs of producing that bundle of goods jointly, a measure of the percentage cost savings (increases) that are due to joint production is obtained.

By computing *Sc* over successive time periods spanning the late nineteenth century, we obtain a quantifiable measure of the degree of economies of scope achieved in various American manufacturing industries because if the *Sc* of each respective industry rose over time, that serves as an indicator that the percentage cost savings that were due to joint production were increasing, thus increasing economies of scope as having been achieved over time in that industry. The same data used in the Scale analysis of Chapters Four and Five were mobilized for this study to the best of their (and my) ability and the empirical results thereof are presented below along with my own assessment of the degree to which they confirm or contradict the beliefs of Chandler as to which industries experienced these rising scope advantages that were said to have occurred over this period, and when they occurred.

The formulation displayed as Equation (1) above is derived from the framework of the Friedlaender, Winston and Wang article, which estimated economies of scope in the Big Three American automobile producers (General Motors, Ford and Chrysler) from 1955-1979 by dividing their output into three output variables: small cars, large cars, and trucks. It does not always conform to the actual formulation used to compute the scope estimates in this study because most of the industries surveyed were two-, not three-output. Due to data limitations (insufficient sample sizes for some industries, years; paucity of multi-output plants within multi-output industries, etc.), it was a struggle in most industries to construct a data set consisting of *two* aggregate output measures, let alone three. Of all the industries surveyed, only one, Men's & boys' formal & work clothing, displayed a clearly identifiable, frequently occurring bundle of similar goods among the firms in the samples that was greater than two in number (coats, pants, and vests). The data sets for most industries displayed either very little integrated production, or when their production was integrated, it was in a willy-nilly, highly variegated pattern which would have required collapsing many other highly variegated goods into single categories even to just form a two-good pairing scheme, which would not tell us much about scope economies.

[24] Friedlaender, Ann F., Clifford Winston and Kung Wang. "Costs, Technology, and Productivity in the U.S. Automobile Industry." *The Bell Journal of Economics*, Vol. 14, No. 1 (Spring, 1983), 1-20, p. 15.

The type of industry cost function used in the above analysis is the hedonic, quadratic, second-order Taylor approximation around the mean cost function similar to that employed by Friedlaender, Winston and Wang in their analysis[25] that is a function of a vector of factor prices *w*, and a vector of output quantities, *y*, and a dummy variable for time, *T*, that captures time-related changes in costs and technology (see discussion on industry selection and input vector data set below for explanation of specific variables used in this analysis, that vary by industry). I thus write the cost function as:

$$\begin{aligned} C &= \alpha_0 + \sum_i \alpha_i (y_i - \bar{y}_i) + \sum_j \beta_j (w_j - \bar{w}_j) + \delta_T (T - \bar{T}) \\ &+ \tfrac{1}{2} \sum_i \sum_m A_{im} (y_i - \bar{y}_i)(y_m - \bar{y}_m) + \tfrac{1}{2} \sum_j \sum_n B_{jn} (w_j - \bar{w}_j)(w_n - \bar{w}_n) \\ &+ \tfrac{1}{2} D_{TT} (T - \bar{T})(T - \bar{T}) + \sum_i \sum_j F_{ij} (y_i - \bar{y}_i)(w_j - \bar{w}_j) \\ &+ \sum_i D_{iT} (y_i - \bar{y}_i)(T - \bar{T}) + \sum_j D_{jT} (w_j - \bar{w}_j)(T - \bar{T}) + \varepsilon \end{aligned} \qquad (2)$$

where $C =$ total costs, $A_{im} = A_{mi} \forall i, m; B_{jn} = B_{nj} \forall n, j$; and ε represents the error term for the cost equation.

Cost functions were estimated for the eight industry conglomerations whose data sets were most well suited for such an analysis for 1850, 1860, and 1870. Of these eight, only four were estimated for 1880 due to a deficiency in the data for that year, which is missing data on individual input and output types, quantities and values.[26] This made a vector of output quantities and material input prices extremely difficult to construct, or even estimate. Nevertheless, an attempt to do so was made that involved assuming a fictional wholly integrated structure of industry with each firm producing a positive quantity of each good in its output vector in homogeneous proportion to the composition of output on the national average level, and using price data to divide out these output value shares to estimate the individual product quantities. The precise methodology and data used are described and presented in the Appendix to this chapter that is contained in the larger work this paper is based on.

Even some of the industry conglomerations for the earlier years contained missing or patchy data for output and input types, values, and quantities, which made construction of variables for total cost, input prices and output quantities difficult without chopping down the size of their data sets to near nothingness. Sufficient data on individual input and output type, value and quantity to form a data set consisting of enough observations with the full set of variables for at least two out of the three years was a prerequisite for an industry grouping for inclusion in the analysis.

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[25] Ibid., pp. 5, 9.

[26] This deficiency is not due to missing data (expert-collected or otherwise), but rather to the fact that the Census Office simply did not instruct its enumerators to collect any of these data that year, and instead merely reduced the measurement of raw materials and final products to their aggregate values. See Atack and Bateman, p. 180.

Industry conglomerations for the analysis were formed and selected based upon further criteria measuring the suitability of their respective data for such an analysis. For instance, another necessary feature of any data set for any industry was a clearly identifiable, frequently recurring pairing of similar goods in the bundle of goods produced by the multi-output firms in the samples. A willy-nilly, highly variegated pattern of goods production observed in an industry was a rejection because this would require collapsing many other highly variegated goods into single categories, which would not tell us much about scope economies of any one particular goods pairing. Discernable, frequently recurring pairing patterns that were observed in an industry group, or could be formed by aggregating the data of more than one industry group were thus an essential feature I looked for in determining which industry conglomerations were selected for the analysis.

By "frequently recurring", I mean there had to be an adequate number of observations of the two or three goods selected for the analysis within the samples, and there had to be at least a modicum of occurrences of the that good grouping being produced jointly by individual firms for evidence of any testable scope economies. Collapsing of similar outputs into single product categories was used for both these purposes of supplementing and bolstering a weak data set, and also to keep the number of outputs in the analysis down to two or a maximum of three. This is because if more outputs are used, the number of coefficient estimates explodes due to the interaction and squared terms in the type of cost functions employed in these type of analyses. [27]

These said criteria unfortunately excluded many industries from the analysis. Iron, which never had great sample sizes to begin with, did not appear to have been a heavily integrated industry. Those firms that were multi-product within its samples were an even smaller sliver out of the total. The multi-product firms produced different forms of iron, such as bar, pig, blooms, and "unspecified"—however, these did not appear in pairs. Collapsing them into a single category called simply "iron" was a possible option, but because their partner products were so highly variegated, a second goods category was off the table. They were very diverse casted items like doors, nails, wires, railings, and were listed in very variegated units definitions (tons, number, etc.).

Textiles was even more unmanageable. It had many multi-product firms, but the products were too highly variegated to collapse into a couple of neat categories of frequently-recurring pairs. Cotton-specializing firms alone, which were very few out of the total samples in the "Textiles" category, produced cotton goods, cloth, skirting, sheeting; different kinds of cloth, printed and unprinted; all in just a few samples! Wool-specializing firms, which were abundant in the samples, produced a myriad different things: woolens, yarn, rolls, satinets, flannel, blankets, carpets, cassimeres—in yards, pounds, feet, and number. It was nearly impossible to pick out a frequently-occurring pair combination. Virtually every multi-product firm had its own idiosyncratic output mix.

Intuitively, it would appear to make sense that an industry with a highly variegated product mix would be less able to exploit economies of scope than an industry that specialized

[27] Besides the modified version of Friedlaender, Winston and Wang's hedonic, quadratic, second-order Taylor approximation around the mean cost function that appears in this study, see also the translog flexible functional form found in Stewart, Kenneth G., *Introduction to Applied Econometrics*. Thomson Brooks/Cole, 2005, p. 504, as well as the quite more elaborate version of the same in Shin, Richard T. and John S. Ying. "Unnatural Monopolies in Local Telephone." *The RAND Journal of Economics*, Summer, 1992, Vol. 23, No. 2: 171-183, pp. 173-74.

in two or three main product lines. It is far more likely that an industry such as Men's Clothing, that specialized in coats, pants and vests, would have more economies of scope than a textiles firm that produced a great variety of products. An industry with a more manageable data set was therefore probably also more likely to be an industry with greater potential for measurable economies of scope.[28]

Consequently the data were mobilized for the handful of the industries with the most easily manageable data sets. Out of the thirteen major industry groupings compiled and discussed in the final scale analysis of Chapter Five, eight have been mobilized for the scope analysis here.[29] These are delineated below in Table 2, along with their respective output vectors. Of the eight I have organized as such, only five exhibit potential for robust *Sc* estimates; in other words, there was frequent incidence of the two- or three-good production among the firms in the samples across the years. The remaining three had problems such as infrequent appearance of firms with this pairing scheme, or frequent incidence of it in the earlier years, but infrequent or non-incidence of it in 1870, for example. These suitable, but less-than-exemplary industries appear denoted by an asterisk in the below table.

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[28] It is worthy of noting that while Iron was completely unsuitable for analysis, its vertical cousin, Foundaries, which consisted heavily of fabricated and casted items made from iron, was suitable, but did not exhibit potential for robust *Sc* estimates. It is also noteworthy that while Textiles was unsuitable for analysis, the sub-conglomeration of its vertical cousin, Men's clothing, possessed one of the best data sets in the samples for such an analysis. A comparison of industries in the entire group reveals that the better the data set, the more likely that industry was one that concentrated on final, rather than intermediate goods. The ratio of industries that concentrated more heavily on final goods to those that produced intermediate goods was much higher, six to one, in the industries that made it into the analysis than the same ratio among the rejects, which was just over one. This may lead one to believe that integration and economies of scope were much more heavily present in consumer goods than producer goods.

[29] The industry groups delineated here are all identical in their organization and method of analysis as presented in the Scale analyses of Chapters Four and Five with the exception of Men's clothing, which is here a sub-conglomeration of the conglomeration "Clothing" as it was organized and analyzed in Chapters Four and Five. While "Clothing" was composed of many inter-related industry groups, this new conglomeration is only composed of two of those that were originally included in "Clothing": those that fell under the rubric of SIC code 231, Men's And Boys' Suits, Coats, And Overcoats; and those that fell under SIC 232, Men's And Boys' Furnishings, Work Clothing. The remaining industry groups were excluded from this analysis because they were too few in sample size to perform any kind of meaningful analysis upon as separate industry groups, and/or could not be analyzed in aggregation with Men's Clothing as defined above due to a heterogeneous product mix.

TABLE 2
Industry Groupings and Output Vectors for Scope Analysis

Industry Grouping	y_1	y_2	y_3
Shoes	Shoes, prs.	Boots, prs.	----
Flour	Wheat flour, bbl.	Corn meal, bu.	----
Men's clothing	Coats, nos.	Pants, prs.	Vests, nos.
Millwork	Sashes, nos.	Doors, nos.	----
Furniture	Bureaus, nos.	Bedsteads, nos.	----
Tobacco*	Cigars, nos.	Loose tobacco, lbs.	----
Foundaries*	Castings, tons	Plows, nos.	----
Meat*	Beef, lbs.	Mutton, lbs.	----

I now complete the discussion of the above cost function with an analysis of the variables corresponding to the vector of input prices, *w*, and total costs, *C*.

The data for the industries selected for this analysis are sufficient for constructing variables pertaining to basic input costs, and are in keeping with the necessary data for a basic generic form of a cost function that states that total cost is a function of a vector of factor prices and (in my case of a multi-output industry) a vector of output quantities.[30]

Friedlaender, Winston and Wang had three basic input prices in their cost functions; price of labor, capital, and other factors/materials.[31] In this analysis, price of labor was computed by dividing the total amount paid in wages for the year for each firm by the total number of persons employed in each year to obtain an estimate of the average annual compensation per employee. Price of capital was computed by dividing capital expense by total aggregate value of output so as to produce a real capital/output ratio. In the final empirical analysis, this ratio was converted to prices of a single year so as to better measure the real cost of capital faced by firms in the sample. So an industry that say, experienced diminishing cost of capital relative to the value of its output over time was said to have obtained capital more cheaply in real terms. Price of materials was constructed by identifying one or two basic material inputs for each industry, obtaining prices for each input for which sufficient data was available (i.e. for which there were data of value of each input that could be divided by a respective quantity), and computing an average price for a basic unit input based on these fragmentary data. Finally, data for total costs for each firm were constructed by aggregating total capital expenses for each firm with the total amount paid in wages for year, and the aggregate value of raw materials for each firm for each year.

[30] See Stewart, Kenneth G., *Introduction to Applied Econometrics*. Thomson Brooks/Cole, 2005, p. 478, or Berndt, Ernst R. *The Practice of Econometrics: Classic and Contemporary*. Addison-Wesley, 1991, Eq. 3.3, p. 63.

[31] For a complete description of Friedlaender, Winston and Wang's and Shin and Ying's input prices data construction, see Shin and Ying, pp. 174-75 and Friedlaender, Winston and Wang, pp. 7-8.

V. ECONOMIES OF SCOPE: EMPIRICAL RESULTS AND ANALYSIS

In this section, I present the empirical results of the study, and provide a synopsis of the basic trends and patterns found in the results in order to determine the degree to which the results support the Chandlerian hypothesis in terms of which industries reaped the greatest benefits of scope economies with respect to the expansion of the railroad network as would be seen in ascending scope estimates over the time period in question.

Table 3 (a-h) presents the estimated economies of scope that were calculated for each industry for each year, using alternating means/totals raw data input for the input prices and output quantities (i.e. *w-means/y-totals*, *w-totals/y-means*, etc.) yielding four different input data sets, which are delineated in the far left column in each sub-table. Following Friedlaender, Winston and Wang's practice[32], for each of these means/totals combinations, I computed 3 different scope estimates using different values of small numbers in place of zeros for the disjoint cost predictions: 1, 10, and 100. The zero-replacement number used in each analysis is delineated in the far left column of Table 3 to the immediate right beside the input data set group. This amounted to 4 X 3 = 12 scope estimates per industry per year, and 24 for the industries for which 1880 data sets were able to be constructed. These were wholly separate analyses because a separate cost function that included the 1880 data was computed for each of these industries. These analyses appear as "double-deck" tables in the same sub-table as the 1850-70 analyses for the industries for which they apply, and are denoted by a hyphen followed by a capital "E" following each year in the year heading—the "E" denoting the fact that these analyses contain data for the year "Eighty". Varying these zero-replacement numbers usually did not create much variation in the results within each input data set.

[32]Friedlaender, Winston and Wang, pp. 15-16 and footnote 42, p. 16.

TABLE 3

Industry Groupings Scope Analysis Estimates, 1850-1870 [1880]

Table 3 (a). Shoes

Input Data	1850	1860	1870	1850-E	1860-E	1870-E	1880-E
WmnYmn1	0.240823	0.129158	0.132358	0.245361	0.117324	0.122775	-0.02895
WmnYmn10	0.244643	0.131503	0.134302	0.249056	0.119753	0.124811	-0.02636
WmnYmn100	0.28285	0.154953	0.153747	0.286017	0.144044	0.145168	-0.00042
WmnYtot1	-0.56536	-1.01692	-0.68307	0.151045	-2.19622	0.278608	119.6342
WmnYtot10	-0.56534	-1.01691	-0.68303	0.151021	-2.19613	0.278514	27.479
WmnYtot100	-0.56516	-1.01678	-0.68268	0.150786	-2.19513	0.277573	27.4713
WtotYmn1	0.999845	1.001957	1.000602	0.999866	1.00162	1.000243	1.001248
WtotYmn10	0.999837	1.001946	1.000578	0.99986	1.001612	1.000226	1.001242
WtotYmn100	0.99976	1.001841	1.000343	0.999804	1.001523	1.000051	1.001183
WtotYtot1	0.936064	6.387836	1.080372	0.950264	3.473437	1.03408	3.371701
WtotYtot10	0.936057	6.387769	1.080347	0.950258	3.473406	1.034062	3.371681
WtotYtot100	0.935986	6.387104	1.080097	0.950204	3.473099	1.033881	3.37148

Table 3 (b). Flour

Input Data	1850	1860	1870	1850-E	1860-E	1870-E	1880-E
WmnYmn1	0.23398	0.095499	0.217353	0.248558	0.090223	0.273712	0.018847
WmnYmn10	0.236613	0.098168	0.219447	0.251116	0.092903	0.275674	0.020971
WmnYmn100	0.262943	0.124865	0.240387	0.276695	0.119709	0.295293	0.042212
WmnYtot1	-0.50437	-0.58504	-0.56528	-0.53215	-0.58571	-0.5691	-17.4822
WmnYtot10	-0.50435	-0.58503	-0.56525	-0.53213	-0.5857	-0.56907	-17.482
WmnYtot100	-0.50415	-0.58491	-0.56492	-0.53193	-0.58559	-0.56877	-17.48
WtotYmn1	1.00379	1.002622	1.011563	1.004276	1.002974	1.014193	1.004743
WtotYmn10	1.003777	1.002614	1.011532	1.004261	1.002965	1.014155	1.004737
WtotYmn100	1.00365	1.002538	1.011215	1.004111	1.002876	1.013776	1.004673
WtotYtot1	231.7391	-66.9525	-2.2556	-8.11176	-6.60286	-1.30394	-0.40287
WtotYtot10	231.7361	-66.952	-2.25552	-8.11164	-6.6028	-1.3039	-0.40287
WtotYtot100	231.7067	-66.9469	-2.25482	-8.11043	-6.60221	-1.30341	-0.40284

Table 3 (c). Men's clothing

Input Data Set	1850	1860	1870
WmnYmn1	-0.00738	-0.2333	-0.24038
WmnYmn10	0.031579	-0.21385	-0.2038
WmnYmn100	0.419741	-0.02008	0.160771
WmnYtot1	-1.95338	-1.27885	-1.68623
WmnYtot10	-1.95078	-1.27856	-1.68365
WmnYtot100	-1.92486	-1.27566	-1.65784
WtotYmn1	2.01323	1.910025	2.375191
WtotYmn10	2.013234	1.91004	2.368561
WtotYmn100	2.013282	1.910197	2.302275
WtotYtot1	3.051633	0.673977	-0.77688
WtotYtot10	3.051404	0.673943	-0.77517
WtotYtot100	3.049124	0.673604	-0.75807

Table 3 (d). Millwork

Input Data Set	1850	1860	1870
WmnYmn1	1.499427	0.244278	1.059855
WmnYmn10	1.509642	0.247866	1.063521
WmnYmn100	1.604521	0.281322	1.09782
WmnYtot1	-0.12823	-0.25386	-0.57797
WmnYtot10	-0.12634	-0.25349	-0.58018
WmnYtot100	-0.10811	-0.24986	-0.60088
WtotYmn1	1.412856	1.685678	1.021653
WtotYmn10	1.412781	1.685634	1.021582
WtotYmn100	1.412036	1.685198	1.020874
WtotYtot1	-0.32334	-0.16941	1.133047
WtotYtot10	-0.32332	-0.1694	1.132967
WtotYtot100	-0.32314	-0.16935	1.132174

Table 3 (e). Furniture

Input Data Set	1850	1860	1870
WmnYmn1	-0.30969	0.075866	-0.3631
WmnYmn10	-0.24418	0.174312	-0.20124
WmnYmn100	0.408694	1.153916	1.415417
WmnYtot1	-0.98677	-0.97058	-0.8247
WmnYtot10	-0.98413	-0.9648	-0.79705
WmnYtot100	-0.9578	-0.90692	-0.52066
WtotYmn1	0.590909	0.941305	0.996353
WtotYmn10	0.612153	0.950839	0.931965
WtotYmn100	0.824608	1.046188	0.287822
WtotYtot1	0.552011	0.642028	-0.77488
WtotYtot10	0.552704	0.644568	-0.75713
WtotYtot100	0.559638	0.669969	-0.57966

Table 3 (f). Tobacco*

Input Data	1850	1860	1870	1850-E	1860-E	1870-E	1880-E
WmnYmn1	1.219094	1.705935	0.355234	2.076544	1.664364	0.282973	0.293539
WmnYmn10	1.218356	1.706433	0.355386	2.074298	1.664184	0.283615	0.294532
WmnYmn100	1.21098	1.711408	0.356902	2.051831	1.662381	0.290033	0.304461
WmnYtot1	0.124653	-1.38326	51.95966	0.030383	3.041498	0.262598	29.23821
WmnYtot10	0.124492	-1.38322	51.95618	0.030344	3.041421	0.262581	29.23815
WmnYtot100	0.122877	-1.38288	51.92135	0.029956	3.040646	0.262414	29.23755
WtotYmn1	0.940254	0.980794	0.984174	0.825232	0.915334	0.947792	0.96384
WtotYmn10	0.940204	0.98076	0.984153	0.825142	0.915272	0.947754	0.963826
WtotYmn100	0.939703	0.980416	0.983942	0.824242	0.914656	0.947373	0.963677
WtotYtot1	0.297212	0.540109	0.402834	0.111284	0.18506	0.163126	0.179722
WtotYtot10	0.297195	0.54009	0.402825	0.111271	0.185049	0.163119	0.17972
WtotYtot100	0.297027	0.539905	0.402736	0.111144	0.184934	0.163053	0.179703

Table 3 (g). Foundaries*

Input Data Set	1850	1860	1870
WmnYmn1	-1.15888	-2.92911	1.833433
WmnYmn10	-0.94733	0.38862	-0.96724
WmnYmn100	1.189063	33.59179	-29.1429
WmnYtot1	-0.99663	-0.89277	-1.04581
WmnYtot10	-0.99007	-0.84774	-0.97147
WmnYtot100	-0.92443	-0.39743	-0.22779
WtotYmn1	0.998074	0.963958	0.994719
WtotYmn10	0.9982	0.962351	0.994593
WtotYmn100	0.999455	0.946264	0.993314
WtotYtot1	1.757864	1.645903	1.007331
WtotYtot10	1.755296	1.612229	1.003602
WtotYtot100	1.729611	1.275475	0.966292

Table 3 (h). Meat*

Input Data	1850	1860	1870	1850-E	1860-E	1870-E	1880-E
WmnYmn1	1.319933	-2.3082	1.630131	1.18297	0.984964	1.299663	0.59736
WmnYmn10	1.316407	-2.30258	1.63129	1.183355	0.983382	1.29872	0.597415
WmnYmn100	1.281101	-2.24629	1.642793	1.187283	0.967604	1.289669	0.597976
WmnYtot1	-1.2992	-1.07997	4.221603	-2.0579	-1.70937	1.826761	111.3913
WmnYtot10	-1.29738	-1.07982	4.238871	-2.05589	-1.70913	1.823291	111.3911
WmnYtot100	-1.27926	-1.07832	4.417107	-2.03586	-1.70676	1.790437	111.3891
WtotYmn1	1.577558	1.22034	-5.51679	0.995498	0.99524	0.788896	1.001207
WtotYmn10	1.583855	1.22112	-6.42854	0.995477	0.995232	0.789069	1.001207
WtotYmn100	1.646826	1.228926	17.67061	0.995273	0.995156	0.790802	1.001201
WtotYtot1	-0.2145	-9.32862	-0.71746	0.958631	0.941393	0.649219	1.475725
WtotYtot10	-0.21655	-9.32362	-0.74514	0.958609	0.941384	0.649431	1.475724
WtotYtot100	-0.23704	-9.27364	-1.09325	0.958396	0.941295	0.651562	1.475714

Referring back to Table 1, it can be recalled that in the upper left hand quadrant are listed the industries that Chandler believed were the great industries that experienced these great impacts of the decline in transport costs and technological advance that led to large-scale production methods. Two of the industries that made it into the Scope analysis, Meat packing and Flour milling, are in this quadrant. So according to Chandler, we ought to see the most robust results in those two industries. The remaining industries all fall into one of the medium categories; either the lower left quadrant that refers to industries that experienced a high impact of technical progress and a low impact of transportation, or the upper right quadrant that refers to a low impact of technical progress but a high impact of transportation. In the high-tech/low transport quadrant, we find tobacco manufacture, clothing and shoes, and in the low-tech/high transport quadrant, we find millwork, furniture, and foundaries.

In terms of specific mention of which industries reaped the most scope economies in the United States before WWI, Chandler explains that it was mainly in the dynamic industries of food, chemicals, and machinery groups in which cost advantages developed through utilizing economies of scope led to investment in related products.[33] Since the latter two industries are not represented in our study, that leaves us only food groups in which to check for robust and ascending scope estimates, which mirrors the predictions made in the upper left quadrant of Table 1.

Consequently, it is in the industry groups of Meat and Flour that we ought to see the best results. Unfortunately, the weakness of the Meat data set, as an asterisked industry described above (and in further detail in the appendix to Chapter Six contained in the larger work this paper is based on) makes us cast a shadow of doubt upon the results obtained from it. But the good thing, though, is that for both Flour and Meat there are 1880 scope estimates obtainable, which more closely approaches the era in which Chandler claimed that the scope economies were more firmly in the saddle.

Given 12 or 24 scope estimates per industry per year, it was not hard to find some kind of ascending pattern in at least one of the input data sets for each industry. However, there was little consistency in which input data set this pattern was found, and it was often in the one that I thought to be the least intuitively pleasing of the four, which was *w-totals/y-means*. Nevertheless, there do appear to be some “winner” and “loser” industries among the bunch, using frequency of appearance of an ascending pattern within the four input sets as a criterion.

The two clear winners in the analysis are Shoes and, to a lesser extent, Flour. Shoes, which had one of the best data sets of the bunch, displays a more or less ascending and positive pattern of scope estimates in two of the four input sets, *w-totals/y-means* and *w-totals/y-totals* and also in the *w-means/y-totals* input set that included the 1880 data. One interesting phenomenon is the observance of a slight dip in the overall ascending scope estimates in 1870 in the *w-totals/y-means* and *w-totals/y-totals* input sets, followed by a rebound in the scope estimates for 1880 in the results for those input sets that included the 1880 data. This phenomenon mirrors that contained in many of the scale estimates of Chapters Four and Five, including that of Shoes, that displayed a dip in the MES for 1870 corresponding to the post-Civil War aftermath shock.

The skyrocketing 1880 scope estimates that appear in the *w-means/y-totals* input set for Shoes are by no means unique phenomena, as they are mirrored in the exact same input set for Meat and Tobacco. Meat displays a steeply ascending scope pattern in this input set, including in its 1850-70 estimates. Although such steeply ascending results are not seen in any of Meat’s

[33] Chandler, p. 92.

other input sets, these are nonetheless encouraging results considering the weakness of the Meat data (particularly its 1870 estimates), and considering the weak results of the other industries in the analysis; most of whom had much better data sets than Meat.

The same may be said for the results for Tobacco in its *w-means/y-totals* input group. While these are not the most consistently rising estimates to be found in Tobacco, which are to be found in its *w-totals/y-means* inputs group, they confirm a definite pattern: in 3 out of the 4 industries for whom we were able to construct 1880 estimates, we have skyrocketing 1880 estimates in the *w-means/y-totals* input group. These results, if the study were confined to this input group, would serve as testimony to the efficacy of our methodology. Recalling that the 1880 data sets were constructed as perfectly integrated industries with each firm producing a positive quantity of each good in its output vector in homogeneous proportion to the composition of output on the national average level, we would expect to see greater scope estimates for that year if there was any validity to the study, which indeed we do. While there are other instances of exploding estimates in other industries, such as in Flour for 1850 in its 1850-70 estimates in its *w-totals/y-totals* inputs group, another appearance of them in Meat for 1870 in its *w-totals/y-means* inputs group for 1850-70, and another appearance of them in Tobacco for 1870 in its *w-means/y-totals* input group for 1850-70, these are scattered incidents that do not form a consistent pattern of clustering in a single year and inputs group.

Meat and Tobacco also display the dip in the scope estimates for 1870 followed by a rebound for 1880 in their results for their input sets that included the 1880 data that mirrors that contained in Shoes and in the scale estimates of Chapters Four and Five; Meat in its *w-totals/y-means* and *w-totals/y-totals* input groups, and Tobacco in its *w-means/y-totals* and *w-totals/y-totals* groups, and to a lesser extent in its *w-means/y-means* group. Whether this phenomenon is due to the post-Civil War aftermath shock or merely the weakness of the data sets for those industries for that year is another matter. Since the only other asterisked industry in the analysis, Foundaries, has no 1880 estimates, we have no basis for comparison. However, since this 1870 dip is also present in two of the ascending input groups for Shoes, an industry with a very good data set, we cannot rule out these post-war depression forces as a possible cause. Considering that these dips are seen in 3 out of the 4 industries surveyed that had 1880 estimates, we must therefore view it as an indicator of a distinct pattern.

Furthermore, the Chapters Four and Five scale estimates also displayed the 1870 dip as occurring for Tobacco, Shoes and Flour, although not for Meat. This means that out of the three industries that displayed a 1870 MES dip that also made it into the scope analysis with a complete 1850-80 analysis—Flour, Tobacco and Shoes—that dip is present again in the scope estimates for two out of those three, Tobacco and Shoes. Thus there is a parallel between the scale and scope estimates showing that there was synchronicity between the two, as Chandler maintained. But we have produced new evidence here to indicate that the post-Civil War aftermath shock as described by many authors was indeed a real one that temporarily stymied economies of scale *and* scope; a factor not mentioned to any significant extent by Chandler, but is worthy of noting here in historical context. And our evidence indicates that scale and scope economies resumed in the era after 1870, as maintained by Chandler, and this is displayed in our results that show a recovery in full force as occurring by 1880. However, we must continue to bear in mind that these 1880 scope estimates assumed a fictional wholly integrated structure of industry.

It is quite strange that we do not see the exploding 1880 estimates in the *w-means/y-totals* input group for Flour with its good data set, whose results for that input group explode in the opposite direction, going down to a larger absolute value negative number for 1880. However, those disappointing results are offset by consistently rising scope estimates for its *w-totals/y-totals* estimates that included the 1880 data, and an overall ascending pattern for its *w-totals/y-means* estimates.

VI. SUMMARY AND CONCLUSIONS

In this study, our analysis of economies of scope yields results that are overall supportive of the Chandlerian hypothesis. Our method of empirical analysis, the *Sc* definition of economies of scope presented in Equation (1) that represents the percentage cost savings due to joint production, shows that in that in the food industries of Flour and Meat, which were the two industries among our analysis that were in the upper left hand quadrant of Table 1 that Chandler believed were the great industries that experienced these great impacts of the decline in transport costs and technological advance that led to large-scale production methods, we do see results that show an ascending scope pattern in at least some of their input data groups. Flour contains results that display this pattern more conspicuously across its input groups than the typical industry of the bunch. While Meat does not stand out as above the average in terms of this characteristic of an ascending pattern across input groups, the fact that it fares no worse, and in fact better than some of its counterparts despite having a very weak data set speaks volumes. Had better data been available for Meat, particularly for 1870, who knows how the results could have differed. The only surprise in the bunch that Chandler would not have anticipated was Shoes, which was probably the most robust industry in the bunch in terms of displaying ascending scope results. One may say this is really not that much of a surprise, considering its very good data set. However, Clothing, which also had a very good data set, did not fare that well in terms of observation of an ascending pattern. So overall, we must view the robust results of Shoes as an unanticipated surprise result. The efficacy of our methodology is confirmed by the presence of exploding scope estimates for 1880 in 3 out of the 4 industries whose data included 1880 estimates that were derived from estimates of a perfectly integrated industrial structure, and by a dip in the scope estimates for 1870 followed by a rebound in 1880 seen in 3 of those 4 industries, which must be viewed as a continuation of a pattern observed in Chapters Four and Five that displayed the same frequently-occurring phenomenon in its scale estimates.

Assessing these scope estimates in the context of the overall findings of the analyses of the previous chapters and the degree to which they support or contradict those of Chandler, we must view them as a bright spot on an overall gloomy prognosis for the empirical validity of the Chandler hypothesis. The preliminary comparison of the development and growth of the American, British and German railroad networks in Chapters Two and Three failed to produce any concrete evidence that a greater expansion of the railroad systems of the United States and Germany at mid-century and resultant vastness thereof with respect to Britain *circa* the 1870's was a paramount factor contributing to a more concentrated industrial sector intensive in the new science-based technologies of the Second Industrial Revolution in those countries. Further comparison and analysis of rates of railroad physical capital accumulation, railroad mileage per square mile of national territory, and the stock of railroad financial capital in combination with the revealed history detailing the tremendous impact of the construction of the railroads on the British iron and coal industries and financial system point to an impact of the railroads on the British industrial landscape that may have been just as great as that experienced by the United States and Germany, but of a different character.

In the empirical analysis of economies of scale that focused on American industry as it developed from 1850-1880 in Chapters Four and Five, we also find mixed evidence in support of Chandler's contention that the growth of the American railroad network expanded markets and augmented the American financial sector such that the result was a more concentrated, large-scale mode of industrial organization characterized by extensive and increasing economies of scale in sync with the growth of its extensive railroad system that was inaugurated by around 1870 and ought to have been in full bloom by 1880. It was found that even when the industries that Chandler said were the great industries that experienced the greatest impact of the decline in transport costs and technological advance that led to large-scale production methods were re-tested using superior data in place of that which was found to be flawed, or split into finer product group distinctions so as to cleanse and distill a product group of a flawed component, there were little scale economies achieved by 1880; the time by which, if Chandler's theory were correct, there ought to have been. In our results that measured and quantified economies of scale through the method of Minimum Efficient Scale (MES), the general pattern of the industries surveyed is relatively great economies of scale as having been achieved by 1860, followed by a pronounced dip at 1870, and only modest increases by 1880 that often do not regain their 1860 levels. A similar examination of a sample of industries that Chandler believed were less strongly impacted by the technological and transportation improvements of the era for the sake of comparison yielded results that were no better or worse. While the dips of 1870 made sense in the context of the Civil War aftermath shock, there is no rational explanation for the extremely low MES's observed at 1880 in the context of Chandler's hypothesis. If 1870 were the benchmark period in which to begin to expect to see the effects of transportation improvements upon scale economies in American industry, then 1880 is certainly a liberal allowance in terms of time to expect to see the effects of the railroads upon market expansion and financial intermediation to have been taking place; post-war resumption of investment and capital accumulation notwithstanding.

In taking a retrospective assessment of these omnipresent dips at 1870 seen in both the scale and scope estimates, it appears that Chandler may have been incorrect in pointing to that date as the benchmark period in which to begin to expect to see the effects of transportation improvements upon scale and scope economies in American industry. He may have underestimated or overlooked the severity and duration of the Civil War aftermath shock that greatly retarded investment and capital accumulation in the economy well into the 1870's, not producing a recovery until the 1880's. Or perhaps the impact of the railroads upon scale and scope of industry were not felt until much later than Chandler believed they were—say 1900, as Atack's 1985 study suggested.[34]

[34] Atack, p. 47.

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Internet Resources

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Manufactures, 1850-1880, are presented in a common format with uniform integrated coding to facilitate their use, and are available on line and downloadable for free through the Inter-university Consortium for Political and Social Research (ICPSR) at the University of Michigan (http://www.icpsr.umich.edu/index.html) and at http://www.vanderbilt.edu/Econ/faculty/Atack/atackj.htm.

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The coding method by which industries are categorized in these data is delineated in detail in the U.S. Office of Management and Budget, *Standard Industrial Classification Manual*, ([GPO, 1987], Dun & Bradstreet Information Resources, 1989.) cited above, and also at http://www.osha.gov/pls/imis/sicsearch.html, the exact page of the site of the U.S. Department of Labor Occupational Safety & Health Administration that allows the user to search the 1987 version SIC manual referred to above by keyword.