Cleveland from Startup to the Present:

Innovation and Entrepreneurship in the 19th and Early 20th Century

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A report of the Center for Regional Economic Issues

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I. INTRODUCTION

Shocked by staggering job losses in their "anchor" industries during the 1970s and early 1980s and by a rate of growth that suddenly seemed slower than the national average, virtually all older industrial city-regions in the U.S. have struggled for nearly two decades to rebuild their industrial bases.[1] Many industries had prospered for over a century in these city-regions. As decline continued, terms like "Rustbelt/Sunbelt" and "deindustrialization" became part of our vocabulary. As one response to decline, the industrial states turned to Boston's Route 128 and California' s Silicon Valley as models for redevelopment.[2] In most cases, efforts based on these models have produced few large successes.[3]

Cleveland and Northeastern Ohio constitute of the best known of these older industrial city-regions. Current efforts to revive Northeastern Ohio's economy raise some simple but fundamental questions that apply equally to other older industrial metropolitan regions that are seeking new, high-tech industries: What made Northeastern Ohio, an innovative, entrepreneurial place in the nineteenth century, and then allowed it to succeed for over 100 years in nurturing new companies and industries? Why did the region then seem to lose its entrepreneurial capacity? And why has it been so difficult to turn such older industrial economies around?

On one level, the answer may be fairly easy: It is often said that metropolitan regions have life-cycles which reflect the life-cycles of their industries. As established industries mature and decline, a city eventually loses its ability to create new industries and the so-called "incubator" or "seed" function which creates new industries shifts to other regions.[4] But these

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[1] An important part of the struggle has involved efforts to develop knowledge of regional economic growth and decline, and the effectiveness of various programs and policies.

[2] Coburn, Christopher, 1995 "Partnership: A Compendium of State and Federal Cooperative Technology Programs." Columbus: Battelle Memorial Institute. Also see http://www.ssti.org/

[3] See Harvard Business School, "The Cleveland Turnaround (A, B. C. and D): Responding to Crisis" (1978-1988), August 24, 1998, pages 1-25, 1-19, 1-27, and 1-14. Also see See Michael S. Fogarty and Amit K. Sinha, "Why Older Regions Can't Generalize from Route 128 and Silicon Valley," in Lewis M. Branscomb, Fumio Kodama and Richard Florida, eds., Industrializing Knowledge (Cambridge, MA: MIT Press, 1999), 473-509. Also see Fogarty, Michael S., "Cleveland's Emerging Economy: A Framework for Investing in Education, Science, and Technology," (Cleveland: Center for Regional Economic Issues), May 12, 1998.

[4] See, for example, R.D. Norton, City Life-Cycles and American Urban Policy (New York: Academic Press, 1979). (This form becomes a relatively small, less visible component as the agglomeration grows in size and complexity.) The view of city life-cycles is also consistent with Joseph Schumpeter's analysis of "creative destruction," which characterizes the roots of city life-cycles as technological. Also see Forrester, Jay W., Urban Dynamics, The M.I.T. Press, Massachusetts Institute of Technology, Cambridge, MA, and London, England, 1969 and Pred, Allan R., The Spatial Dynamics of U. S. Urban-Industrial Growth, 1800-1914: Interpretive and Theoretical Essays, The M.I.T. Press, Massachusetts Institute of Technology, Cambridge, Massachusetts, and London, England, 1966.

are very broad statements: on another, more practical level, we need a deeper understanding of the mechanisms that creating regional prosperity – and that sometimes create regional decline. What is it, we want to know, that allows some urban agglomerations to develop a "critical mass" (to use another metaphor), to produce increasing returns on investment – what allows some regions to exhibit cumulative and self-reinforcing growth? Turning the question on its head, why have so many urban regions lost this capacity? Why have once-prosperous places lagged since the 1970s?[5]

Before we undertook this investigation, no one had adequately documented –let alone explained -- the origins of Cleveland's industrial agglomeration. Nor had anyone adequately investigated its demise as a leading regional economy. (The same can be said about other older industrial regions.) In Cleveland's case, community leaders began a search for causes almost twenty years ago.[6] Initially, business leaders pinned the region's decline on high labor costs and unions. Academics identified many possible causes for decline, ranging from the energy price rises of the 1970s to reduced transportation costs to a decline in innovation and productivity growth, to allegedly poor amenities and environmental quality and inadequate public infrastructure, to poverty and racism.[7] In our view, two elements are missing from all of these arguments. None starts with an examination of the sources of Northeast Ohio's century-long period of success. And none offers an economically persuasive understanding of the mechanisms that encourage growth to occur.

Implications

Good knowledge is essential for effective policy. Some policy efforts have simply revealed that our knowledge is inadequate. Like many other communities searching for a "magic bullet," Cleveland leaders concluded in the mid-1980s that a lack of venture capital accounted for the low startup rate of new high-tech businesses in the region. In response, they created a

[5] For an analysis of the sources of the growth of the economy of the New York metropolitan region from 1870 to 1910, see David C. Hammack, *Power and Society: Greater New York at the Turn of the Century* (New York: Russell Sage Foundation, 1982; Columbia University Press paperback, 1987), chapter 2.

[6] Gurwitz, Aaron S. and G. Thomas Kingsley, The Cleveland Metropolitan Economy, Rand, Santa Monica, CA, March 1982.

[7] See Bradbury, Katharine L., Anthony Downs, Kenneth A. Small, Futures for a Declining City: Simulations for the Cleveland Area, Academic Press, New York, London, Toronto, Sydney, San Francisco, 1981.

new venture capital fund.[8] Yet today most of this fund's investments are located in other regions. In fact, Cleveland investors have made many venture investments – at least one group manages a multibillion dollar pool of venture capital funds from the center of the city itself – yet the Cleveland region has produced very few new high-tech companies in recent years, and certainly not a new industry. The venture capital fund effort has in effect served as an effective experiment, demonstrating that the region's problem is not a lack of local capital for new ventures. In this paper we hope to make a more direct contribution to policy-relevant knowledge about the region's economic development, and about its current challenges.

Two Broad Hypotheses

Underlying our paper are two broad hypotheses about regional innovation systems:

1) To achieve increasing returns and a high rate of productivity growth, a region must develop a significant source of invention and innovation, with national networks linking inventors and entrepreneurs to investors and to local firms and specialists.
2) To produce successful transitions as the economy evolves, local innovation systems must both support existing industries and facilitate the development of new industries.

We evaluate these hypotheses through three pilot case studies of Cleveland and Northeastern Ohio from about 1820 to World War II. Deriving an answer to our basic question -- What made this region such an innovative, entrepreneurial place in the nineteenth and early twentieth centuries, and what has been missing in recent years? -- presents a significant challenge for at least two reasons.

First, there are really two parts to the question:

- What explains Northeastern Ohio's emergence as a major industrial region and its 100 years of continuous growth?
- What factors would assure continued growth and development [9] as markets and technologies change over time?

These are very big question. A satisfactory answer requires a full analysis of the local mechanisms involved in innovation.[10] Unfortunately, knowledge of this sizable landscape is

[8] N. Bania, R. Eberts, and M. Fogarty, "Universities and the Startup of New Companies: Can We Generalize from Route 128 and Silicon Valley?" The Review of Economics and Statistics, (November 1993).

[9] See R.D. Norton, op. cit

scarce, and what exists in the literature is fragmented and often conflicting. We will seek below to offer a framework that will enable us to piece together a scattered and fragmented body of relevant literature.

Our big questions and the inadequacy of previous analyses give us our second major challenge: a persuasive analysis requires new time-series and new historical data (concerning patents, industry employment, industry productivity, business firms, investors, legal arrangements, and other matters). Some of the most basic data for earlier periods—data whose availability we take for granted today—is very difficult to obtain and requires great effort to assemble into shape for testing new hypotheses. For example, it took nearly a year to develop the database of nineteenth-century patents we constructed for this study. (Only patents since 1975 are available on the U.S. Patent & Trademark Office website.[11]) It also required very extensive work to create a second database that (although still incomplete) proved very useful, based on the Cleveland firms listed in the rating books published by Dun & Bradstreet and its predecessors in 1860, 1880, and 1900, and 1925.

Contributions

Our paper makes several contributions. First, we assess and interpret an extensive literature, providing a new perspective on Northeastern Ohio's economic history and in general on studies of the economic development of metropolitan regions in the United States. We consider the older literature from today's vantage point—especially today's concern with entrepreneurial activity, innovation, and a dramatically increased emphasis on university-industry interactions as the mechanism for creating new industries.[12]

Second, we document the growth of Cleveland's core industries and the region's economic performance from 1850-1997. We seek to establish a sound benchmark for assessing economic change, to identify the major turning points in the region's economic development,

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[10] An alternative research strategy would be to focus on one specific factor, such as the role of patents and entrepreneurs in Cleveland's electrical products industry in the latter part of the nineteenth century. Instead, we chose to take the broader perspective in order to assess the range of possible explanations. For example, before undertaking this study there was no evidence that patents provide an important window on innovation within cities during the latter half of the nineteenth century.

[11] See http://www:uspto.gov.

[12] Fogarty, Michael S., Amit K. Sinha, and Adam B. Jaffe, "Sustaining the New Economy: An Analysis of the R&D Networks that Maintain California's Position of a Preeminent Source of World Technology," A paper prepared for the Public Policy Institute of California (2000).

and to assess the competitive performance of Northeast Ohio's dominant industries. Because productivity plays a central role in the growth and development of cities and regions, we developed a new long-run regional productivity series (value added per production worker as reported in the U.S. Census of Manufactures) for the long period from 1879 through 1997. Third, we developed a new patent database and analyzed patent activity by metropolitan region and technology for the period 1880-1900.[13] In addition, we developed a separate database of about 2,500 particularly "important" patents by technology for the period 1870-1900. Our primary objective was to gain insight into the origins of leading inventions and their connections to emerging industries, regions, and entrepreneurs.

Fourth, we provide the first evidence in support of our basic hypotheses by examining growth of Cleveland's metal-working industries from the mid-1800s through 1925. Our analysis shows that the industries grew steadily for nearly a century: they focused first on the production of iron, steel, and other metals; then on the production of basic metal commodities; then shifted to the production of increasingly complex and valuable devices. We demonstrate a close connection between patenting and growth and change in Cleveland's metal-working industries. We also establish links between the region's patents, inventors, entrepreneurs, firms, and industries – and between Northeast Ohio and New England. We refer to these networked activities as entrepreneurial-innovation clusters. The mechanisms underlying these clusters help explain the region's growth; changes in these mechanisms help explain its relative decline. Fifth, we used the patent data to provide the first statistical test of the basic hypothesis: A critical mass of local inventions was key to a region's growth during the last part of the nineteenth century. The statistical results are consistent with evidence developed from our study of the metal-working industries.

In short, we show that Northeast Ohio did, in the years after the Civil War, develop a significant source of invention and innovation with national networks linking inventors and entrepreneurs to investors and local industry. From its first development as a key hub linking the Great Lakes with the Northeast, Northeastern Ohio benefited from close ties with the investors and the advanced metal-working industries of New England, with the national market-makers in

[13] Pred, Allan R., The Spatial Dynamics of U. S. Urban-Industrial Growth, 1800-1914: Interpretive and Theoretical Essays, The M.I.T. Press, Massachusetts Institute of Technology, Cambridge, Massachusetts, and London, England, 1966. Also see Thompson, Wilbur R., "Locational Differences in Inventive Effort and Their Determinants," The Rate and Direction of Inventive Activity: Economic and Social Factors (Princeton: Princeton University Press, 1962), 253-272.

the New York Metropolitan Region, and with geological and mineralogical specialists in New England, New York, Pennsylvania, and Washington, D.C.

For over one hundred years, Northeast Ohio successfully negotiated a series of transitions, as its local innovation systems supported both existing industries and the development of new industries. The region emphasized materials processing and the production of more and more complex and more and more precisely designed goods, ranging from auto parts to pumps to office equipment to household appliances. It began in the age of steam, but made notable contributions in gas and oil, and also in electricity. In negotiating these transitions, Northeast Ohio drew both on its links to the Northeast, and on its significant local design and production and market-making skills.

We seek to make these contributions through Sections II – V:

Section II utilizes population trends from 1820-2000 and the region's productivity trend to put Cleveland's experience in historical perspective. These trends, which show a period of economic takeoff, slowdown, and eventual decline, were shaped by the growth and decline of the region's industries. We use the data to break Cleveland's history into three broad periods: startup, buildup of the agglomeration, and transition. This section also includes an analysis of the region's industries from 1850-1920. Below the surface sit the specific industries that became Cleveland's industrial base (steel, metal-working, chemicals, etc.). In addition, Section II pulls together the core ideas, views, and hypotheses gleaned from the literature and our rethinking of evidence and hypotheses to characterize the three stages. We then offer our first assessment of the literature and evidence to begin to answer the study's main question.

In Section III we look for evidence in support of our first hypothesis by focusing on Cleveland's metal-working industries from the mid-1800s through 1925. Our analysis -- of all large and middle-sized firms in those industries, of "millionaires" in 1892, and of patents granted to inventors in Northeast Ohio – documents the growth of a complex of related industrial clusters over nearly a century. Starting with a cluster of firms engaged in obtaining ores and fuels and producing metal, the region added first a nut-and-bolt, hardware, and other basic metal commodity cluster, then several clusters involved in the production of increasingly complex and valuable devices. The findings demonstrate a close connection between patenting, entrepreneurship, and growth in Cleveland's metal-working industries.

Section IV explains the development of our national patent database for 1860, 1880, and 1900, and our method for sorting patents into cities, technologies, and industries. This section also explains our analysis of a report listing the 2,300 "important" patents from 1871-1900 identified by the U.S. Patent Office in 1900. Our analysis of patent data on a national basis puts the regional story into its larger context.

Section V develops a simple statistical test of the basic hypothesis: A regional economy in the late nineteenth century achieved stronger economic performance when it produced important patents and was highly innovative. We test this hypothesis against our new estimates of growth in value-added by manufacturing from 1880 to 1900 for 48 U.S. cities. The Tests support our hypothesis.

Finally, the last section draws several conclusions, discusses implications, and identifies important areas for future research.

II. DEFINING THE PHASES OF NORTHEASTERN OHIO'S ECONOMIC DEVELOPMENT

Explaining Northeastern Ohio's economic performance over a century and a half is a challenge. An extraordinarily large number of factors shaped the region's economic history (wars, depressions, major transportation and communications investments, discovery of new resources, development of new technologies, waves of immigration, the rise and fall of the tariff, the drive of particular entrepreneurs and investors, and more).[14] Until the mid 1980s, with the proliferation of academic papers and media stories about Silicon Valley and Route 128, education, technology, and a city's entrepreneurial climate were rarely mentioned. Now these factors have moved to the top of the list of possible explanations for long-run regional growth.

The purpose of this section is to describe the framework we have developed for organizing this study and to discuss several important hypotheses and implications. We begin by using two basic data series we have assembled to identify the main phases of the region's remarkable economic history:

- the metropolitan region's population trend since the first Census in 1790
- the Cleveland industrial district's average productivity, or value added per production worker, from 1879 through 1997

Together, the two charts shown below tell an interesting, though incomplete, story. Two points are particularly noteworthy: Northeast Ohio grew quite steadily over a long span of about one hundred years, with a rate of growth that surpassed the Baltimore and Cincinnati regions after the Civil War and Pittsburgh after the 1880s. Northeast Ohio began to falter after 1940, finding it difficult to make the transitions that would allow it to maintain its relative position. Northeast Ohio's population size has actually declined, relative to the nation as a whole, since the 1970s.

Population Trend Since 1790

Figure 1 shows both Northeast Ohio's absolute population and the share it represents of the U.S. total from 1790 to 2000. (See the Appendix, Figure A1, for a similar chart incorporating several Great Lakes metropolitan areas.) Clearly, a particular region's share of U.S. population will increase if the area's economic growth is strong relative to other places; it will fall if its economic performance lags that of other regions. Overall, Northeast Ohio's population share grew continuously until about 1970, after which it declined sharply due to industrial decline.

[14] See Harvey S. Perloff, et al, Regions, Resources and Economic Growth (Lincoln: University of Nebraska and Johns Hopkins Press, 1960) for an excellent presentation of basic economic trends in U.S. regions from the mid-nineteenth century until the mid-1950s. This 700 page book also underscores the difficulty of explaining why some regions grow and other decline.

Northeastern Ohio's share of U.S. population dipped twice (once in the mid-1800s and then briefly following World War II), and then began a continuous downward trend beginning about 1960.

Productivity: Long-Run Economic Performance

Perhaps the best overall measure of economic performance is productivity. Figure 2 tracks the Cleveland industrial district's average productivity in manufacturing (valued added per production worker) from 1879 through 1997, using new estimates we have developed with data we have pieced together from various (and not always strictly compatible) U.S. Census of Manufacturers reports. From 1879 to World War II, the Cleveland district's productivity grew relative to that of the U.S. as a whole. Shortly before the beginning of World War II, the district's productivity was more than 20% above the national level. Following World War II, the region's productivity began a period of relative decline. The productivity decline began more than a decade before the region's population started its relative decline. Both declines have continued to the present.

The period of productivity growth coincides with the buildup of Cleveland's industrial agglomeration. Most observers think of the 1970s as the decade when the Manufacturing Belt fell into its sharp industrial decline, but the productivity data make it clear that the region's industrial decline began much earlier. Given that there is an average time lag of roughly 6-15 years between initial research and development and the appearance of measurable economic effects, *Cleveland's relative productivity decline may have begun as early as the Depression of the 1930s*.[15]

Phases of Development

We can use Figures 1 and 2, coupled with other data, to roughly define Northeastern Ohio's phases of development, and then offer several broad hypotheses to explain them. We will supplement the two charts with data on important events, infrastructure investments, the growth of specific industries, and technology developments.[16]

At the risk of oversimplifying, the data in Figures 1 and 2 suggest that Northeast Ohio's economic history can be divided into three broad periods:

[15] For analysis of R&D lags, see James D. Adams, "Fundamental Stocks of Knowledge and Productivity Growth," Journal of Political Economy, 98(41), pp 673-702, 1990.

[16] There exist a variety of measures that could be used to define stages, including: 1) external events (e.g., the Civil War, Depression of the 1930s); 2) the role played by specific dominant industries (e.g., iron & steel, petroleum refining, the automobile), technology (e.g., electricity), or development of crucial infrastructure (e.g., canals, railroads, telegraph); and 3) clear distinctions of rates of growth and decline.

Figure 1: The Cleveland Region's Population from 1790 to 2000

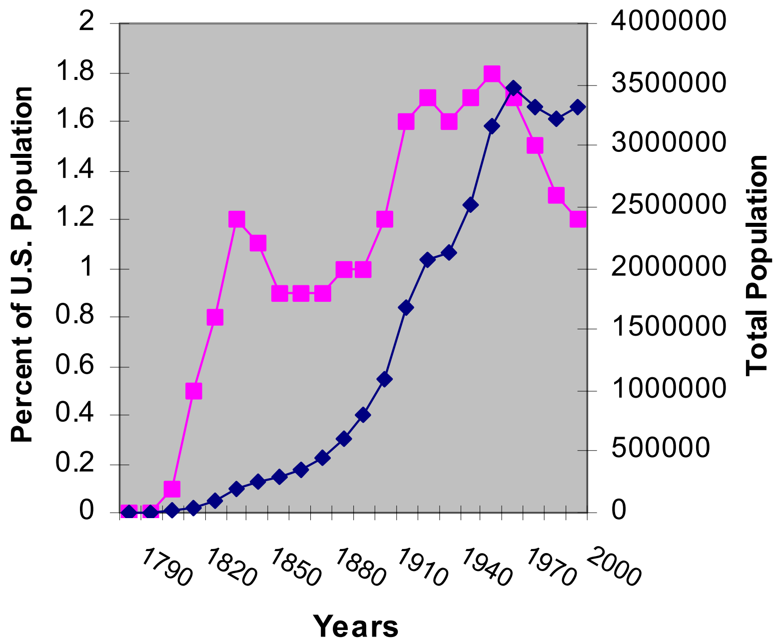
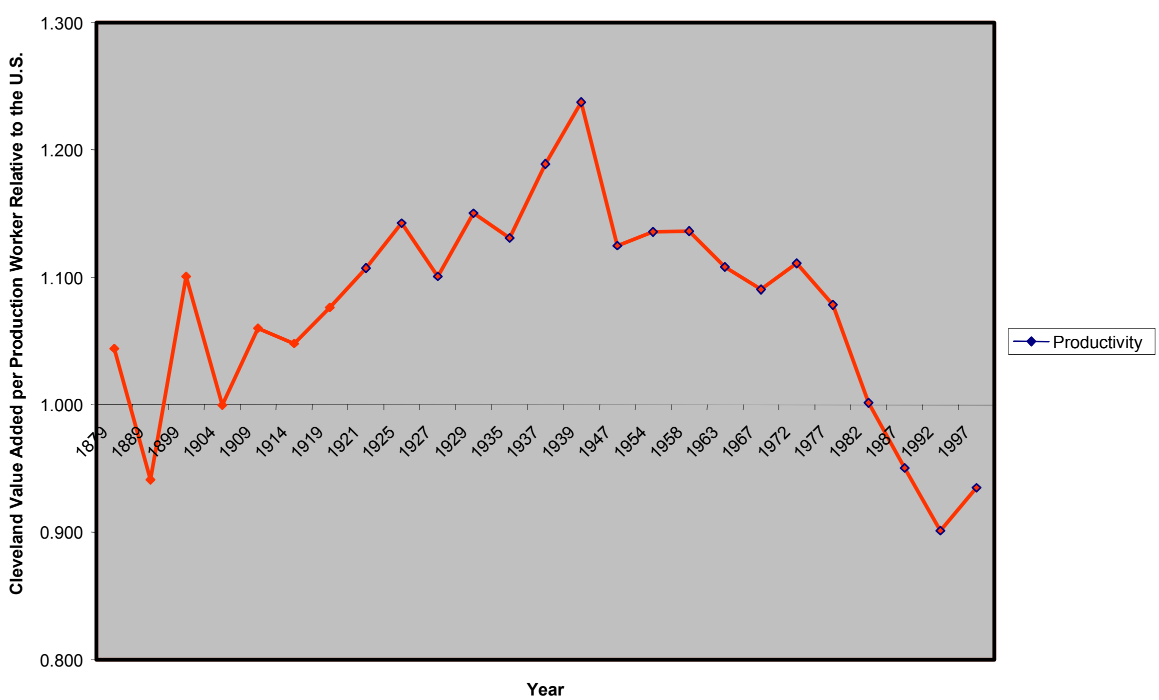


Figure 2: Cleveland's Manufacturing Productivity Relative to the Nation's Since 1879



1) startup -- in two parts, 1800-1840 and 1840-1880;
2) buildup of the agglomeration, 1880-1930;
3) transition: challenges in the 1930s and 1940s, post-World War II slow-down, absolute decline from 1970 to the mid-1980s.[17]

In this paper we focus primarily on phase 2 in a way that allows us, we think, to offer some useful speculation about phase 3. The following section briefly characterizes each phase and offers a broad hypothesis to explain its dominant pattern of growth. Our summary characterization for each phase is derived from our assessment of the literature and our research.

Stage 1. Startup (1810-1840 and 1840-1880)

> **Hypothesis:** Growth is determined by the region's *cost advantage* explained by access to important natural resources and markets – and also by the region's links to expertise and capital from the Northeast.

Northeastern Ohio's "startup" story perfectly fits Classical Location economics.[18] Of course, infrastructure investments--particularly investments in the canal system and railroads, but also in the telegraph--played a crucial role in determining Cleveland's cost advantage. Prior to the canal system, Ohio's goods were kept out of national markets by high transportation costs.[19] It's not uncommon to hear remnants of this explanation for Cleveland's growth well beyond 1880. It is crucial to note, however, that investors also brought critical scientific and technological knowledge to bear on efforts to locate the ore, coal, oil, and chemical deposits that

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[17] Hoffman identified three primary periods in his study of Cleveland from 1825 to 1920: 1825-53 (rail); 1853-1880 (rail fully integrated); and 1886-1920 (peak in 1920).) See Naphtali Hoffman, The Process of Economic Development in Cleveland, 1825 – 1920, Dissertation, Case Western Reserve University, Department of Economics, Thesis Advisor: William Peirce, 1981. Using state-level data on income per capita and unemployment, Richard Vedder and Lowell Galloway also identify 1880 and 1930 as the two key turning points in "Economic Growth and Decline in the Old Northwest," in David C. Klingaman and Richard K. Vedder, editors, *Essays on the Economy of the Old Northwest* (Athens: University of Ohio Press, 1987), pp. 299-318.

[18] See, for example, Hoover, Edgar M., An Introduction to Regional Economics (Second Edition), Chapter 4 (New York: Alfred A. Knopf), 1975.

[19] The classic account of canal development in this region is Harry Scheiber, *Ohio Canal Era: A Case Study of Government and the Economy, 1820-1861* (Athens, Ohio: The Ohio University Press, 1969). An excellent essay on the economic development of the Great Lakes region from Minnesota to Ohio is William N. Parker, "Native Origins of Modern Industry: Heavy Industrialization in the Old Northwest before 1900," in David C. Klingaman and Richard K. Vedder, editors, *Essays on the Economy of the Old Northwest* (Athens: University of Ohio Press, 1987), pp. 243-274. For Northeastern Ohio's economy before the Ohio Canal, see Ruth J. Milne, "The Economic Development of Cleveland: 1796-1827" (Cleveland: Case Western Reserve University, M.A. Thesis, 1994); for an account of the development of the economy of Northeastern Ohio, see David C. Hammack, "Economy," *Encyclopedia of Cleveland History*, 2nd edition (Bloomington: Indiana University Press, 1996), pp. 371-376; available on the web at ech.cwru.edu).

supplied Cleveland with critical raw materials after the 1850s. Cleveland benefited greatly from its location at the crossroads of trade in timber, iron ore, coal, and other materials – but it also benefited from the knowledge, skill, and energy of those who were seeking those materials. By the 1880s, Northeastern Ohio supported an internationally significant cluster of experts in the application of scientific knowledge to the search for materials.[20]

From the late 1840s on, Cleveland was at the center of construction work that gave Ohio more miles of railroad track than any other state by 1860.[21] Many of Cleveland's early business leaders built national businesses through this work: Selah Chamberlain and Stillman Witt, who moved from New England to Cleveland in the late 1840s to build the Cleveland & Pittsburgh Railroad and stayed to develop railroads, iron mines, and banking across the Old Northwest; Jeptha Wade, who led what became the Western Union Telegraph Company from a base in Cleveland after 1856; Zenas King and Amasa Stone, who developed two of the nation's biggest bridge-building companies in Cleveland from the 1850s. Access to iron and steel and to skilled labor also drew New England-born shipbuilders Ahira Cobb and Alva Bradley to Cleveland from Vermillion in the 1860s, and helped Bradley and others develop a substantial shipbuilding industry on the banks of the Cuyahoga.[22]

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[20] Among these experts were Albert Michelson of the Case School of Applied Science and Edward Morley of Western Reserve University, whose famous 1886 experiment advanced knowledge of light and influenced Albert Einstein. On the aggressive use of scientific knowledge to locate mineral deposits in the Great Lakes region, see Gavin Wright, "Can a Nation Learn? American Technology as a Network Phenomenon," in Naomi Lamoreaux, Daniel M.G. Raff, and Peter Temin, eds., *Learning by Doing In Markets, Firms, and Countries*" (Chicago: University of Chicago Press for the National Bureau of Economic Research, 1999), pp. 307-310. Cleveland was very well located with respect to majuor deposits of iron ore, coal, copper, and other materials, and became a center for such searches, although the key institutions were the Pennsylvania State Geological Survey, the University of Pennsylvania, Yale, and the Columbia University School of Mines. The region's property-right laws, ability to provide law and order, and access to capital also gave it very important advantages, especially over areas in the South. See, for example, Christopher Waldrep, *Roots of Disorder: Race and Criminal Justice in the American South, 1817-80* (Urbana: Univ of Illinois Press, 1998).

[21] Scheiber, *Ohio Canal Era,* p. 271.

[22] For information on Chamberlain, Witt, Wade, King, Stone, Cobb, and Bradley, see Van Tassel and Grabowski, *Encyclopedia of Cleveland History*, and David D. Van Tassel and John J. Grabowski, editors, *Dictionary of Cleveland Biography* (Bloomington: Indiana University Press, 1996), and additional material on the related website, www.ech.cwru.edu. All the people listed here appear on the 1892 list of million-dollar fortunes published by the *New York Tribune.*

Stage 2. Buildup: Cleveland's Entrepreneurial Peak (1880-1930)

> **Hypothesis:** Northeastern Ohio's economic growth was increasingly determined not just by classic location advantages, but also by the development of increasing returns associated with the buildup of the agglomeration and the increasingly complex character of its products. The region developed self-generating concentrations of entrepreneurs, firms, and experts skilled in metal-working and related technologies. In this process, it drew strongly on Northeastern expertise and capital, on European expertise, and on increasingly close links with other industrial regions around the Great Lakes, especially Chicago and Detroit.

As we will see in the next part of this paper, Northeastern Ohio's manufacturing strength developed as metal-working and related industries grew through a process that continued over nearly a century. It began with the production of metal; added the manufacture of basic metal commodities and work on rails, bridges, and ships; then built on these assets to produce more and more complex and valuable metal-based devices. This process required both invention and entrepreneurship. The region's growth resulted from the intensive use of technology originating elsewhere—especially in New England and New York but also in Great Britain and Germany—as well as in Northeastern Ohio. Operating in national markets, independent inventors were the nation's primary source of new technology.

Did Cleveland become highly innovative and entrepreneurial, or was its growth largely due to its location and to low cost production? Our answer is that innovators and entrepreneurs helped create Northeast Ohio's advantages in transport and production, and that they built on them. Cleveland built an agglomeration of industries linked to iron and steel, including shipbuilding, metal-working, chemicals, and electrical apparatus. *Strong networks of inventors, entrepreneurs and investors with strong local and national connections fed this growing agglomeration of highly interdependent industries.* [23]

23 Allan R. Pred, *The Spatial Dynamics of U. S. Urban-Industrial Growth, 1800-1914: Interpretive and Theoretical Essays*, (Cambridge: The M.I.T. Press, 1966), argues that metropolitan areas generate self-sustaining growth as they become sufficiently large to support expanding clusters of manufactures and services within their own markets. Following the English economist Alfred Marshall, we would add that cities can develop self-generating clusters of innovators – inventors and entrepreneurs. Marshall noted that "at every successive stage, the alert business man strives so to modify his arrangements as to obtain better results with a given expenditure, or equal results with a less expenditure. In other words, he ceaselessly applies the principle of substitution . . . and, in so doing, he seldom fails to increase the total efficiency of work, the total power over nature which man derives from organization and knowledge." Marshall argued that location made a big difference. "Those internal economies which each establishment has to arrange for itself are frequently very small," he wrote, "as compared with those external economies which result from the general progress of the industrial environment."

During this period, Northeastern Ohio both produced new ideas and welcomed new ideas from elsewhere. We show that Cleveland's patenting rate became the highest in the nation. The Cleveland region also attracted talent, skills, ideas, technology, entrepreneurs, and capital investment. People from many locations were drawn to the region's business and job opportunities, as well as to the presence of important inventors. During this period Northeastern Ohio produced more millionaires than Cincinnati or Pittsburgh, more than Buffalo and Milwaukee combined: their fortunes came from the region's core industries and provided capital for the region's expansion into industrial equipment, motors, and appliances (See Section IV). These connections begin to reveal the origins of Cleveland's innovation system.[24]

We conclude that because the regional innovation system worked more effectively in Northeastern Ohio than in most areas of the U.S., the region's relative manufacturing productivity increased sharply in the early 1900s before peaking with World War II. Thus

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"Situation," he added "nearly always plays a great part in determining the extent to which [a firm] can avail itself of external economies." He emphasized especially the "situation value" provided by "the growth of a rich and active population," by "access to a labour market specially adapted to his trade," as well as by "the opening up of railways and other good means of communication with existing markets." Marshall's discussion of the importance of the market for "labor specially adapted to the trade," suggested the possible importance not just of workers, but of the skills and ideas that workers might provide. Marshall, *Principles of Economics* (1890), Book V, Chapter IV, text as at www.socsci.mcmaster.ca/~econ/ugcm/3ll3/marshall/prin/prinbk5.htm/). Nathan Rosenberg developed this insight for the machine tool industry in his classic early essay, "Technological Change in the Machine Tool Industry, 1840-1910, *Journal of Economic History* xxiii (December, 1963), and expanded it in *Technology and American Economic Growth* (New York: Harper & Row, 1972); Diane Lindstrom applied it to ante-bellum Philadephia in *Economic Development in the Philadelphia Region, 1810-1850* (New York: Columbia University Press, 1978); David Hammack applied it to the New York metropolitan region in *Power and Society: Greater New York at the Turn of the Century* (New York: Russell Sage foundation, 1982), chapter 2. Also relevant is W. Paul Strassmann, *Risk And Technological Innovation; American Manufacturing Methods During the Nineteenth Century.*
(Ithaca, N.Y., Cornell University Press, 1959}.

[24] Periodically, we observe a discontinuity in the economic growth of a region, sometimes traceable to a particular event or person. (Figure 1 suggests several discontinuities in Cleveland's history.) We can think of the sources of these discontinuities as economic "drivers," which we define as follows: A change initiated by a person, technology, event, or investment which occurs at the origin of a place or industry, triggering a lengthy, sustained sequence of events sufficient to achieve a threshold or critical mass level (probably due to external economies), leading to or enabling the formation of an important new industry or set of related industries driving the growth of a specific place. The definition implies that drivers can be of several types—e.g., individuals, technologies, events, or infrastructure.
We can also think of "drivers" as the people whose efforts maximize the potential from opportunities imbedded in networks. In other words, opportunities are created in various ways (e.g., discovery of iron ore in Michigan or shifts in demand caused by World War II); however, the implications vary by place based on the existing transportation and communications facilities relative to resources and markets. In this sense, drivers are the people who exploit opportunities to the benefit of a specific city. By this definition, John D. Rockefeller, Samuel Mather, Marcus Hanna, and others may be thought of as important "drivers" of Cleveland's economy in the last half of the nineteenth century. These leaders perceived and exploited opportunities to the region's economic benefit, contributing to 'chain-reactions' of industrial development that continued into the twentieth century.

whereas Cleveland benefited most from low transport costs during its Start-Up phases, during its Buildup phase the Region competed very effectively on the basis of both productivity and costs.

What mechanisms connected inventions to performance of the industries in our region? One key was clearly Cleveland's success in developing entrepreneurs who knew how to apply technical knowledge to practical problems, from the location of mineral deposits to the making of steel and the refining of oil to the production of industrial equipment.[25] Another key was Cleveland's ability to maintain close connections with inventors and investors in the Northeast, especially New England, as it developed networks of capital for funding local businesses during the first few decades of the twentieth century.[26] A third key was producing, attracting and retaining a considerable body of skilled inventors, both on the shop floors of the region, and in its early laboratories.

Our general hypothesis is straightforward: Regions with strong networks linking investors with entrepreneurs and ideas will exhibit better economic performance. Many, many entrepreneurs played important roles in Cleveland in this period; the next section of this paper will identify some of them.

[25] A classic case is that of Jacob D. Cox, Sr., who published his autobiography as *Building an American Industry: The Story of the Cleveland Twist Drill Company and Its Founder* (The Cleveland Twist Drill Co., 1951). The son of a governor of Ohio and Secretary of the Interior (and grandson of Oberlin President Charles Grandison Finney), Cox decided that rather than go to college he would learn the metal-working trade from the ground up. He served a very thorough seven-year apprenticeship at the Cleveland Iron Company and the Cuyahoga Steam Furnace Co., learning many iron- and steel-making skills and mastering many machine tools, before moving to establish his own firm. During his apprenticeship and after Cox also made it a point to attend lectures on scientific subjects at Oberlin. For Cleveland entrepreneurs and the early development of Dow Chemical Company's bromine mines in Michigan, see Margaret Levenstein, *Accounting For Growth: Information Systems and the Creation of the Large Corporation* (Stanford: Stanford University Press, 1998).

[26] We identify many of these entrepreneurs in the next section of this paper. Margaret Levenstein has begun to study a group of some 540 directors of Cleveland banks and investment companies at the beginning of the Buildup period; see "Networks of Capital and Midwestern Industrialization: Cleveland, Ohio: 1880-1914 (mimeo draft). The Cleveland Stock Exchange (1890-1931), initiated by local banks and the local chamber of commerce, particularly served local manufacturing firms too small for listing on the New York Stock Exchange; it emphasized the innovations of the firms whose stocks it listed. Stock exchanges also formed in several other cities: Chicago, Toronto, Toledo, St. Louis, Pittsburgh, Louisville, Detroit, Columbus, and Cincinnati

Stage 3. Transition: Productivity Slowdown and Rising Costs (World War II-1970)

> **Hypothesis:** Decline was due to a slowing down of innovation and productivity growth coupled with rising costs and a diminished ability to create new industries. Slowing down of innovation and productivity growth was significantly related to the relative decline in the education of people in the region, to diminished innovation and entrepreneurial activity, and to a reduced ability to cultivate new industries.

Our analysis shows that following World War II, Cleveland's manufacturing productivity began to decline, relative to the nation. The decline has continued to the present day. Our broad hypothesis is that Cleveland's decline began when innovation associated with established industries became insufficient to offset rising costs (including social costs associated with environmental pollution and deteriorating infrastructure as well as relatively high labor costs) and the region experienced diminished entrepreneurial activity.[27] This reversal of fortunes is central to explaining what has changed since Cleveland's entrepreneurial peak of 1880-1930.

Why didn't Cleveland make a successful transition from the earlier generation of technologies and industries to post-World War II technologies and industries? Surprisingly, Cleveland's declining (relative) manufacturing productivity occurred *in spite of* the region's buildup of corporate R&D. (Cleveland was not alone: Over half the country's older industrial regions lost manufacturing jobs between 1947 and 1972.[28])

How Could this Happen?

Until we have more evidence, we are forced to speculate about the causes. By taking a long-run perspective, we may have discovered a previously hidden, potentially important explanation. During this period the nation's innovative capacity shifted away from the Manufacturing Belt so that new industries largely developed in other regions. We know that toward the end of the phase 2 Buildup, there was a transition from independent

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[27] See Garofalo, Gasper A., and Michael S. Fogarty, "The Role of Labor Costs in Regional Capital Formation." The Review of Economics and Statistics, (November l987), pp. 593-599. For an argument that labor costs account for much of the economic decline across the industrial Midwest, see Vedder and Gallaway, "Economic Growth and Decline in the Old Northwest," *op. cit*.

[28] See Norton, R. D., City Life-Cycles and American Urban Policy, *Academic Press*, New York, San Francisco, London, 1979.

inventors/entrepreneurs to corporations as the main source of new technology.[29] After 1930, corporations established their own R&D labs and increasingly controlled the development and diffusion of new technology. Previously, inventors owned the patents, even when working for a firm. Cleveland, for instance, became home to 65 industrial labs by 1930.[30] (In 1920 there had been only 14 industrial labs in the Cleveland region.)

Of course, these labs were focused on developing technology for existing companies and industries.[31] One hypothesis is that Cleveland's development as a major location for industry R&D labs in the 1920s increased the rate of innovation within *existing* industries, while diminishing the role of entrepreneurial activity and constraining the development of *new* industries. (Without additional data, we can't know what fraction of new technology originating in Cleveland's labs stayed in Cleveland.)

Because the buildup of Cleveland's industrial agglomeration consisted of industries that were largely connected to the original industries, R&D and innovation tended to focus on maturing sectors. The region's extensive corporate R&D likely extended the life of existing industries and firms for very long periods of time. And the region's growth could continue as long as there were new, related industries that evolved from this core. During Cleveland entrepreneurial "hey day" entrepreneurs and investors were primarily focused on the development of industries related to the original agglomeration. Therefore, it is not surprising that new industries with little or no connection to the original agglomeration developed elsewhere. Evidence from this period shows that the nation's more rapidly growing regions exhibited a more favorable mix of new industries in the 1970s.[32]

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[29] See Naomi Lamoreaux and Kenneth Sokoloff, "Inventors, Firms, and the Market for Technology," in Naomi R. Lamoreaux, Daniel M.G. Raff, and Peter Temin, editors, *Learning by Doing: In Markets, Firms, and Countries* (Chicago: University of Chicago Press for the National Bureau of Economic Research, 1999), *op. cit*.

[30] Data on R&D labs was compiled from the Bulletin of the National Research Council, vol. 1 (1919-21), 60 (1927), 81 (1931).

[31] There is some evidence that these labs were in part, at least, defensive, devoted to evaluating technology developed elsewhere, protecting a firm's own technology, and reverse-engineering that of its rivals and of independent inventors rather than solving new problems. See Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Inventors, Firms, and the Market for Technology in the Late Nineteenth and Early Twentieth Centuries," and Steven W. Usselman, "Patents, Engineering Professionals, and the Pipelines of Innovation: The Internalization of Technical Discovery by Nineteenth-Century American Railroads," both in Naomi R. Lamoreaux, Daniel M.G. Raff, and Peter Tamin, Learning By Doing: In Markets, Firms, and Countries (Chicago: University of Chicago Press for the National Bureau of Economic Research, 1999).

[32] See Beverly Duncan and Stanley Lieberson, Metropolis and Region in Transition (Beverly Hills: Sage Publications, 1970).

The Growing Significance of Universities

Cleveland built its agglomeration on access to natural resources, low costs, and technologies that were based on "trial and error." Newer industries are based on science, raising the significance of universities (and government labs). This suggests an important question: To what extent does Ohio's relatively low commitment to higher education, from the early part of the twentieth century on, explain the failure of the state's metropolitan regions to develop new industries? Did many older industrial regions, in Ohio and elsewhere, seal their economic fate early in the twentieth century by under-investing in higher education? One interpretation of the current obsession across the country with developing effective university technology transfer programs is that these initiatives represent efforts to recreate the "incubator" or "seed" function in older industrial cities. At some point, however, a smooth transition becomes nearly impossible.[33] [34]

[33] Fogarty, Michael S. , Amit K. Sinha, and Adam B. Jaffe, "ATP and the U.S. Innovation System—A Methodology for Identifying Enabling R&D Spillover Networks With Applications to Microelectro-mechanical Systems (MEMS) and Optical Recording," draft submitted as an NBER research paper for the Advanced Technology Program of the National Institute of Standards and Technology, October 2000.

[34] Although our research primarily focuses on patents as a window on the innovation and entrepreneurial activity shaping Cleveland's economic growth and development, a number of other factors determine the economic and population trends depicted in Figure 1. These can be summarized as consisting of several elements: external conditions (factors not within local control, such as war, the business cycle, weather); and infrastructure (e.g., the Ohio Canal altered Cleveland's access to raw materials as well as access to markets on the East Coast). An infrastructure component includes innovations in communications and transport facilities as well as efforts to harness these improvements to Cleveland's advantage.

III. CLEVELAND'S METAL-WORKING INDUSTRIES, 1830-1900

In this section we pursue a detailed examination of Cleveland's metal-working industries to gain deeper insight into the role of invention and entrepreneurship in shaping Cleveland's industrial structure and economy from the mid-1800s until WWII. We've singled out this particular set of industries industry because Northeast Ohio's economic growth between 1820 and the 1920s came largely through the expansion of its cluster of metal-working industries, as shown in Table 1.

A close look reveals that Northeast Ohio's metal-working and related industries grew through a process that continued over nearly a century: *a shift from the production of metal, to the manufacture of basic metal commodities, to the production of more and more complex and valuable metal-based devices. This process required both invention and entrepreneurship.* Before 1900 Cleveland's investors maintained close ties with entrepreneurs and inventors.

TABLE 1: Industrial Wage Earners in Cleveland by Industry, 1880-1940

	Wage Earners					
	1880		1910		1940	
Industry	**No.**	**Share**	**No.**	**Share**	**No.**	**Share**
Clothing & related products	3,027	14%	9,494	11%	9,455	8%
Printing & publishing	590	3%	3,104	4%	6,883	6%
Specialty & luxury items	200	1%	229	0%	739	1%
Metal-working	6,605	30%	34,352	41%	71,201	64%
Food processing	1,150	5%	3,081	4%	8,194	7%
Subtotal	12,977	60%	54,413	64%	99,223	89%
Other industries	8,747	46%	30,315	41%	12,869	13%
All industries	21,724	100%	84,728	100%	112,092	100%

Source: U.S. Census of Manufactures, 1880, 1910, 1940.

- **New technologies** helped to locate ores, fuels, and other raw materials; improved the production of iron and steel; made the movement of raw materials more efficient; led to the manufacture of more and more precisely formed and shaped metallic goods; and created the hoisting, conveying, hauling, trucking, appliance, machine-tool, and other metal-using industries that made the region grow.

- **New firms**—in ever larger numbers and a wide variety of sizes—did the work of putting new technologies into action and of building the region's industries. Some of the key early firms carried out a wide variety of tasks; as business grew, many firms specialized in particular operations.

For perhaps seventy or eighty years, from 1860 to the 1930s, Northeast Ohio produced and attracted striking numbers of new technologies and new and reorganized firms. Close examination makes clear that key technologies, and key firms, *very often originated elsewhere*—most frequently in New England—then moved to the region.

Several distinct measures reinforce the conclusion, evident in the data on the occupations of Cleveland's industrial workers, that the region's economic distinction lay in its internationally notable cluster of metal-producing and metal-working business firms.

Northeast Ohio's Millionaires

One of the most intriguing measures was the product of the 1892 debate over the tariff. As a contribution to the pro-tariff argument during that presidential-election year, the *New York Tribune*, the nation's leading Republican newspaper, published a pamphlet listing every millionaire in the United States by place of residence. Since anti-tariff Democrats had their own capable and highly motivated journalists who worked steadily to debunk pro-tariff propaganda, historians have taken this list to be quite complete.

The data in Tables 2 and 3 indicate that by 1892 Northeast Ohio was already home to more millionaires than any other Great Lakes or Ohio Valley city-region except Chicago. With 85 millionaires, Cleveland and Northeast Ohio (including Youngstown, Akron, Canton, and smaller places within the region) outpaced both the Pittsburgh-Allegheny (79) and the Cincinnati regions (71).

As we might expect, Chicago's millionaires made their fortunes in a wider variety of fields, including the processing and distribution of timber and agricultural products and the general wholesaling and distribution of products of many kinds. Northeast Ohio's economy was more narrowly based, to judge from the list of million-dollar fortunes. But in the fields of mining and manufacturing, "Greater Cleveland" approached Chicago, equaled Pittsburgh, and greatly surpassed other Great Lakes and Ohio Valley cities.

In 1892, mining, metal-working, railroad and bridge development, and the manufacture of goods from iron, steel, and non-ferrous metals dominated Northeast Ohio’s millionaire’s row, although of course oil had also played a key role.

Table 2: Million-Dollar Fortunes in 1892 by Main Source,
Great Lakes and Ohio River Cities and Baltimore

	Total	Mining, Rails, Manufacturing, Distilling Chemicals, Oil, Electric Goods	Lumber, Meat, Leather Goods, Grain, Brewing, Clothing, Tobacco	Wholesale, Shipping, Merchandising, Publishing	Real Estate, Banking, Law, etc.
Chicago	266	67	80	68	51
Cleveland/NE Ohio	85	57	7	10	11
Pittsburgh/Allegheny	79	56	1	10	12
Cincinnati	71	28	11	16	16
Baltimore	53	19	10	14	10
Detroit	43	10	17	9	7
Buffalo	33	13	15	5	0
Milwaukee	28	6	21	0	1

Table 3: Cleveland’s Million-Dollar Fortunes
In shipping, mining, iron and steel, manufacturing, and oil,
By name of wealthy individual

Lake Shipping	**Mines**	**Iron And Steel Making**	**Bridges, Railroad Building**	**Nuts, Bolts; Hardware Farm Equipment, etc.**	**Oil**
Bradley, M.A Cobb, A Johnson, P Wilson, T.	Burke, Stevenson. Hanna, Marcus Hanna, Melvil. Holden, Liberty Pickands, James Rainey, Rhodes Arms (Youngstown)	Bissell/Wick Chisolm, Wm. Harmon Johnson, Tom Mather, Samuel Otis, C.A. Pope, A.J. Tod Andrews (Y’tn) Perkins (Warren)	Chamberlain, Selah Clark, J King, Zenas Stone, Amasa Wade, Jeptha Witt, Stillman	Lamson Miller (Akron) Conger (Akron) Seiberling (Akron) Crouse (Akron) Aultman (Canton) Russell (Massillon)	Andrews, S. Corrigan, J. Crocker, T.D. Harkness Huntington Kerr Payne Rockefeller Scofield

FIRMS IN CLEVELAND’S METAL-WORKING INDUSTRIES, 1860-1925

More detailed measures of business activity in Northeast Ohio can be obtained from the credit ratings of all U.S. firms published quarterly by R. G. Dun & Co. and its successor, Dun and Bradstreet, from the late 1850s to the present. We have used the printed files to construct a database for analysis.

Limiting ourselves to firms listed under the City of Cleveland and thus omitting other substantial manufacturing centers in Youngstown, Akron, and other cities, we find that Dun's listings for early 1860, 1880, and 1900 include rapidly growing numbers of firms in industries related to metal working. This data also allows us to track the diversification of the region's metal-working industry over time.

1860

In 1860, R. G. Dun & Co. listed just two large firms in metal-related industries in Cleveland, hardware wholesalers William Bingham & Co. and George Worthington & Co. These two firms engaged largely in moving metal goods—tools, fasteners, handles, hinges, horseshoes, etc. —from the East for the use of Ohio's farmers, craftsmen, and shopkeepers. In the process, Bingham and Worthington and their associates learned about market needs and market opportunities in both Northeast Ohio and the East. They helped Eastern manufacturers find Ohio markets and learned what Ohioans might sell to the East. Information they provided surely helped lead to the appearance of many mining, shipping, iron-making, and iron and steel commodity producing firms in the next twenty years and beyond.

1880

By 1880, Cleveland boasted a thriving and rapidly growing group of twenty-three metal-industry firms capitalized at levels from several hundred thousand to more than one million dollars. Appendix Table A1 lists all of Cleveland's largest manufacturing and mercantile companies in metal-producing and substantial metal-using fields in 1880.

To judge from this list, by 1880 the region was home to firms notable for the mining, transportation, and distribution of ores and fuels, the production and distribution of iron and steel, and the stamping, drawing, and forging of iron and steel into such basic commodities as nails, bolts, washers, nuts, screws, hardware, and agricultural implements. Bingham and Worthington had been joined by several other major wholesalers in the field, including Rhodes & Co. in iron, McCurdy and Cleveland, Brown in iron, steel, and nails, and Fuller, Warren in stoves. Only six large Cleveland firms made hard goods in 1880: Younglove (farm implements), Chisolm (steel shovels), Wilcox, Treadway & Co. (hardware), Union Steel Screw Co. (screws), and Lamson, Sessions & Co. and Bourne & Knowles (nuts, bolts, and washers).

As shown in Table 4, in 1880 the region was not yet notable for the production of more complex metal parts or the assembly or distribution of sophisticated manufactured goods composed of many pieces. Data on firms assigned to Dun's 3rd, 4th, and 5th groups by amount of capitalization bear this out, as shown in Appendix Table A2.

TABLE 4: Middle-Size Manufacturing Firms in Cleveland by Field, 1880	
Coal miners and dealers	13
Shippers etc.	4
Iron Ore miners and dealers	3
Pig Iron	3
Steel, Malleable Iron	3
Lime, Stone	2
Oil	4
Lead, pipe, pipe joints	2
Chemicals, ammonia, powder	4
Paint	4
Foundry	3
Shipbuilding, Dry Dock, Bridges	6
Stoves, Grates, sidewalk lights	8
Hardware	9
Nails, washers, nuts, bolts, screws	9
Wholesale hardware	2
Car journals, gas traps, boilers, telegraph supplies, lightening rods	5
Sewing machines, cotton gins, wagons, axles, steam gauges, box machines	6
Other manufacturers	5
TOTAL	95

Source: R.G. Dun & Co. *Reference Book,* 1880.

The largest number of these larger middle-size firms dealt in or produced iron or steel (or the fuels and chemicals used in their production) or turned out more hardware. Other middle-size firms made stoves, boilers, grates, railway car parts, axles, and lightning rods. Cleveland was home to some substantial bridge and ship builders. And in 1880 it already had a few producers of more complex machines (cotton gins, paper box machines, sewing machines) and machine tools—but only a few.

1900

The fifty-four large firms listed in Dun and Bradstreet for 1900 (see Appendix Table A2) indicate that the transition from producing iron and steel in the form of sheets, tubes, rods, nuts, and bolts to more exactly shaped and more complex metal goods was already well underway. The list in Table A5 also reflects Cleveland's remarkable growth between 1880 and 1900: In the twenty years, the number of Cleveland metal-working-related firms capitalized at several hundred thousand dollars or more had increased from twenty-three to fifty-four. The number of middle-size firms increased much more rapidly. Altogether, this represented a remarkable flow of investment money, and of entrepreneurial and managerial skills, into Cleveland in the last twenty years of the nineteenth century**.**

The 1900 list of large Cleveland firms in metal-working and related industries resembles the 1880 list in the prominence of ores and fuels; the production and distribution of iron; and the stamping, drawing, and forging iron and steel into such basic commodities as nails, bolts, washers, nuts, screws, hardware, and agricultural implements. In 1900, of course, steel was much more prominent, relative to iron, than it had been in 1880.

Shipbuilders, hoist and conveyor builders, and bridge builders, which had been only middle-size firms in 1880, appeared among the largest firms in 1900. Four large hardware manufacturing firms had located in Cleveland in 1800; there were ten in 1900. The American Washboard Company was now among the largest firms and so were half a dozen makers of complex devices requiring precision parts, such as pumps, compressors, and bicycles. As in the United States in general, wholesalers—the traditional market makers—were much less prominent than they had been twenty years before.[35] Integrated firms in iron and steel manufacturing and hardware, played a more central role in organizing the region's economy.

The scope and scale of Cleveland's metal-working cluster is further indicated by the fields of its middle-size metal-working firms in 1900 as shown in Table 5.

[35] The classic study on this point is Glenn Porter and Harold C. Livesay, *Merchants and Manufacturers* (Baltimote: The Johns Hopkins University Press, 1971).

TABLE 5: Middle-Size Firms by Field, 1900	
Iron ore miners and dealers	13
Pig iron	11
Steel, Malleable iron	3
Lime, Stone, Fire brick	2
Lead, Pipe, Plumber's supplies	10
Chemicals, Ammonia, Powder	1
Paint	4
Foundry	12
Shipbuilding, Dry docks, Bridges	4
Hoists, etc.	4
Stoves, Grates, Sidewalk lights	12
Hardware	12
Nails, Washers, Nuts, Bolts, Screws	11
Wholesale hardware	5
Belts, Filters, Screens, Dies	6
Sewing machines, Bicycles, Pumps	6
Other machines	7
Engines	3
Machine tools	2
Electrical goods	2
Other manufacturers	5
TOTAL	135

Source: R. G. Dun & Co, *Reference Book*, 1925.

A More Exact Account of the Region's Industry Structure and Transition

The information summarized in this section gives us a much more exact account of the development of industry and industrial employment in Northeast Ohio than has previously been available. Northeast Ohio's large firms clearly played a central role in a much larger complex of small and middle-size firms. The market-making wholesalers Bingham and Worthington came first and persisted. Suppliers of raw materials—pig iron, steel, coke—were prominent by 1880 and a number of middle-size manufacturers in Cleveland were specializing in components for other manufacturers (pipe, couplings, springs, axles, fasteners, tools, hardware, steam gauges) or for builders (grates, iron cornices, sidewalk lights). By this time, makers of wire, nails, stoves, and such products had gained prominence. In 1880, Cleveland manufacturers were already assembling such complex products as steamships, bridges, carriages, rail cars, cotton gins, agricultural implements, box machines, and sewing machines. The city's increasingly complex manufacturing enterprises expanded the region's market for a wide variety of parts. Many manufacturers, such as the Cleveland Iron Company, made many products to order, including large items such as ship engines, cranks, and propellers. They relied largely on hand work and the application of basic tools and one-of-a-kind patterns.[36] Market makers like Bingham and Worthington had mastered not only an extraordinary expansion of the Northeast Ohio market, but also a radical reorientation from consuming metal products to producing iron and steel and their manufactures in unprecedented quantities. By 1900, Cleveland was home to many more manufacturers who purchased components produced by others as they assembled more complex and sophisticated products such as pumps, hoists, conveyors, compressors, ships, sewing machines, bicycles, and machine tools.

1925

A preliminary analysis of the biggest Cleveland firms listed by Dun and Bradstreet in 1925 demonstrates that producers of increasingly complex and sophisticated – and more valuable – products continued to flourish. Nearly all U.S. manufacturers produced goods in a single field or a very closely grouped set of fields, so the Dun & Bradstreet note on field of activity is quite informative. (see Table 6)

Iron, steel, and their products, especially heavy industrial equipment, automobiles, and machines of all kinds, predominated in 1925. It is interesting to note, however, that Northeastern Ohio was home to numbers of firms in oil, chemicals, paint, and varnish; in electrical equipment; and in clothing. *These provided points from which Northeastern Ohio's economy might have diversified after World War II*.

[36] For a remarkably vivid and detailed account of work at the Cleveland Iron Company in the 1870s, see Cox, *Building an American Industry*, Part II.

TABLE 6: Middle-Size Manufacturing Firms in Cleveland by Field, 1925	
coke, miners and wholesalers	41
Iron ore, pig iron, steel	31
Steel alloys, etc.	6
Foundries, Casting plants, heaters, punches, presses	34
Wheels, agricultural implements, structural steel	7
Non-ferrous metals	21
Nuts, bolts, screws, springs, wire, hardware	38
Machines, sprinkler systems, typewriters	47
Automobile and truck parts, engines	30
Oil, chemicals, paint, varnish	65
Glass, stone, brick	15
Machine tools, heavy equipment, mechanical engineering	50
Electrical equipment	36
Clothing	30
Printing and publishing	13
Rubber Goods	12
Food and beverages	28
Lumber and wood products	21
Paper, boxes	18
Leather goods	6
Building contractors, building supplies	14

SPECIALIZED KNOWLEDGE HELPS EXPLAIN THE SUCCESS OF NORTHEAST OHIO'S METAL-WORKING INDUSTRIES

Why did this increasingly sophisticated and complex cluster of metal-working firms develop in Northeast Ohio? Clearly, part of the answer lies in the region's geographic position—and in the enhancement of that position by the construction of the Erie Canal to the Hudson River (opened 1825) and the Ohio Canal to Akron, Canton, and south to the Ohio River (opened in the mid 1830s). Northeast Ohio's location at the southeastern corner of the Great Lakes, with excellent water-level or near-water-level routes to Toronto and Montreal, Albany and New York City, Baltimore and Philadelphia, Cincinnati, Detroit, Chicago, Minneapolis and Sault Ste.

Marie, gave it exceptional advantages. The availability of coal, coke, oil, iron ore, and copper, in locations easily accessible from Cleveland, solidified the region's position in metal production and opened the way to the creation of an internationally notable cluster of metal-working firms. But it was not enough that the region could make steel cheaply and could easily ship goods to North America's largest markets. *It took specialized knowledge, entrepreneurial effort, capital, and skilled labor to take advantage of the opportunities afforded by geographic location. We are beginning to appreciate that Northeast Ohio had developed, by the 1880s, a remarkable concentration of experts in applied science, production technology, and business*.

Moving to More Complex Manufacturing from 1860-1900: The Significance of Northeast Ohio Patents

Patenting activity provides one indicator of Northeast Ohio's expertise in applied science, production technology, and business. As we have noted, Northeast Ohio produced significantly more than its share of patents per capita during the last forty years of the nineteenth century. *The region's patents reflected its relatively high level of education as well as its ties to the Northeast and its receptiveness to migrants from Europe. Its patents derived from existing industries and in a number of cases pointed toward future growth*.

Most successful inventors in the region focused on problems in the movement of bulk commodities, the refining of oil, the making of bridges, and the production of screws and other more exactly shaped metal parts. Cleveland-area people did not originate the scientific and technical knowledge needed for creating and developing the iron and steel industries, or the rubber industry. In these fields, relevant knowledge, like entrepreneurial talent and capital, came from elsewhere. *But the region did develop strong expertise in a number of areas that helped it move from making iron and steel and producing bulk commodities, to the manufacture of complex industrial equipment and consumer goods*.

The 127 patents granted to Clevelanders in 1880 can be placed in the categories shown in Table 7. The areas of innovation in 1880 clearly relate to the specializations of Northeast Ohio's firms. Patents clustered in areas related to moving raw materials, metallurgy, the shaping of metal objects and parts, and making the components of such complex goods as boilers, bicycles, and sewing machines. It was these industries that would shape Cleveland's transition from a producer of bulk iron, steel, wire, nails, nuts, and bolts, to a highly diversified producer of complex mechanical goods by 1900 and after.

TABLE 7: Patents Granted to Northeast Ohio Residents, by Purpose, 1880	
Hoisting and handling bulk ores and similar goods	9
Oil refining	2
Metallurgy	9
Hardware (including nails, wire, shovels, plumbing goods, iron fence design, bridge gate), manufacture and design	22
Carriage and rail car parts (axles, journal boxes, roofs, etc. etc.)	12
Lamps and stoves	17
Steam boilers	6
Motors, components	3
Bicycle parts (especially chains)	5
Sewing machine components	6
Paper bags, tubes, and boxes	12
Electrical devices	2

It is also interesting to note the areas in which Cleveland-area people did *not* file patents in 1880. There were only two patents related to the production and refining of oil and none for chemical processes, paints, varnishes, etc. There were very few for motors, engines, railroads, etc. Just two patents related to electrical goods. Given the prominence of iron and steel making in Cleveland (and the rising prominence of goods made from lead, copper, tin, and bronze), relatively few local patents related to metallurgy. The bulk of Cleveland's 1880 patents related to the production of goods from iron and steel. Very few patents were leading Clevelanders into chemistry, electricity, or the production of food, drink, or furniture. A number—but not a really large number—of patents were leading toward increased production of the most important complex devices of the day—bicycles and sewing machines. As David Hounsell has shown, the centers of innovation in the production of these devices were elsewhere, in New England, New Jersey, and Chicago.[37] A larger number of Cleveland's 1880 patents, however, led toward the making of production equipment for factories.

[37] David A. Hounshell, From the American System to Mass Production, 1800-1932 (Baltimore: The Johns Hopkins University Press, 1984, chapter 2, 5.

What We Learn From "Important" Patents

Yet another view of Northeast Ohio's industrial innovators comes from an examination of a list of all "important" patents compiled by the U. S. Patent Office for the period 1871-1900. Table 8 shows the industries for the seventy such patents that were granted to inventors in Northeast Ohio.

TABLE 8: ALL 70 "IMPORTANT" PATENTS GRANTED TO INVENTORS IN NORTHEAST OHIO, 1871-1900, BY INDUSTRY	
Metal-working (smelting, casting, cutting)	6
Oil extraction and refining	3
Hoisting, unloading coal, ore, etc.	13
Conveying bulk goods	7
Hydraulic devices for shipping, hauling	7
Steam valve	1
Tow boat	1
Bicycle parts	3
Automobiles, brakes, tires	5
Automobile engines	5
Traction engine	1
Refrigeration	1
Addressing machines etc.	3
Electric motors, lights, batteries	6
Electric recording devices	2
Rubber goods, fabric	2
Show cases, boxes,	3
Source: Ladd's "Important" patents	

This list is interesting in several ways.

- It includes few or no patents related to the location of ore fields or the making of iron and steel. New knowledge made Northeast Ohio's key iron and steel industry possible, but Northeast Ohio people did not develop that knowledge themselves. It came from Germany, New England, New York, Pennsylvania, and the U. S. Coast and Geodetic Survey. Clevelanders focused on moving raw materials. Several of Cleveland's metallurgical patents went to Eugene and William Cowles in the 1890s, and they seem not to have done much to exploit them.
- Only three important patents related to oil production and refining; all of these went to Hermann Frasch, a German-trained specialist brought to Cleveland by Standard Oil

Company well after John D. Rockefeller and his associates had made Cleveland the center of the oil industry.

- Only two or three patents related to the rubber goods industry; none of these was described, in this 1900 analysis, as central to the making of goods from rubber. Although the Akron and Cleveland rubber industry did produce many patents, the key innovations were brought to the region from elsewhere.
- About a third of the important patents related to the handling and transportation of coal, ore, and other bulk goods. Northeast Ohio had been a key center for the building, improvement, and maintenance of railroad and telegraph lines from the 1840s, and for Great Lakes shipping, so these patents grew out of older industries. Most of them went to men born and raised and long employed in Ohio.
- The conveyors, hoists, and hydraulic devices developed to handle bulk raw materials on and around the Great Lakes had many applications in industrial plants and in the movement of a very wide range of goods. So, too, did much of the hardware, tools, screens, and other metal goods produced in Cleveland. *Patents granted in these fields during the 1880s and 1890s laid the basis for a continuing expansion of the region's factory- and industrial-equipment industries into the next several decades*.
- *About a sixth of the important patents related to automobile parts (engines, brakes, tires), an industry that would expand dramatically after 1900.*
- *About one in ten patents related to electrical goods; altogether, more than one in ten related to a wide variety of complex manufactured goods, including valves, bicycle parts, refrigeration, traction, sound recording, etc. These fields also relate closely to the expansion of Cleveland's electrical goods, office machine, and appliance industries after 1900.*

Thus nearly two fifths of the important patents of 1871-1900 anticipated the remarkable variety of automotive, electrical, appliance, and complex mechanical devices produced in Northeast Ohio in the first half of the twentieth century.

Looking forward, in 1900, inventors in the Cleveland-Youngstown-Canton-Lorain region received a total of 351 patents. These patents confirmed the region's shift from moving raw materials and making iron and steel to the production of metal-based products of increasing complexity, notably automobiles, typewriters and office machines, machine tools, and other complex devices. As Table 9 shows, the region's patents covered a wide range of activities. However, fewer related to electricity than we might have expected, given the local prominence of Western Union, Brush, and the firms that would later form the National Electric Lamp Association, predecessor of General Electric's Lighting Division. Despite the presence of Standard Oil, National Carbon, Sherwin-Williams, and Glidden, and despite Case Institute's role in founding the Dow Chemical Company, not many patents related to the expanding chemical industries. (It is possible, of course, that the big firms in those industries often treated innovations as trade secrets and avoided recourse to the patent office. However, none of our research answers this question.) Despite a significant clothing industry, very few patents related to textiles. Nor did many relate to clay and glass, wood and lumber, food, or farming.

Table 9: 351 Patents Granted to Inventors in Northeast Ohio[38], 1900, By Industry	
Metal-working (smelting, casting, cutting)	23
Chemicals, Oil extraction and refining	10
Hoisting, unloading coal, ore, etc.	26
Shipbuilding	3
Hardware, simple metal goods; wire-drawing	46
Plumbing goods	10
Nonferrous Metals	13
Ranges, stoves, etc.	3
Typewriters, etc.	18
Automobile engines	9
Automobiles, trucks	47
Rubber & Tires	23
Mechanical Devices	14
Electric motors, lights, batteries	17
Machine tools, wire-drawing machines	25
Paper and Printing	15
Miscellaneous	39
Clay and Glass, Food, Lumber, Textiles	27

[38] Cleveland, Cuyahoga Falls, Willoughby, Painesville, Akron, Kent, Canton, Massillon, Medina, Youngstown, Warren, Niles, Elyria, Oberlin, and Lorain.

Overall, these patents both reflected the region's early prominence in metal production and metal working, and anticipated its diversification into the production of a wide variety of complex goods manufactured from metals. The metal-working industries (broadly defined to include bulk moving and industrial equipment of all kinds), supported a very active concentration of inventors. Other industries in the region seem to have supported many fewer innovators. *The region's history of late-nineteenth century patents can thus be read as a warning that the region's diversification would have limitations*.

Northeast Ohio as an Integral Part of a Larger Manufacturing Realm

Northeast Ohio developed notable inventive and entrepreneurial capability in the nineteenth century. It produced more than its share of patents and a number of remarkable entrepreneurs. Some entrepreneurs clearly encouraged inventive activity: Several firms were assigned two or more patents in 1880 or 1900 or were assigned or associated with the inventors of at least one important patent. Very incomplete information suggests that *just thirteen firms were led by, employed, or purchased the rights to more than half the region's important patents*. A consideration of the region's firms also indicates that a key group of inventors and other innovators played central roles. John D. Rockefeller is by far the most famous entrepreneur to appear in the region, but there were many others. Among the most successful were William Bingham (who came from Connecticut in 1836), Charles Brush, Marcus A. Hanna, George Hulett, Timothy Long, Samuel Mather, James Pickands, Daniel Rhodes, Louis Severance, and George Worthington (who came from Cooperstown, New York, in 1832). Together, they founded some of the region's most notable firms. Hanna, Mather, Pickands, Rhodes, Severance, and Rockefeller played leading roles in finding and moving ores; Bingham, Brush, Hulett, Long, and Worthington made notable contributions to the metal-fabrication industry. Bingham, for example, played a role in starting the Cleveland Iron & Nail Works (1863), the Cleveland Iron Co., Standard Tool Co. (twist drills), and the Parrish & Bingham Co. (bicycle parts, 1894). Brush employed people who launched Brown Hoist, National Carbon, Lincoln Electric, and several other firms. But many of Northeast Ohio's notable entrepreneurs brought entire firms to the region after the Civil War, in order to take advantage of the region's raw materials and its increasing concentration of metal-working specialists.

Close Ties With New England

Three key groups of Northeast Ohio firms maintained very close ties with New England. These ties added to and reinforced ties already present through merchants associated with the Bingham Co. and with the Mather, Rhodes, Severance, and other trading families from Massachusetts and Vermont – as well as with the Cox family, founders of the Cleveland Twist

Table 10: Northeast Ohio Firms Associated with Significant Patents, By Industry,1870-1900			
Firm	**1880 Patents**	**1900 Patents**	**Important Patents, 1871-1900**
Metal production			
National Malleable Castings Co.		13	
Hardware (shovels, screws, pipe)			
Chisolm Steel Shovel	3		
Cleveland Machine Screw Co.		4	
Plumbers Brass & Iron Manufacturing Co.		2	
Industrial equipment (hoists, etc)			
Brown Hoist	1		3
Long Manufacturing/Long Arm System Co.			10
McMyler Manufacturing/Car Dumping Co.	1		5
Standard Welding Co.		2	1
Warner & Swasey Co.		2	1
Webster, Camp & Lane Manufacturing, Akron		6	2
Wellman-Seaver Engineering Co.		6	
Russell & Co., Massillon (traction engine)			1
Electrical goods			
Brush Electric	2		8
Interstate Electric Co.		4	
National Electric Valve Co.			1
Westinghouse Electric Co.		4	
Rubber goods			
Diamond Rubber Co.		3	
Goodyear Tire and Rubber, Akron (Seiberling)		2	
Sewing Machines, adding machines, bicycles, automobiles			
Cochran Co., Lorain (refrigeration)			1
A. L. Moore Co. (bicycle part; Rollin White, inventor)			1
National Addograph Co.		2	
White Sewing Machine	4		
Winton, Alexander			5
Chemicals, oil, powder			
Austin Cartridge Co.		3	
National Carbon Co.		5	
Standard Oil (Solar Refining Co., Lima)	1	2	3
Other			
Gilliam Manufacturing, Canton (harnesses)		2	

Drill Company. One group of firms maintained close ties with the Boston area over a considerable period of time. Thomas White brought his White Sewing Machine Company from the Boston area to Cleveland in 1866; his associate, George Baker, followed in 1871. White, Baker, and their sons and associates played central roles in the development of a number of the region's most important metal-working companies over three generations. These include White Sewing Machine, Cleveland Automatic Screw Co., Cleveland Machine Screw Co., White Motor, Baker Motor Vehicles, Baker Materials Handling, White Consolidated Industries, American Ball Bearings, Standard Parts, Inc., and Cleveland Tractor Co. These firms developed technical specialists and brought others into the region. The earliest firms—White Sewing Machine, Cleveland Machine Screw Co., and Baker Motor Vehicles—are represented in the above list of firms connected with important patents in the late nineteenth century.

A second group of firms maintained close ties with key firms in Connecticut, especially Pratt & Whitney, which was then internationally recognized for its work in tools, water power, rifles, and other precision metal-working industries. Isaac P. Lamson and Samuel W. Sessions (who do not seem to have had ties to Pratt & Whitney) moved their new carriage bolt factory from Connecticut to Cleveland in 1866; six years later they helped start the Cleveland Nut Company to complement their original business. In 1892 the *New York Tribune* listed Lamson as one of the region's millionaires. Worcester Warner and Ambrose Swasey, both of whom had worked for Pratt & Whitney, launched what seems to have been a larger set of connections when they left Hartford for Chicago in 1880, and then for Cleveland in 1881.

Warner & Swasey specialized in machine tools and precision scientific instruments, a combination that set them up well for the ongoing changes in Cleveland's metal-working industries. Among their employees were George C. Bardons and John Oliver, founders of Bardons & Oliver, Inc., which began as a maker of bicycle hubs in 1891 and became a major producer of machine tools; and Henry Lucas, an apprentice who rose to chief draftsman at Warner & Swasey and later established Lucas Machine Tool Co. Other Pratt & Whitney people who came to Cleveland included machine tool leaders Edwin Henn and Remholdt Hakewessel, founders of National Acme Co. in 1895 (which absorbed firms from Vermont and Connecticut before merging with Cleveland Twist Drill in 1968), and A. W. Foote, founder of Foote-Burt Co.[39]

Through the location decisions promoted by these relationships, Ohio became the leading state in the machine tool industry early in the twentieth century. In 1914, according to the *American Machinist*, 117 of the 570 U.S. firms that made machine tools, small tools, and related items, were located in Ohio: 98 were in Massachusetts, 66 in Connecticut, 60 in Pennsylvania, 57 in New York, 42 in Illinois.[40]

Northeast Ohio's ties with New England were crucial. David A. Hounshell's definitive recent book, *From the American System to Mass Production, 1800-1932*, demonstrates that New England was the initial home of the metal-working industry. Hounshell also shows that effective mass production of complex machines made from metal appeared first in firms closely tied to national markets (such as the McCormick Reaper works in Chicago and the Singer Sewing Machine Company with headquarters in New York City, and that it was perfected in action only by the Ford Motor Company just before World War I. Cleveland is almost entirely absent from his story – with the exception of a reference to White Sewing Machine as a Massachusetts company! Hounshell ignores some important Northeastern Ohio innovations, but he makes it very clear that essential developments occurred to the East and, after 1900, in the Western Great Lakes as well.

Yet to be fully explored is the very important topic of European contributions to Northeast Ohio's metal-working expertise. Among Cleveland's significant metal-working firms were the piano works of German Baptiste Dreher (arrived 1853), the Wilhelm Ploetz (later Plotz) Iron Works (1888); Hungarian Theodore Kundtz's cabinet-, wheel- and auto-body-making business (founded 1878; 2500 employees at incorporation in 1915), and German Gustav Schaefer's 1880 Wagon Works (an early producer of auto bodies). Frank Vlchek became a skilled instrument-maker in Austria; his Vlchek Tool Co. (founded 1889) was producing a large share of the tool kits that came with new automobiles in the teens. After World War I another Czech immigrant, tool maker Frank Andel, founded the Cleveland Brake Co. (now American Monarch). Among the most important contributors to Cleveland's expansion was Viggo

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[39] For information on the firms discussed in this and the preceding paragraph, see the Encyclopedia of Cleveland History, available on-line at <http://ech. CWRU. edu/>. Several of the most helpful articles were written by Darwin Stapleton, then a member of the CWRU Department of History.

[40] *American Machinist*XL (Jan. 29, 1914, 210, quoted by Nathan Rosenberg, "Technological Change in the Machine Tool Industry, 1840-1910," *Journal of Economic History* XXIII (1963).

Torbensen, who had studied in Denmark's public schools and Naval Technical School and in Germany, and had apprenticed in Britain. Torbensen designed the first internal automobile gear drive used in the U.S. in 1899; in 1915 he moved his Torbensen Gear & Axle Co. from Newark, New Jersey, to Cleveland. Years later, his firm became the core of the Eaton Corporation. Cleveland's hospitality to skilled and entrepreneurial migrants from Central Europe paid rich dividends, adding significantly to the pool of metal-working expertise developed at home and in the American Northeast.

SUMMARY: METAL-WORKING EXPERTISE ALLOWED NORTHEAST OHIO TO CAPITALIZE ON ITS LOCATION

Northeast Ohio grew rapidly—a little more rapidly than the nation as a whole—between 1860 and 1930-1940. The lion's share of the region's economic growth took place in the metal-working and (broadly defined) machine-building industries; in 1940, these industries accounted for two-thirds of industrial employment in the region.

In developing its metal-working and related industries, Northeast Ohio benefited from its strategic location at the southeastern corner of the Great Lakes basin, central to supplies of coal, gas, and iron ore, and well located for the distribution of goods and materials to the cities and industrial regions of the Northeast and the Mid-Atlantic. (The region also benefited from the protective tariff and from the Pittsburgh basing-point system that set steel prices; we leave these matters for future studies).

No analysis of Northeast Ohio's nineteenth century growth can limit itself to Ohio alone. Through 1900 and beyond, several of Cleveland's key large firms retained close ties with entrepreneurs, inventors, and investors from New England, New York, and beyond. Northeast Ohio was not responsible, by itself, for the inventions that helped it grow. It was an important node in a much larger system of economic innovation, development, and growth with its heart in Massachusetts and Connecticut, close ties to other centers from New England to Chicago, and hospitality toward skilled and entrepreneurial migrants from Western and Central Europe. Cleveland depended on and benefited from that system. Those involved in that system of economic innovation gladly engaged Northeast Ohio, but they had no particular loyalties to the region for its own sake.

Northeast Ohio did not originate most of the technologies that allowed it to grow. It was not an important center of innovation in geology, metallurgy, or chemistry. Despite some notable innovations in these fields and in electricity, the region did not become internationally significant in them, and by 1900 was not producing a steady stream of patents in them. But Northeast Ohio did benefit from the presence of technicians and scientists who understood the best developments in those fields, and who did contribute to them. It benefited also from the alertness of key entrepreneurs, who were quick to find and bring to bear the expertise necessary to exploit the opportunities inherent in the region's location, and to make connections with national markets and Eastern sources of capital.

Northeast Ohio also benefited from the innovations of numerous metal workers. One group of inventors and entrepreneurs, largely based there, made major contributions to the design of bridges, ore unloaders, derricks, hoists, conveyors, and related equipment. This equipment had many applications in industrial work of all kinds, throughout the world. A second group, of inventors and entrepreneurs made major contributions in transportation equipment, helping to create the automobile industry.

Finally, Northeast Ohio benefited greatly from its connections to the technical expertise of metal workers based in New England, New York, and Central Europe. In the 1860s, 1870s, and 1880s, New Englanders in particular brought key technical innovations to the region. These innovations laid the groundwork for the nut, bolt and screw; sewing machine, bicycle, and automobile; and machine tool industries.

In this case, as in the industrial equipment field, a small group of key innovators both developed patentable new ideas and organized key groups of firms. By the 1880s many of the region's innovators were well educated, though nearly all worked directly in industrial settings and focused their attention on immediate problems of commercial importance. Several of the nation's most notable inventors in these years spent important parts of their careers in Cleveland. Among these were Walter Baker, Alexander Brown, Charles F. Brush, Hermann Frasch, Elisha Gray, George Hulett, Elmer Sperry, and Rollin White.

There is much more to be learned about the ways in which Northeast Ohio's business environment encouraged significant innovation during the last third of the nineteenth century, but it seems clear at least that further study should focus on these key firms and innovators in the metal-working and machine-making industries—and on the relative failure of the region to develop more significant clusters of economic activity in other fields, especially, perhaps, electric and chemical goods.[41] Future work might also, certainly, consider the modest recent expansion in the region's service industries (exemplified in MBNA and Progressive Insurance), and ask whether there are ways to encourage their expansion as well.

[41] Historian Philip Scranton recently argued, in *Endless Novelty: Specialty Production and American Industrialization, 1865-1925* (Princeton: Princeton University Press, 1997), that business historians who follow Alfred D. Chandler (*The Visible Hand: The Managerial Revolution in American Business*; Cambridge: Harvard University Press, 1977) have overemphasized the importance of bulk and mass production of basic commodities. They have neglected, he insists, "those firms and sectors which did not achieve throughput, sustain mergers, increase minimum effective size, raise public capital, venture internationally, and move resolutely to manage markets along with employees and production" (p. 6). Scranton's important book shows that several clusters of firms in industries that continued to use batch, custom, and specialty production techniques worked effectively to protect market share, firm income, and wages well into the twentieth century. His chief examples include silverware and costume jewelry makers in Connecticut and Rhode Island, printers in New York City, carpet and other manufacturers in the Philadelphia area, the furniture industry in Grand Rapids, the machine tool industry in Cincinnati, and elements of the electrical equipment industry. John N. Ingham has made some similar points about the independent iron and specialty steel mills of Pittsburgh (*Making Iron and Steel: Independent Mills in Pittsburgh, 1820-1920* (Columbus: Ohio State University Press, 1991). Scranton laments the impact of U.S. trade, anti-trust, and other policies that made it difficult for firms in these industries to set prices, exclude cheaper producers, and maintain market share, wages, and firm income after the 1930s.
The case of the metal-working industries of Cleveland makes a very interesting test of Scranton's propositions. The Cleveland case certainly supports the point that the American economy consists of much more than the *Fortune* 100 largest industrial firms, that it is important to think about the shop floor as well as the executive suite (a point never lost on Chandler), and that it makes great sense to consider clusters of firms and related industries. But the Cleveland case also suggests the complexity of the task of understanding the development of firms, industries, and regions in the United States, and the central importance of competition in the market. Although Cleveland's firms did not grow as large as Ford Motor Company or Carnegie Steel, and the biggest, Standard Oil, moved its headquarters to New York and most of its production facilities to other locations, many Cleveland firms did grow to very considerable size. Cleveland entrepreneurs prided themselves on increasing volume and sought increasing returns to scale; some of them achieved large throughput. Cleveland's firms sustained many mergers. In many industries, Cleveland's firms increased their effective size. Many did raise public capital, and others found ways to attract external investment. Even before World War II many did venture internationally. And as advocates of the tariff, leaders of such trade associations as the National Association of Manufactures, and builders of innovative compensation, labor relations, and welfare organizations, many Cleveland business leaders moved "to manage markets along with employees and production." Cleveland firms competed vigorously, taking advantage of the presence of specialists, often hiring people away from one another and using ideas explored by their neighbors (Jacob Cox describes several his experience in hiring, finding ideas, and seeing his own ideas adopted by neighbors in *Building an American Industry*). For all this, Cleveland's metal-working firms did find it impossible to maintain their pre-depression prominence after World War II.

IV. EARLY PATENTS AND MEASURING PATENT ACTIVITY: A WINDOW ON REGIONAL INNOVATION

Moving from our general account of the region as a whole to the specific activity of inventing, this section provides an overview of patenting in Cleveland and other major U.S. cities during the last half of the nineteenth century, emphasizing the implications for innovation and regional economic growth. For this section we created new databases of a separate list of about 2300 "important" patents as identified by the U.S. Patent Office in 1900, as well as of ALL patents issued in 1860, 1880, and 1900. We find that Cleveland had the highest rate of patents per capita in the nation during this period – and that Cleveland's patenting rate for important patents was more than DOUBLE its overall rate of patenting. Until the rise of corporate R&D laboratories in the 1920s, patents were primarily awarded to individual inventors and entrepreneurs rather than to corporations. Clearly something about the Northeast Ohio environment in this period encouraged invention.

Methods of Measuring Patent Activity by City/Metropolitan Region

We measure patent activity in a city with two measures: (1) patent counts (number of patents granted to inventors who reside in the city), and (2) important patents (number of important patents granted to those inventors).[42] The methodology for each dataset is different.

Patent Counts

One way to measure a city's patent activity is to count the number of patents granted to inventors who list the city as their residence. Currently, the U.S. Patent Office provides an electronically searchable dataset from 1969 to the present. However, very little information is available electronically for years preceding 1969, except the patent number and the technology class.

Since our study examines the late nineteenth century, we had to create our own dataset from primary sources provided in print form by the U.S. Patent Office. Two of these sources exist: the *Official Gazette* of the U.S. Patent Office and the *Annual Report of the Commissioner of Patents*. Because our primary interest is the geography of invention, the most appropriate source is the *Annual Report of the Commissioner of Patents*. This report contains information

[42] For an analysis of the patent citation literature, see Ibid.

about the inventor (including residence) and the assignee and a brief description of the invention. (The *Official Gazette* is designed to give a detailed description of the patent for use by other inventors.)

We chose to analyze three separate years: 1860, 1880 and 1900, because these years define the period when Cleveland began to develop into a major industrial center. Our hypothesis is that innovation was a key ingredient causing Cleveland's rapid growth in the late nineteenth century. The twenty-year intervals allow us to examine patterns of invention and innovation in Cleveland and other industrial cities during this time.

We scanned each patent description in the *Annual Report of the Commissioner of Patents* for 1860, 1880 and 1900.[43] Using scanning software, we were able to create a spreadsheet with the following information: patent number, name of inventor (first name listed if there were multiple inventors), company assignee (if any), city of inventor, state/country of inventor, city of company assignee, state/country of company assignee, and a brief description of the invention. In this way, we created a database of all patents granted by the entire United States for 1860, 1880, and 1900.

The Geography of Early Patents

Since we are particularly interested in the geography of these patents, we organized them by the inventor's place of residence. Table 11 presents the city location of inventors in 1860, 1880 and 1900, ranked by number of patents. In general, the geographic concentration of patents changed very little from 1860 to 1900. (Figure 3 shows the geographic distribution of patenting by city in 1900. Cleveland ranked 8th with 1.25% of all U.S. patents and 2.6% of all "important" patents.)

The top 12 cities produced approximately 30% of the patents granted in any given year. However, the geographic distribution of patents did change. For instance, New England's dominance of patent activity declined from 1860 to1880 and from 1880 to 1900. Although Boston certainly continued to rank high as a source of patents, cities such as Providence,

Worcester, New Haven, Hartford, and Lynn dropped substantially in the rankings. Chicago experienced the greatest gain in patent activity during this period. (It ranked twelfth in 1860, third in 1880, and second in 1900.) Chicago led the Midwest's sharp increase in patent

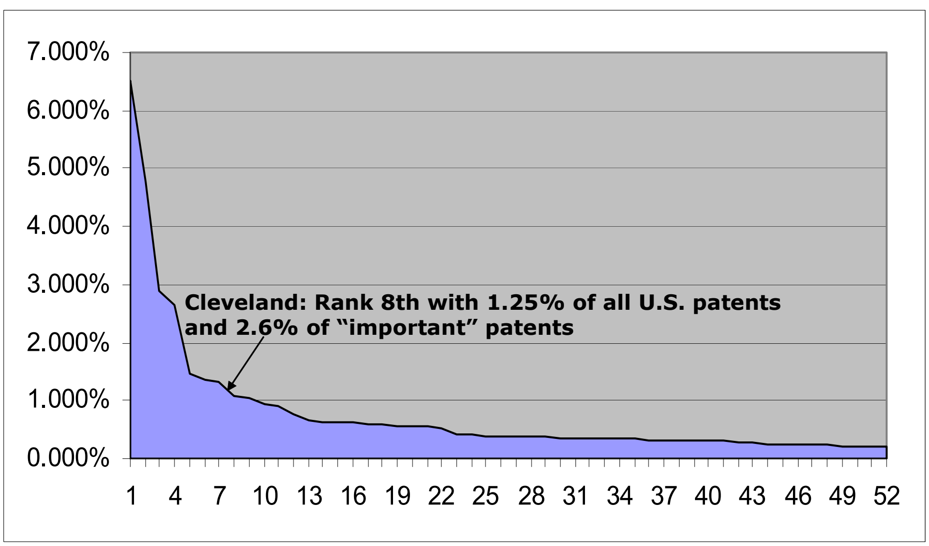
[43] *Annual Report of the Commissioner of Patents,* U.S. Department of Commerce, U.S. Patent Office (Washington: GPO).

activity, while cities such as Cleveland, Pittsburgh, Detroit, St. Louis, and Milwaukee experienced substantial gains in their rankings. Cincinnati was the only exception: It ranked sixth in 1860 but had dropped to thirteenth by 1900.

Patent Mixed Change Reflect Shift to More Complex Technologies

Not only did Cleveland gain in rank between 1860 and 1900, the mix of its patent activity also changed considerably. For example, in 1860 Cleveland's patents were primarily agricultural. Almost 30% of its patents represented improvements in farm implements, especially harrows. However, importantly, in 1860 Cleveland also showed patent activity in industries that would subsequently flourish. (See Section IV.) For example, washing machine patents and railroad patents were prominent in 1860. The most prominent inventor in 1860 was George Stanley who patented new types of candles.

Figure 3: Patents by City as Percent of U.S. in 1900



By 1880 Cleveland's patenting activity had changed dramatically: patents in lighting, electric generation, petroleum refining, derrick construction, sewing machines, vapor-burning furnaces, engines, and dies predominated. Patents ranged across a wide spectrum of technologies.

Table 11: Patent Count by City, 1860, 1880, and 1900

1900			1880			1860		
		Percent			Percent			Percent
City and State	Total	1900	City and State	Total	1880	City & State	Total	1860
New York NY	1172	8.466%	New York NY	1088	8.426%	New York NY	505	11.585%
Chicago IL	827	5.974%	Philadelphia PA	507	3.927%	Philadelphia PA	213	4.886%
Philadelphia PA	505	3.648%	Chicago IL	462	3.578%	Boston MA	122	2.799%
Boston MA	254	1.835%	Brooklyn NY	435	3.369%	Brooklyn NY	116	2.661%
London GBX	233	1.683%	Boston MA	386	2.989%	Buffalo NY	63	1.445%
Pittsburgh PA	198	1.430%	Baltimore MD	185	1.433%	Cincinnati OH	60	1.376%
St. Louis MO	183	1.322%	Cincinnati OH	172	1.332%	Washington DC	49	1.124%
Cleveland OH	173	1.250%	St. Louis MO	163	1.262%	Providence RI	43	0.986%
Baltimore MD	151	1.091%	San Francisco CA	161	1.247%	Pittsburgh PA	42	0.964%
Washington DC	135	0.975%	Pittsburgh PA	131	1.015%	**Cleveland OH**	41	0.941%
Detroit MI	124	0.896%	Providence RI	131	1.015%	Baltimore MD	40	0.918%
San Francisco CA	113	0.816%	**Cleveland OH**	127	0.984%	Chicago IL	38	0.872%
Cincinnati OH	110	0.795%	Buffalo NY	117	0.906%	New Orleans LA	35	0.803%
Berlin DEX	103	0.744%	Newark NJ	117	0.906%	Newark NJ	34	0.780%
Minneapolis MN	101	0.730%	Washington DC	111	0.860%	Worcester MA	34	0.780%
Paris FRX	99	0.715%	New Haven CT	103	0.798%	Albany NY	32	0.734%
Newark NJ	96	0.693%	Detroit MI	91	0.705%	New Haven CT	31	0.711%
Milwaukee WI	91	0.657%	Worcester MA	82	0.635%	Rochester NY	30	0.688%
Denver CO	84	0.607%	Jersey City NJ	72	0.558%	St. Louis MO	29	0.665%
Buffalo NY	74	0.535%	Indianapolis IN	71	0.550%	Roxbury MA	27	0.619%
Providence RI	73	0.527%	Paris FRX	67	0.519%	Troy NY	26	0.596%
Indianapolis IN	69	0.498%	Albany NY	55	0.426%	Hartford CT	24	0.551%
Hartford CT	69	0.498%	Milwaukee WI	52	0.403%	Indianapolis IN	23	0.528%
Rochester NY	63	0.455%	Rochester NY	52	0.403%	San Francisco CA	23	0.528%
Dayton OH	57	0.412%	Springfield MA	52	0.403%	Lancaster PA	19	0.436%
Los Angeles CA	56	0.405%	Columbus OH	51	0.395%	Middletown CT	18	0.413%
Allegheny PA	51	0.368%	Louisville KY	51	0.395%	Lynn MA	16	0.367%
Ludwigshafen DEX	50	0.361%	Troy NY	50	0.387%	Utica NY	15	0.344%
Springfield MA	50	0.361%	Allegheny PA	49	0.379%	Charlestown MA	15	0.344%
Worcester MA	50	0.361%	Bridgeport CT	49	0.379%	Dayton OH	14	0.321%
Paterson NJ	50	0.361%	Lynn MA	47	0.364%	Jersey City NJ	14	0.321%

The two most prominent inventors in 1880 were Daniel Appel, who invented new ways to make paper bags, and George Baker, who invented new processes in sewing machines. Most of Baker's inventions are assigned to the White Sewing Machine Company of which he was a leading officer; this firm and several spin-off firms later expanded (as we have seen) into bicycles, automobiles, and trucks.

By 1900 many patents had been granted for automobiles, railways, batteries, conveying and dredging machines, furnaces, machine tool products, and electric lighting. One of Cleveland's leading inventors in 1900 was Elmer Sperry, who was granted 17 patents in 1900 alone. His inventions improved electric railways, batteries, and automobiles. Many were assigned to the Cleveland Machine Screw Company, a leader in the machine tool industry at the turn of the twentieth century.

Important Patents (1871-1900)

A patent count reveals one significant aspect of innovative activity found in a city. It is, however, only a simple measure of volume. Most important, not all patents are equally important. One drawback of simple patent counts is that their importance is influenced by that city's age and industrial structure. Consider a city that is dominated by a mature industry. If the inventors in that city are producing patents for that industry, due to the industry's maturity the impact of these patents on the city's economic growth may be relatively modest.

Ideally, we would like to know if a patent makes a significant contribution to technological change because "important" patents are more likely to cause industrial growth in a region.[44] However, these important patents are often difficult to identify. Fortunately, the 1895 *Annual Report* included a list of patents for the years 1871 to 1895 that were considered particularly important because they represented advances in many technology classifications. Federal patent examiners identified the most important patents in the technology class of their expertise.

The Ladd Report

This report became the basis for an expanded list of important patents published in the 1900 U.S. Census.[45] Ladd's list identifies approximately 2,300 patents that U.S. patent examiners viewed as having made a significant contribution to the industrial art of the period. Patents on this list are called "important" patents in this paper.[46]

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[44] The current patent literature uses patent citations to measure "importance." See Fogarty, Michael S. , Amit K. Sinha, and Adam B. Jaffe, op. cit. This method is not available for the period we are studying because early patents did not include citations to prior art.

[45] Story B. Ladd, "Patents in Relation to Manufacturers." *Twelfth Census of the United States: Manufacturing, Vol. 7, United States by Industries* (Washington: US Census Office, 1902).

[46] Story B. Ladd was the author of a report titled "Patents in Relation to Manufacturers." All patents found in the 1895 Annual Report of the Commissioner of Patents are included in Ladd's article, along with important patents from 1896 to 1900.

Table 12: Important Patent Count by City 1870-1890		
City and State	**Total**	**Percent of Total**
New York, NY	230	9.754%
Chicago, IL	154	6.531%
Philadelphia, PA	102	4.326%
Boston, MA	85	3.605%
Cleveland, OH	62	2.629%
Washington, DC	61	2.587%
London GBX	46	1.951%
Pittsburgh, PA	41	1.739%
Brooklyn, NY	36	1.527%
Lynn, MA	29	1.230%
Rochester, NY	28	1.187%
St. Louis, MO	28	1.187%
San Francisco, CA	28	1.187%
Paris FRX	27	1.145%
Baltimore, MD	21	0.891%
Brockton, MA	21	0.891%
Hartford, CT	20	0.848%
Berlin DEX	19	0.806%
Detroit MI	18	0.763%
Newton, MA	18	0.763%
Newark, NJ	17	0.721%
Providence, RI	17	0.721%
Florence ITX	16	0.679%
Syracuse, NY	15	0.636%
Indianapolis, IN	13	0.551%
Columbus, OH	12	0.509%
Dayton, OH	11	0.466%
Grand Rapids, MI	11	0.466%
Jersey City, NJ	11	0.466%
Cumulative Total		**50.762%**

The report gives the last name of the inventors, patent numbers, the year each patent was granted, and a technology classification. Using this information and the three Annual Reports, we were able to create a spreadsheet with the same information we collected from the counts of all patents in 1880, 1890, and 1900. *This dataset yields a picture of the technological landscape as it existed for the last thirty years of the nineteenth century.*

Table 12 presents a ranking of cities based on these data. Cleveland ranked fifth on the list of important patents with 62 patents. One finding is that important patents were more geographically concentrated than all patents. For instance, the top 25 cities (including foreign cities such as London and Paris) account for almost 50% of the important patents.[47] In Cleveland, important patents were more than double the concentration of all patents (roughly 2.6% of "important" patents and 1.25% of all patents over this period—2.6/ 1.25=2.25).

Agglomeration Economies Are Correlated With Important Patents

This finding suggests that agglomeration economies may be more closely associated with important patents than all patents. For one thing, inventors of important patents tend to attract other influential inventors. Charles Brush provides a good example for Cleveland. Credited with six important patents as a resident of Cleveland, Brush was able to attract Bentley and Knight, the first inventors to create an electric railway in a city, and Elmer Sperry, who was instrumental in developing Cleveland's machine tool and battery industries.

A major inventor, Brush was the first to patent a dynamo to generate electricity and the first U.S. inventor to develop arc-lamp lighting. Brush used his inventions to produce the arc lamps that made Cleveland the first city in the world with electric street lighting. His inventions created a Cleveland legacy: Inventions in the arc lamp, electric generation, and batteries led to the formation of major industries in Cleveland, including electric lighting (NELA Park–General Electric), batteries (Union Carbide), arc welding (Lincoln Electric), engineering (Brush-Wellman), and electrical generation (Cleveland Municipal Light).

Some Important Patents in Cleveland

Charles Brush dominated the period 1877 to 1883, during which he obtained important patents in lighting, electricity generation, and batteries. Two types of inventions dominated the period 1884 to 1895. Most prominent are patents in hoisting and conveying. As an important center of steel manufacturing during this period, one of Cleveland's key location advantages was the low cost of shipping iron ore from Minnesota. Much of this advantage can be attributed to the inventions of George Hulett, Alexander Brown, and Timothy Long. They were instrumental

[47] Our U.S. patent lists include patents assigned to inventors or companies located in other countries.

in developing the methods of loading and unloading iron ore that reduced the cost of producing steel in Cleveland.

The refining of oil also became an important source of innovation in Cleveland. In fact, for a time during this period Cleveland was the oil refining capital of the nation. Standard Oil of Ohio recruited the best petroleum-refining inventor in the world to Cleveland. Working in Standard Oil laboratories, Herman Frasch created a process for removing sulfur from crude oil. This was one of the most commercially valuable patents produced by Cleveland inventors.

The period 1896 to 1900 was dominated by transportation developments. In Cleveland, Alexander Winton was the inventor most associated with the automobile industry; his company was the first in the U.S. to sell an automobile. In 1900, Winton Automobile Company was the nation's largest producer of gasoline-powered automobiles. At the same time, Elmer Sperry became an important inventor of electric railways and batteries and George Hulett continued inventing processes to unload iron ore.

In summary, when coupled with additional information, patents provide a very important window on innovation. The data clearly show Cleveland's rising stature as a source of inventions and the increasingly complex character of the technologies originating in the region from 1860-1900. However, Cleveland played a role more like Seattle in today's economy than San Francisco.

V. A STATISTICAL TEST OF THE IMPACT OF PATENTS ON REGIONAL ECONOMIC GROWTH

Our case study of the metalworking industries provides one level of evidence in support of our hypothesis: To achieve increasing returns and a high rate of productivity growth, a region must develop a significant source of invention and innovation with national networks linking inventors. This section makes use of the our new patent databases to essay a simple statistical test of a related, narrower hypothesis covering all manufacturing industries: *A regional economy in the late nineteenth century achieved stronger economic performance when it produced important patents and was highly inventive.* The results are consistent with the metalworking industry findings.

We examined value-added growth in manufacturing from 1880 to 1900 for 48 U.S. cities (see Appendix Table A3.). These are the largest 48 cities in terms of the value of shipments that have data in both the 1880 and 1990 U.S. Censuses.[48] The period 1880 to1900 is a particularly good one for testing our hypotheses because at that time virtually all patents came from independent inventors who often were also entrepreneurs; it is possible to identify the city in which the inventor was working, an identification that becomes much more difficult to make once corporations become prominent in the patenting process.

Our statistical tests use five variables to explain the growth rate of value added. Three of these variables measure innovative activity:

- patents per capita granted to inventors located in a city during 1880 (patpcap),
- the total number of important patents granted to inventors located in the city (impats), and
- the interaction between the patents per capita in 1880 and important patents (ipcapimp).

The 1880 population was included as a control variable because large cities during this time period were the primary sources of new patents. Finally, we included two regional dummy variables to control for broad regional shifts in manufacturing activity from New England to the Great Lakes during this period:

- One identifies cities located in the New England states (NE).
- The other identifies cities located in the Great Lakes states (GL).

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[48] In addition, the city had to have at least one important patent. Many of the smaller cities did not satisfy this criterion.

[All variables in Table 13 should be described with abbreviation in this section.]

Our regression model is derived from the standard growth equation given as follows:

$$VA00 - VA80e^{g(x)t} \quad (1)$$

Where VA00 is the city's value added in 1900, VA80 is the city's value added in 1880, g(x) is the growth rate function, x is a set of explanatory variables, and t represents time. The function g(x) is represented as

$$g(x) = a_o + a_1 lnpatpcap + a_2 lnimpats + a_3 lnipcapimp + a_4 lnpop + a_5 NE + a_6 GL + u$$

where in is the logarithm and u is the error term. Taking the logarithm of equation (1) and letting grva = lnVA00 – lnVA80 yields the estimated regression equation:

$$grva = a_o + a_1 lnpatpcap + a_2 lnimpats + a_3 lnipcapimp + a_4 lnpop + a_5 NE + a_6 GL + u.$$

The model is estimated with ordinary least squares.

The intuition underlying the regression equation is straightforward: Cities grow faster when they have a high rate of inventive activity combined with the production of important technology. Both conditions must exist for a city's innovative activity to cause more rapid manufacturing growth. (Our simplified analysis assumes that a significant fraction of new, locally developed technology is also locally commercialized in the form of new companies and/or investment in existing facilities.) Therefore, we expect the sign on lnipcapimp to be positive. We also expect that greater patenting activity generates faster growth.

In addition, the regression equation's form implies a nonlinear interaction between patenting activity (patpcap) and the manufacturing value-added growth rate. In order for more patents to lead to faster growth ($\partial lngrva/\partial lipcapimp > 0$), the sign on lnimpats must be negative or insignificant. A negative and significant sign implies that a threshold level (critical mass) of important patents is necessary for a city's patenting activity to generate economic growth.

A similar argument holds for important patents. In other words, in order for $\partial lngrva/\partial lnipcapimp$ to be positive, the sign on lnimpats must be positive or insignificant.[49] If the sign is positive and significant, then an increase in important patents will cause more value-added growth only after exceeding a threshold in patents per capita.

Because most large cities grew at a relatively slow pace between 1880 and 1900, we expect a negative sign on the logarithm of population. The most rapid industrial growth occurred in smaller cities, particularly in the Midwest. Given the broad regional

[49] The sign must be positive since pats < 1.

shifts in manufacturing, we expect a negative sign on the New England dummy variable and a positive sign on the Great Lakes dummy.

The Results Support the Hypothesis and Imply Two Thresholds

The regression results are reported in Table 13. All the independent variables are significant and have the expected signs. As expected, the results imply two key thresholds:

1) For a city to exhibit a positive relationship between the growth rate and the rate of patenting activity (pats), it must have at least 10 important patents.[50] Of the 48 cities in our sample, 22 have 10 or more patents. (These are indicated in Appendix Table A-4.) Except for Cincinnati (with only 5 important patents), every city in the top 10 places ranked by value added in 1880 had 10 or more patents. With 62 important patents, Cleveland was well above the threshold necessary for the rate of patent activity to lead to faster value-added growth in manufacturing.

2) To experience a positive relationship between the value-added growth in manufacturing and the number of important patents, a city had to have a patenting rate of 0.00056 (roughly 1 patent per 2,000 people). All 48 cities in our sample were above this threshold. Therefore, the findings support the hypothesis that important patents were positively related to the city's manufacturing growth.

The results for the remaining variables are consistent with our expectations: Larger cities grew more slowly than smaller ones; cities in New England experienced slower manufacturing growth than cities in other regions of the country; and cities in the Great Lakes region experienced faster manufacturing growth.

In conclusion, a high rate of patenting activity per se is not sufficient to cause rapid growth in manufacturing output. However, this finding should not come as a surprise. For one thing, the patenting rate is sensitive to a city's industry structure as well as to the industry's maturity. For example, in this time period there were many patents for the improvement of cooking stoves. However, none of these patents were deemed important by the U.S. Patent Office, which is typical for patents in mature industries. A city such as Lowell, Massachusetts, fits this pattern. Lowell had many patents (mostly in textiles) but only a few important patents. In contrast, new technologies such as photography had

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[50] The derivative $\partial \text{lngrva}/\partial \text{lnpatpcap} \geq 0$ when imppats ≥ 9.2.

relatively few patents, yet a large fraction were evaluated as important, and they were located in places with rapid growth. Rochester provides a case in point.

Table 13: Regression Results for Explaining the Effect of Local Inventions on Manufacturing Growth from 1880-1900

Variable	Coefficient	Standard Error
Intercept	-0.60692	1.6301
lnpatpcap	-0.52150	0.1790
lnimpats	1.75751	0.6475
lnipcapimp	0.23477	0.0887
lnpop	-0.21919	0.0931
NE	-0.35204	0.1743
GL	0.32331	0.1536
Adj. R2 = 0.325		

VI. CONCLUSIONS AND IMPLICATIONS

This paper poses a fundamental question raised by a prominent Cleveland venture capitalist: What made Cleveland an innovative, entrepreneurial place in the nineteenth and early twentieth centuries that is missing today? One objective of our larger research project is to begin answer this question.

We draw several conclusions:

First, there is clear evidence that Cleveland was a highly innovative, entrepreneurial city (but more like Seattle than the San Francisco Bay Area) during the latter nineteenth and early twentieth centuries. We see this in at least three ways:

- Cleveland's high patenting rate of "important" technology;
- Cleveland's numerous entrepreneurial business histories, with increasingly complex products;
- The Cleveland industrial district's sharply increasingly manufacturing productivity from 1879 through the 1920s, with its resulting dramatic growth of the region's industries, many of which were emerging industries nationally—many with close connections to local patents.

Cleveland also developed a sizable number of millionaires associated with its core industries.

Second, our case study of Cleveland's metalworking companies and industries strongly supports our basic hypothesis that a region must both develop a concentration of specialists capable of producing significant inventions and innovations – AND connect effectively with the national and international networks that link inventors and entrepreneurs to investors and local industry. The qualitative case study evidence for this period indicates that Northeast Ohio's connection between patents and industrial growth was built on highly networked clusters of entrepreneurs, inventors, and investors with close ties to local industry.

Third, our statistical findings for 48 cities support our hypothesis and are consistent with the case study evidence. The results yield new evidence that a critical mass of "important" patents, coupled with a highly inventive local environment, are an important part of the explanation of a region's growth rate in value-added manufacturing during the buildup stage of urban industrial agglomeration (the last two decades of the nineteenth century). Nevertheless, the data also show that the presence of "important" patents doesn't guarantee development of a new industry or survival of an existing industry. (In fact, several of Cleveland's most important patents contributed significantly to innovation in petroleum refining while helping to move the industry out of Cleveland.) We also note that Cleveland benefited from inventions, innovations, and skills developed elsewhere, notably in the Northeast and in Germany. Even in the nineteenth century, localization of economic benefits from invention of a new technology couldn't be taken for granted.

Northeast Ohio's Recent Efforts to Transition to a New Productivity Regime

Unfortunately there exists much less evidence concerning Cleveland's transition. The data clearly show that Cleveland's manufacturing productivity—relative to other places—peaked at a level substantially above the national level much earlier than previously thought—prior to WWII—and has declined since then.

Without additional data, and study, we have to speculate concerning the reasons for Cleveland's decline. But we know some basics. For example, we know that places like Cleveland became increasingly expensive locations for manufacturing, due in large part to factors such as unionization. We also know that Cleveland lost some of its transportation cost advantages – slowly before World War II, more rapidly later with the growth of industrial centers on the West Coast and the opening of the St. Lawrence Seaway. Therefore, the combination of declining relative productivity and rising costs made Cleveland increasingly less competitive. *But what was causing Cleveland's relative productivity to fall?*

Clearly, several key factors were involved. By taking a very long-run perspective, however, we can suggest one important, previously unrecognized factor that is consistent with the productivity finding: Northeastern Ohio benefited from its relation to national and international innovation systems from the 1830s to the 1930s: it enjoyed close ties to New England and New York, it welcomed skilled entrepreneurs from Central Europe, its people were among the best educated and most literate in the United States, it built internationally significant concentrations of technical and business expertise in fields related to metal-working and transportation and industrial equipment. After 1920, we suspect, regional innovation systems evolved in ways that worked to the region's disadvantage—and to the disadvantage of many older industrial regions – and Northeastern Ohio failed to respond to the new innovation systems as effectively as it might have done.[51] [52] The region maintained a notable presence in metal-working and machine-building, and it transformed many productive processes, especially after 1970. In some ways, Northeastern Ohio has continued to lead the nation in devising ways to integrate new populations, now including African-Americans, into the region's economy. But it placed less emphasis on public education and on higher education and university-based research than other regions. It did not develop new firms in rapidly growing industries. It did not develop a new, internationally significant concentration of expertise.

The early inventions that helped build Cleveland's industries came almost entirely from independent inventors who themselves were often the entrepreneurs who marketed the technology and often founded companies based on the patents. As technology became increasingly science-based, the origin of new technology shifted from independent inventors to corporate R&D labs and university research. Cleveland's corporate R&D base emerged virtually overnight. The region's corporate R&D labs apparently displaced independent inventors as the primary source of new technology as the number of corporate labs increased from 14 in 1920 to 65 in 1931. Corporate labs naturally focused their attention on developing technologies for existing industries – and on protecting the technological assets their companies already enjoyed. *One implication seems to be that the locus for inventions stimulating the growth of new industries shifted to other regions.*

As technology became increasingly science-based, with closer connections to universities and government labs, Ohio made relatively small, fragmented investments in higher education. A set of data for older industrial metropolitan regions that we put together suggests that areas that had significant higher education activity at the turn of the

[51] For a good summary of the literature on regional innovation, see Maryann P. Feldman and Richard Florida, "The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States," in Annals of the Association of American Geographers, 84(2), 1994, pp. 210-220. Drawing from a much larger literature, Feldman and Florida divide the topic into three parts: 1) the location of R&D inputs and technology-based industries; 2) through use of case studies, the origins and development of "regional innovation complexes"; and 3) the role of geography and geographic concentration in economic development and technological innovation. Feldman and Florida describe what they call the "technological infrastructure" of regions: the local manufacturing capabilities embodied in the network of firms, both university research and local industry R&D facilities, and commercialization support services.

[52] Until recently, researchers lacked the knowledge necessary to pinpoint the main components of innovation systems (i.e., the components of regional economies that link R&D and entrepreneurship to the development of new technology and new industries), as well as the patterns of interaction among the components and the mechanisms that make an innovation system We'll return to this issue later.

twentieth enjoyed higher per-capita incomes in 1969 and in most cases faster growth rates in per-capita income from 1969-1997; Northeastern Ohio had a relatively small university base in 1900.[53]

Related research on the innovation systems of metropolitan regions for the period 1975-1996 clearly shows that, with few exceptions, today's older industrial regions have become less influential sources of new technology since World War II, draw less technology through connections to universities, and draw even less from local universities.[54]

Policy Implications

If our analysis of economic transitions is correct, it suggests stark policy implications for older industrial cities. Unfortunately, the same increasing returns phenomenon (i.e., a doubling of economic scale leads to more than a doubling of regional output) and the nature of the regional growth process that favors growing regions also disproportionately punishes declining regions. Without intervention, the process can produce cumulative decline.

To offer a reasonable expectation of success, places that lack a major research university will have to create one. Places with reasonably strong research universities have the best chance of success, but even those places can fail if their institutions and industries lack the mechanisms *inside and outside their universities* needed to link education and research to the region. Places like Cleveland would need to invest more and to invest very strategically in their innovation systems.[55] *No magic bullet will move Cleveland to a strong position*. We can achieve that only by choosing a niche, increasing the scale of investment in specific universities so that they attain critical mass in a variety of areas, carefully match research capabilities with Cleveland's industries. Cleveland and Northeast Ohio must also take steps to produce and attract a new, internationally significant concentration of expertise: this will require state as well as local efforts in elementary and secondary as well as higher education, in the commercialization of technology, and in promoting the region as an attractive place to live.[56] Finally, states clearly need to take much more responsibility for being knowledgeable. They should

[53] Reference?
[54] See Fogarty and Sinha, MIT Press, op cit.
[55] See Fogarty, "Cleveland's Emerging Economy," op cit.
[56] See Michael S. Fogarty, Ohio MEMS: Developing a Systems Approach to Investments in University Research (Cleveland: Center for Regional Economic Issues), August 17, 2000.

commit to the research essential to understanding the policies that will enable their industries, innovation systems, and regional economies to grow.

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APPENDIX

Table A1: Large Cleveland Firms in Metal-Related Industries, 1880

Firm Name	Industry	Rating*
Republic Iron Co.	Iron	A+
Jackson Iron Co.	Iron	A
Lake Erie Iron Co.	Iron	A
Andrews, Hitchcock	Pig iron, Coal	A
Cleveland Iron Mining	Iron mining	B+
Rhodes & Co.	Wholesale pig iron	B+
Pittsburg & Lake Angeline Iron Co.	Iron	B
Saginaw Mining Co.	Iron ore	B
Hand Gold Mining Co.	Gold mining	B
Cleveland Rolling Mill Co.	Iron rolling	AA
Cleveland City Forge & Iron Co.	Iron forgings	B
Younglove & Co.	Iron~~making~~, Farm implements	B+
Chisolm Steel Shovel Works	Steel shovels	B
McCurdy, W.H. & Co.	Wholesale iron, Nails, Steel	B
Cleveland, Brown, & Co.	Wholesale iron, Nails, Steel	B+
Fuller, Warren & Co.	Wholesale stoves &c.	A+
Willcox, Treadway, & Co.	Hardware mfg.	A
Union Steel Screw Co.	Screws	A
Lamson, Sessions & Co.	Nuts & bolts mfg.	B+
Bourne & Knowles	Nuts & washers mfg.	B
Worthington, Geo. & Co.	Wholesale & retail iron & hardware	B+
William Bingham. & Co.	Wholesale & retail iron & hardware	B
Cleveland Non-Explosive Lamp Co.	Lamps	B

Source: R. G. Dun & Co

Table A2: Large Cleveland Firms in Metal-Related Industries, 1900

Firm Name	Field	Rating*
Brown, H.H. & Co.	iron ore	AA
The Cleveland Cliffs Iron Co.	iron ore	AA
Cleveland Iron Mining Co.	iron ore	AA
Iron Cliffs. Co.	iron ore	AA
Oglebay, Norton & Co.	iron ore merchants	AA
Pickands, Mather & Co.	iron ore merchants	AA
Hanna, M.A. & Co.	coal & iron ore	AA
Chapin Mining Co.	iron ore	A+
Commonwealth Iron Co.	iron ore, mine	A
Stewart Iron Co. Ltd.	iron ore?	A
Pittsburg & Lake Angeline Iron Co.	iron ore	A
Eureka Iron & Mining Co.	iron ore mine	B+
Sunday Lake Iron Mining Co.	iron ore	B
Kelley Island Lime & Transport Co.	limestone	A
Corrigan, McKinney & Co.	iron ore, pig iron, mfg & wholesale	AA
Republic Iron Co.	iron	AA
National Malleable Castings Co.	iron castings	AA
Cleveland City Forge & Iron Co.	iron work	B+
The Van Dorn Iron Works Co.	iron work	B
Union Rolling Mills	steel	A
Cleveland Steel Co.	steel	B
Otis Steel Co., Ltd.	steel	B+
Shelby Steel Tube Co.	steel tubes	AA
Paige Car Wheel Co.	steel wheels	A+
William Chisolm & Sons	steel shovels	A
American Washboard Co.	washboards	B+
Topliff, I.N., Mfg. Co.	carriage hardware	B+
Eberhard Mfg. Co.	carriage, saddle hardware	B+
The Cleveland Hardware Co.	hardware	B+
Standard Tool Co.	hardware	B+
The Van Wagoner & Williams Hardware Co.	hardware	B+
National Screw & Tack	hardware, screws & tacks	B+
The Union Steel Screw Co. Inc.	hardware; steel screws	A
Cleveland Machine Screw Co.	screws, auto. screw machines	A
Lamson & Sessions	manufacturer, nuts & bolts	B
Bingham, William Co.	wholesale & retail hardware	B+
The George Worthington Co.	wholesale & retail hardware	B+
American Ship Building	ships	AA
The Brown Hoisting & Conveying Co.	hoists, conveyors	A+
Ship Owners Dry Dock	dry dock	B+
King Bridge Co.	bridge work	B+
Globe Iron Works	machines	B+
Canadian Copper Co.	copper	AA
Bishop & Babcox	tacks, nails, pumps, brass	A
Schneider & Trenkamp Co.	brass founders, vapor stoves	B+
The Cleveland Faucet Co.	air compressors, brass goods	B
Babcock & Wilcox	pumps, etc.	Rated at NYC
Standard Lighting Co.	light fixtures	B+
W. S. Tyler Co.	fine screens, mining equipment	A
Kilby Mfg. Co.	sugar apparatus & engines	AA
White Sewing Machine Co.	sewing machines, bicycles	AA
Standard Sewing Machine Co.	sewing machines	A+
Lozier H.A. & Co.	wholesale bicycles	AA

Source: R. G. Dun & Co.

TABLE A3 U.S. Cities in the Regression Equation

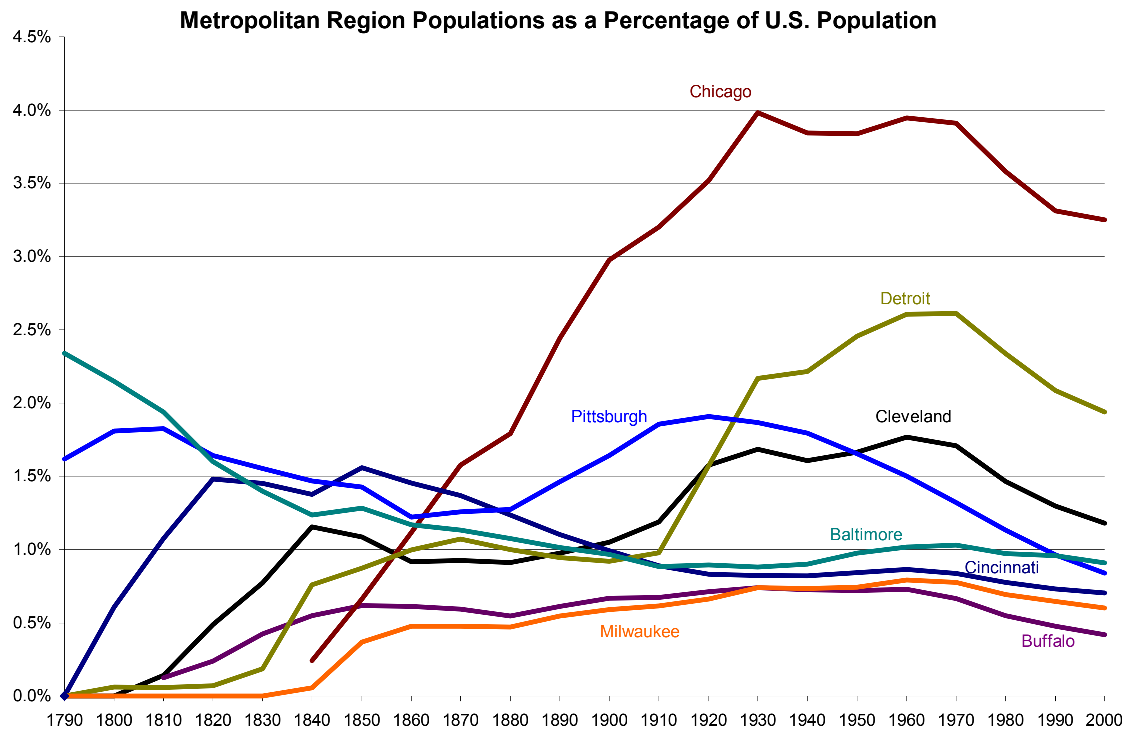
City	City	City	City
Albany, NY	Detroit, MI*	New Haven, CT	Rochester, NY*
Baltimore, MD*	Hartford, CT*	New Orleans, LA	St. Paul, MN
Boston, MA*	Indianapolis, IN*	New York, NY*	St. Louis, MO*
Bridgeport, CT	Jersey City, NJ*	Newark, NJ*	San Francisco, CA*
Buffalo, NY	Kansas City, MO	Omaha, NE	Springfield, MA
Camden, NJ	Lawrence, MA	Patterson, NJ	Syracuse, NY*
Chicago, IL*	Louisville, KY	Peoria, IL	Toledo, OH
Cincinnati, OH	Lowell, MA	Philadelphia, PA*	Trenton, NJ
Cleveland, OH*	Lynn, MA*	Pittsburgh, PA*	Troy, NY
Columbus, OH*	Manchester, NH	Providence, RI*	Washington, DC*
Dayton, OH*	Milwaukee, WI	Reading, PA	Wilmington, DE
Denver, CO*	Minneapolis, MN	Richmond, VA	Worcester, MA

*Cities with at least 10 or more important patents

Table A4. Patent Count by City, 1860, 1880, and 1900

1900			1880			1860		
		Percent			Percent			Percent
City and State	**Total**	**1900**	**City and State**	**Total**	**1880**	**City & State**	**Total**	**1860**
New York NY	1172	8.47%	New York NY	1088	8.43%	New York NY	505	11.59%
Chicago IL	827	5.97%	Philadelphia PA	507	3.93%	Philadelphia PA	213	4.89%
Philadelphia PA	505	3.65%	Chicago IL	462	3.58%	Boston MA	122	2.80%
Boston MA	254	1.84%	Brooklyn NY	435	3.37%	Brooklyn NY	116	2.66%
London GBX	233	1.68%	Boston MA	386	2.99%	Buffalo NY	63	1.45%
Pittsburgh PA	198	1.43%	Baltimore MD	185	1.43%	Cincinnati OH	60	1.38%
St. Louis MO	183	1.32%	Cincinnati OH	172	1.33%	Washington DC	49	1.12%
Cleveland OH	173	1.25%	St. Louis MO	163	1.26%	Providence RI	43	0.99%
Baltimore MD	151	1.09%	San Francisco CA	161	1.25%	Pittsburgh PA	42	0.96%
Washington DC	135	0.98%	Pittsburgh PA	131	1.02%	**Cleveland OH**	41	0.94%
Detroit MI	124	0.90%	Providence RI	131	1.02%	Baltimore MD	40	0.92%
San Francisco CA	113	0.82%	**Cleveland OH**	127	0.98%	Chicago IL	38	0.87%
Cincinnati OH	110	0.80%	Buffalo NY	117	0.91%	New Orleans LA	35	0.80%
Berlin DEX	103	0.74%	Newark NJ	117	0.91%	Newark NJ	34	0.78%
Minneapolis MN	101	0.73%	Washington DC	111	0.86%	Worcester MA	34	0.78%
Paris FRX	99	0.72%	New Haven CT	103	0.80%	Albany NY	32	0.73%
Newark NJ	96	0.69%	Detroit MI	91	0.71%	New Haven CT	31	0.71%
Milwaukee WI	91	0.66%	Worcester MA	82	0.64%	Rochester NY	30	0.69%
Denver CO	84	0.61%	Jersey City NJ	72	0.56%	St. Louis MO	29	0.67%
Buffalo NY	74	0.54%	Indianapolis IN	71	0.55%	Roxbury MA	27	0.62%
Providence RI	73	0.53%	Paris FRX	67	0.52%	Troy NY	26	0.60%
Indianapolis IN	69	0.50%	Albany NY	55	0.43%	Hartford CT	24	0.55%
Hartford CT	69	0.50%	Milwaukee WI	52	0.40%	Indianapolis IN	23	0.53%
Rochester NY	63	0.46%	Rochester NY	52	0.40%	San Francisco CA	23	0.53%
Dayton OH	57	0.41%	Springfield MA	52	0.40%	Lancaster PA	19	0.44%
Los Angeles CA	56	0.41%	Columbus OH	51	0.40%	Middletown CT	18	0.41%
Allegheny PA	51	0.37%	Louisville KY	51	0.40%	Lynn MA	16	0.37%
Ludwigshafen DEX	50	0.36%	Troy NY	50	0.39%	Utica NY	15	0.34%
Springfield MA	50	0.36%	Allegheny PA	49	0.38%	Charlestown MA	15	0.34%
Worcester MA	50	0.36%	Bridgeport CT	49	0.38%	Dayton OH	14	0.32%
Paterson NJ	50	0.36%	Lynn MA	47	0.36%	Jersey City NJ	14	0.32%

Figure A1: Metropolitan Region Populations as a Percentage of U.S. Population



Sources: Population of States and Counties of the United States: 1790 to 1990, Richard L. Forstall, Ed. (U.S. Bureau of the Census: Washington, D.C. 1996); 2000 census at http://www.census.gov/population/www/cen2000/phc-t1.html

Cleveland's Industries by Decade, 1860 through 1920

Industry	Value ($)	Added (%)	Industry	Value ($)	Added (%)
1860			**1900**		
Iron, bar and sheet	$474,300	8.41	Iron and steel, total	$12,963,057	18.99
Clothing	$253,241	4.49	Foundry and machine shop product	$8,729,979	12.79
Machinery, steam engines	$176,093	3.12	Clothing, total	$4,638,999	6.8
Printing	$168,247	2.98	Liquors, malt	$3,193,521	4.68
Boots and shoes	$135,851	2.41	Electrical apparatus and supplies	$1,756,270	2.57
Flour and meal	$112,678	2	Printing and publishing	$1,587,901	2.33
CUMULATIVE TOTAL	**$1,320,410**	**23.41**	CUMULATIVE TOTAL	**$32,869,727**	**48.16**
1870			**1910**		
Iron, total	$1,435,481	11.79	Foundry and machine shop products	$22,119,230	18.9
Machinery, total	$851,248	6.99	Automobile, incl. bodies and parts	$10,986,892	9.39
Coal-oil, rectified	$672,019	5.52	Iron and steel, steel works and rolling mills	$10,424,300	8.91
Tobacco, total	$540,917	4.44	Clothing, total	$9,042,839	7.73
Cooperage	$376,784	3.1	Printing and publishing	$6,854,611	5.86
Liquors and malt, total	$336,289	2.76	Liquors, malt	$3,640,335	3.11
CUMULATIVE TOTAL	**$4,212,738**	**34.61**	CUMULATIVE TOTAL	**$63,068,207**	**53.88**
1880			**1920**		
Iron and steel, total	$3,580,491	21.09	Foundry and machine shop products	$59,028,508	12.35
Foundry and machine-shop products	$2,034,265	11.98	Automobiles, total	$57,348,376	11.99
Men's clothing	$1,198,629	7.06	Iron and steel, total	$41,958,587	8.78

Liquors malt	$549,836	3.24	Electrical machinery	$27,221,752	5.69
Slaughtering and meat packing	$541,167	3.19	Clothing, total	$27,145,040	5.68
Printing and publishing	$429,562	2.53	Machine tools	$13,593,317	2.84
CUMULATIVE TOTAL	**$8,333,950**	**49.1**	CUMULATIVE TOTAL	**$226,295,580**	**47.33**
1890					
Foundry and machine-shop products	$6,279,603	13.19			
Iron and steel, total	$6,126,354	12.87			
Clothing, total	$2,637,195	5.54			
Petroleum refining	$2,219,979	4.66			
Malt liquors	$2,113,764	4.44			
Slaughtering, total	$502,600	1.06			
CUMULATIVE TOTAL	**$19,879,495**	**41.77**			

PhDs Granted in the United States, 1861 to 1958

University or Institution	1st PhD	Number of PhDs Granted 1861-1925	1953	1954	1955	1956	1957	1958	Public/Private Institution	Location
Northwestern Univ.	1896	56	148	145	129	125	125	107	Private	Evanston, IL
Univ. of Chicago	1893	1838	245	286	250	241	220	233	Public	Chicago, IL
Univ. of Illinois	1900	464	312	340	343	291	281	351	Public	Springfield, IL
Johns Hopkins Univ.	1878	1372	90	87	82	88	87	82	Private	Baltimore, MD
Boston Univ.	1877	267	66	89	89	72	94	89	Public	Boston, MA
Harvard Univ.	1873	1516	316	291	313	298	273	327	Private	Boston, MA
Mass. Inst. of Tech.	1907	113	178	155	171	157	171	153	Private	Boston, MA
Tufts Univ.	1895	11	2	9	8	15	6	11	Private	Boston, MA
Univ. of Michigan	1876	442	265	303	274	274	278	268	Public	Ann Arbor, MI
Wayne State Univ.	1948	N/A	22	20	31	38	40	40	Public	Detroit, MI
Univ. of Minnesota	1888	251	205	254	223	230	239	221	Public	Minneapolis, MN
Washington Univ.	1899	29	57	52	48	52	44	22	Private	St. Louis, MO
Princeton Univ.	1879	313	90	90	101	97	95	105	Private	New Haven, NJ
Columbia Univ.	1875	2008	610	629	547	526	529	538	Private	New York
Univ. of Buffalo	1926	NA	31	32	40	40	28	29	Public	Buffalo, NY
Case Inst. of Tech.	1948	NA	16	12	13	17	17	20	Private	Cleveland, OH
Univ. of Cincinnati	1886	57	30	29	19	23	32	21	Public	Cincinnati, OH

Western Reserve Univ.	1929	NA	28	41	52	48	47	47	Private	Cleveland, OH
Carnegie Inst. of Tech.	1920	2	42	44	45	35	41	50	Private	Washington D.C.
Temple Univ.	1905	1	32	20	24	41	33	41	Private	Philadelphia, PA
Univ. of Pennsylvania	1871	919	125	123	151	135	130	155	Public	Philadelphia, PA
Univ. of Pittsburgh	1886	85	98	100	136	113	102	96	Public	Pittsburgh, PA

Note: NA = Not available

Cities Ranked by Number of Important Patents in Engineering, Electricity, and Transportation

Engineering		Electricity		Transportation		Hydraulics		Hoisting & Conveying	
City and State	**Total**	**City and State**	**Total**	**City and State**	**Total**	**City and State**	**Total**	**City and State**	**Total**
New York NY	20	New York NY	26	Chicago IL	20	New York NY	6	Philadelphia PA	12
Pittsburgh PA	13	Menio Park NJ	8	Philadelphia PA	19	Cleveland OH	4	Cleveland OH	7
San Francisco CA	12	Cleveland OH	7	Cleveland OH	16	Boston MA	3	New York NY	5
St. Louis MO	10	Lynn MA	7	New York NY	10	Chicago IL	3	Alliance OH	4
Chicago IL	9	Chicago IL	6	Hartford CT	7	Irvington NY	3	Boston MA	4
Columbus OH	8	Boston MA	5	Boston MA	6	Philadelphia PA	3	Burlington VT	3
Trenton NJ	8	Pittsburgh PA	5	Fairfield IA	5	Brooklyn NY	2	Chicago IL	2
Brooklyn NY	6	Berlin DEX	4	Ottawa IL	5	Dayton OH	2	Indianapolis IN	2
Orangeville CAX	6	Newark NJ	4	Newton MA	4	Erie PA	2	Providence RI	2
Philadelphia PA	6	Philadelphia PA	4	Detroit MI	3	North Plainfield NJ	2	San Francisco CA	2
Harrisburg PA	5	Washington DC	4	Elmira NY	3	Pittsburgh PA	2	Waynesborough PA	2
Ramapo NJ	2	Yonkers NY	4	Pittsburgh PA	3	San Francisco CA	2		
Nashville TN	4	London GBX	3	Schenectady NY	3				
St. Paul MN	4	Weston MA	3	Springfield MA	3				
Wilkinsburg PA	4	Brooklyn NY	2	Belfast IEX	2				
Kenosha WI	3	Ft. Wayne IN	2	Erie PA	2				
Quincy MA	3	Hackensack NJ	2	Jamestown NY	2				
Albany NY	2	Hyde Park IL	2	Lansing MI	2				
Jersey City NJ	2	Middlesex GBX	2	Riverside IL	2				
Johnstown PA	2	Schenectady NY	2	Rome NY	2				
Kennett Square PA	2	U.S. Navy US	2						
Ramapo NY	2								
Rochester NY	2								
Washington DC	2								

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