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# Do Innovative Regions Inevitably Decline? Lessons from Cleveland's Experience in the 1920s

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Cleveland provides an example of a famous center of innovation that ultimately lost its dynamism and declined. Once a hotbed of innovative startup enterprises in a remarkable number of important Second Industrial Revolution industries, including electric light and power, steel, petroleum, chemicals, and automobiles, Cleveland now stands out for its high proportion of residents below the poverty line. In this paper, we use the case of Cleveland to further our understanding of the life cycle of high-tech regions. Using patent data, city directories, census returns, and other sources, we examine trends in the number and productivity of Cleveland inventors and in the way these inventors exploited their discoveries. We find evidence of important changes in Cleveland's economy beginning in the 1920s. Although the city continued to spawn many startup enterprises, their individual contributions to the stock of patented technology were generally much smaller. Moreover, the city no longer attracted as many inventors from other regions.

Many regions that have earned fame as centers of innovation ultimately lost their dynamism and even suffered decline. Are such reversals inevitable? Do innovative regions have life cycles analogous to those of biological organisms? Do they always mature and then suffer sclerosis? Certainly, there are cases that appear to challenge such generalizations. Silicon Valley has been an ongoing source of startup enterprises in the computer and related industries for over half a century and shows no signs of losing its cutting-edge character. Southeastern New England had rates of patenting per capita that were substantially above the national average for most of U.S. history, despite

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suffering the loss of some of its major manufacturing industries during the late nineteenth and early twentieth centuries.

The so-called Rust Belt cities of the Midwest provide another example. During the Second Industrial Revolution, those cities were dynamic places. Cleveland, the focus of this study, was a hotbed of innovative startup enterprises in a remarkable number of important Second Industrial Revolution industries, including electric light and power, steel, petroleum, chemicals, and automobiles. Now, however, we know it mainly for its high proportion of residents below the poverty line. In this paper, we use the case of Cleveland to further our understanding of the life cycle of high-tech regions. Exploiting patent data, city directories, census returns, and other sources, we examine trends over time in the number and productivity of Cleveland inventors and in the ways they earned returns from their technological discoveries. The Great Depression hit Cleveland hard, and it is possible that this shock was at the root of its subsequent decline. Hence, we focus our paper on the 1920s to see if Cleveland's economy was already losing its innovative character before the Depression struck.

## Hypotheses

There are good reasons to expect that regions that stand out as particularly innovative will continue to be sources of important new enterprises and technologies over time. Perhaps most obviously, the complementary investments made to foster this level of innovation in the first place are likely to provide ongoing support for entrepreneurial activity. For example, entrepreneurs require access to finance, which in turn requires that potential investors have some means of finding out about new enterprises and assessing their potential profitability. There are various ways to solve such information problems, but once the necessary institutions are in place, entrepreneurs and investors can tap them again and again. Because these institutions raise the returns to entrepreneurship, they encourage creative individuals to devote more of their own time, energy, and capital to generating new technologies and making them commercially practicable. Moreover, creative individuals are likely to be attracted to regions where the facilities for garnering funds are superior to those elsewhere. Consequently, regions that develop institutions supportive of entrepreneurship can gain an advantage in innovation that persists over time.[1]

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[1] Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Long-Term Change in the Organization of Inventive Activity," *Proceedings of the National Academy of Sciences* 93 (Nov. 1996): 12686-92; Naomi R. Lamoreaux and Kenneth L. Sokoloff,

However, there are also reasons to expect that over time regions that are centers of innovation will lose their creative edge or at least their advantage over other regions. One possibility is that the complementary institutions that sustain innovation are specific to a particular technology. Once that technology becomes outdated, the region loses its advantage. For example, the financial intermediaries that channel funds to entrepreneurs may have specialized knowledge that enables them to discern the relative value of projects in the region's core industries, but they may have difficulty assessing projects in completely new industries. Similarly, the educational or apprenticeship institutions that provide training for would-be entrepreneurs may focus on technologies most relevant to those same industries and not provide students with an adequate foundation in newer technologies.

Such industry-specific investments might explain, for instance, the relative decline of New England by the end of the nineteenth century. The region had long had patenting rates per capita well above the national average, but its position slipped by the turn of the century. New England continued to have high patenting rates in declining industries such as shoes and textiles, but it did not do nearly as well in new industries such as electricity. As Dhanoos Sutthiphisal has shown, invention in the electrical industry disproportionately originated in regions such as the Middle Atlantic where there were greater concentrations of people with the appropriate human capital.[2] More generally, it is likely that the shift toward the more knowledge-intensive industries of the Second Industrial Revolution advantaged regions with universities that offered advanced scientific training. As Zorina Khan and Kenneth Sokoloff have shown, the great inventors of the late nineteenth and early twentieth centuries were much more likely to have university degrees in science or engineering than those active earlier.[3]

We could tell a similar story about finance. The technologies of the Second Industrial Revolution required much greater amounts of physical capital for creative people to be effective researchers or successfully commercialize their

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"The Geography of the Market for Technology in the Late-Nineteenth- and Early-Twentieth Century United States," in *Advances in the Study of Entrepreneurship, Innovation, and Economic Growth*, ed. Gary D. Libecap (Greenwich, Conn., 1999) 11: 67-121; Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Intermediaries in the U.S. Market for Technology, 1870-1920," in *Finance, Intermediaries, and Economic Development*, ed. Stanley L. Engerman, Philip T. Hoffman, Jean-Laurent Rosenthal, and Kenneth L. Sokoloff, (New York, 2003), 209-46; Naomi R. Lamoreaux and Kenneth L. Sokoloff, "The Geography of Invention in the American Glass Industry, 1870-1925," *Journal of Economic History* 60 (Sept. 2000): 700-29.

[2] Dhanoos Sutthiphisal, "Learning-by-Producing and the Geographic Links between Invention and Production: Experience from the Second Industrial Revolution," *Journal of Economic History* 66 (Dec. 2006): 992-1025.

[3] B. Zorina Khan and Kenneth L. Sokoloff, "Institutions and Technological Innovation during Early Economic Growth: Evidence from Great Inventors in the United States, 1790-1930" in *Institutions, Development, and Economic Growth*, ed. Theo S. Eicher and Garcia-Peñalosa Garcia (Cambridge, Mass., 2006), 123-58.

discoveries. It is likely that this increase favored regions such as the Middle Atlantic with larger pools of savings or better-organized financial markets. It may also have spurred a shift in the locus of technological discovery to large firms with in-house R&D (research and development) facilities, which were better able to tap formal financial markets for funds.[4] Large firms, moreover, were likely to have headquarters in regions such as the Middle Atlantic, so they could be close to the capital markets and to the intermediaries that would help them raise funds.

It is also possible that a location's success sows the seeds of its own decline. A region may be a hotbed of startup enterprises, but as the most successful of these enterprises grow or larger firms acquire them, two things may happen. First, the large enterprises may themselves become less innovative as their managers become excessively enamored of the particular technologies responsible for their success.[5] Second, the emergence of large firms may affect the local environment in ways that make it less conducive to startup enterprises, for example by soaking up the available capital and talent or simply by dint of their superior efficiency.[6] Steven Klepper's study of the Detroit automobile industry suggests that these two possibilities can have contradictory effects on the supply of entrepreneurial enterprises, but that ultimately the second will dominate. Employees are more likely to leave their jobs to organize new firms when they have ideas that their employers are not willing to exploit, so the increasing conservatism of incumbent automakers spurred the creation of startups. Over time, however, the growing market power of the incumbents makes it more difficult to get a foothold in the industry. After the mid-1920s, there were essentially no new successful startups in Detroit.[7]

Finally, it is possible that innovative regions can decline for exogenous reasons. For example, it may be that cities such as Cleveland, which were hotbeds of innovation in the early twentieth century, were particularly hard-hit

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[4] Lance Davis, "The Capital Markets and Industrial Concentration: The U.S. and the U.K.: A Comparative Study," *Economic History Review* 19 (Aug. 1966): 255-72; Naomi R. Lamoreaux and Kenneth L. Sokoloff, "The Market for Technology and the Organization of Invention in U.S. History," in *Entrepreneurship, Innovation, and the Growth Mechanism of the Free-Enterprise Economies*, ed. Eytan Sheshinski, Robert J. Strom, and William J. Baumol (Princeton, N.J., 2007), 213-43; Naomi R. Lamoreaux and Kenneth L. Sokoloff, "The Decline of the Independent Inventor: A Schumpeterian Story?" NBER Working Paper 11654 (2005).

[5] Joseph A. Schumpeter, *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*, trans. Redvers Opie (Cambridge, Mass., 1934).

[6] Joseph A. Schumpeter, *Capitalism, Socialism and Democracy*, 3rd ed. (New York, 1950).

[7] Steven Klepper, "The Organizing and Financing of Innovative Companies in the Evolution of the U.S. Automobile Industry," in *Financing Innovation in the United States, 1870 to the Present*, ed. Naomi R. Lamoreaux and Kenneth L. Sokoloff (Cambridge, Mass., 2007), 85-128.

by the shocks of the second quarter of the twentieth century. The Great Depression may have destroyed the local investors and financial institutions that had supported entrepreneurial startups. Moreover, the financial regulations imposed by the federal government in the wake of the Great Depression may have given New York's financial institutions such a competitive advantage that capital markets in places such as Cleveland never recovered. The rise of local venture capital markets in the late twentieth century owed a great deal to regulatory changes, particularly a clarification of the Employee Retirement Income Security Act that enabled pension funds to invest in venture capital partnerships.[8] While these chances spurred the growth of the venture capital sector in Silicon Valley, they may have been too late to help decaying Rust Belt cities regain their earlier dynamism.

We know that Cleveland was an extraordinarily innovative place during the late nineteenth century. We also know that it was subject to a series of major shocks, including the Great Depression. Although it is likely that these shocks had long-term adverse effects on Cleveland's role as a center of technological discovery, we do not explore their effects directly. Instead, our research strategy is to look for signs that the Cleveland economy's ability to spawn new entrepreneurial ventures was already declining before the first of these shocks hit.

## Cleveland as a Center of Innovation in the Late Nineteenth Century

Located on Lake Erie at the terminus of the Ohio Canal, Cleveland had long been the commercial center of northeastern Ohio. Local boosters founded the city's first heavy industrial enterprise, a firm that produced steam furnaces, in the 1830s and built its first iron-rolling mills in the 1850s.[9] However, Cleveland's rise as an industrial powerhouse was largely a post–Civil War phenomenon. As late as 1870, Cuyahoga County, where Cleveland is located, ranked only twenty-second in manufacturing output among counties nationwide. By 1900, it had risen to fourteenth place, and by 1930, the county was the sixth largest producer of manufacturing goods in the country.[10] In the interim, moreover, Cleveland had become a hotbed of patenting activity. In 1900, it ranked eighth out of all U.S. cities in the total number of patents granted to residents, and if the calculation is limited to patents deemed by official examiners to have made significant contributions to the industrial art

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[8] Samuel Kortum and Josh Lerner, "Assessing the Contribution of Venture Capital to Innovation," *RAND Journal of Economics* 31 (Winter 2000): 674-92.

[9] Carol Miller Poh and Robert Wheeler, *Cleveland: A Concise History, 1796-1990* (Bloomington, Ind., 1990).

[10] *Compendium of the Ninth Census* (1870), *Twelfth Census* (1900), and *Fifteenth Census* (1930). Various dates, U.S. Census Office; Historical Census Browser at the University of Virginia, Geospatial, and Statistical Data Center; viewed May 2007. URL: http://fisher.lib. virginia.edu/collections/stats/histcensus/index.html.

of the period, Cleveland was the fifth most technologically important city in the country.[11]

Much of this patenting occurred in the "cutting-edge" industries of the time, such as electric light and power, electrical machinery, steel, petroleum, chemicals, and automobiles, which were at the center of the so-called Second Industrial Revolution. Moreover, much of it led to new enterprises organized for the explicit purpose of exploiting these new technological discoveries. In previous work, we found that by the turn of the twentieth century, a substantial portion of the patents awarded to Cleveland residents went to inventors who were officers in startup companies such as the Baker Motor Vehicle Company, manufacturer of electric automobiles; the Brown Hoisting Machinery Company, whose machines revolutionized the handling of cargo on the Great Lakes; the Wellman-Seaver Engineering Company, designer of steel mills and oil refineries; the Short Electric Railway Company, a pioneer of electric streetcars; and the White Motor Company, producer of steam and then gasoline automobiles.[12]

One of the first and most important of the Cleveland startups was the Brush Electric Company.[13] The manager of the Telegraph Supply Company of Cleveland had encouraged the inventor Charles F. Brush to work on arc lighting in the company's shops. When Brush succeeded in developing a workable system, the firm's officers (all prominent local businesspeople) arranged for a public demonstration and in 1880 launched a new company with a capitalization of $3 million, an enormous amount for a startup company at that time. The Brush Electric Company dominated the market for arc lighting until the mid-1880s and then began rapidly to lose ground to competitors. At the end of the decade, its major shareholders sold all their stock to a competing firm, the Thomson-Houston Electric Company, which joined the General Electric (GE) merger in 1891. The new owners shut down the Brush factory in the early 1890s.

During its short life, the Brush enterprise played an important role in fostering the development of new technologies in Cleveland, less because it generated large numbers of new inventions for the firm itself (although Brush continued to patent new ideas), but more because it was the hub of an overlapping network of inventors and financiers. The inventors' part of the

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[11] Michael S. Fogarty, Gasper S. Garofalo, and David Hammack, *Cleveland from Startup to the Present: Innovation and Entrepreneurship in the 19th and Early 20th Centuries* (Cleveland, Ohio, n.d.).

[12] Naomi R. Lamoreaux, Margaret Levenstein, and Kenneth L. Sokoloff, "Financing Invention during the Second Industrial Revolution: Cleveland, Ohio, 1870-1920," in *Financing Innovation in the United States*, ed. Lamoreaux and Sokoloff, 39-84; Naomi R. Lamoreaux, Margaret Levenstein, and Kenneth L. Sokoloff, "Mobilizing Venture Capital during the Second Industrial Revolution: Cleveland, Ohio, 1870-1920," *Capitalism and Society* 1 (2006); viewed Oct. 11, 2007. URL: http://www.bepress.com/cas/vol1/iss3/art5/.

[13] We base the remainder of this section on Lamoreaux et al., "Financing Invention" and Lamoreaux et al., "Mobilizing Venture Capital."

network included Brush employees who obtained valuable technological training in the course of their work, learned about opportunities for spin-off enterprises, and launched their own companies. Brush supervisor W. H. Bolton, for example, realized that the growth of arc lighting meant rising demand for the carbon electrodes that burned to produce the light. He left Brush to form the Bolton Carbon Company, which grew into National Carbon (later one of the main constituents of Union Carbide). Another Brush employee, John C. Lincoln, left to form a business manufacturing electric motors. After a couple of false starts, Lincoln's enterprise grew and prospered, splitting into two companies: Reliant Electric, which specialized in electric motors, and Lincoln Electric, a pioneering supplier of electric arc-welding equipment.

The inventors' part of the network also included creative individuals who were not Brush employees, but who worked inside the Brush factory developing technologies that were complementary to its main dynamo and lighting businesses. Sidney Short, for instance, moved to Cleveland and to Brush in order to supervise the building of the custom generators he needed for his electric streetcar invention. He stayed and ran the Short Electric Railway Company out of the Brush factory. For Short and others like him, the inventors who gathered at the Brush facility provided a useful vetting function. The conversations they had about each other's inventions—which ones were likely to work and which to prove economically valuable—provided the financiers who plugged into these networks with the information they needed to decide where to put their funds and how to advise others about investing in cutting-edge technology. Thus, Short was able, with Brush's help, to find financial backing for his enterprise. Similarly, Alfred and Eugene Cowles benefited from building their experimental electric aluminum-smelting furnace at Brush. Brush had originally scoffed at their ideas, dismissing their smelting process as just an expensive way to burn coal, but after they built their furnace at the factory, he became a believer and used their aluminum in the manufacture of his dynamos. The conversion of Brush and other observers at the factory helped the Cowles brothers raise capital, as did their ability to invite potential backers to come to the Brush facility and see their furnace in operation.

As the hub of these overlapping networks of inventors and financiers, the Brush facility became the site of a set of complementary, albeit informal, institutions that facilitated the development and economic exploitation of new technologies. Intriguingly, it continued to function as such a hub even after Thomson-Houston acquired the Brush enterprise and shut down the factory. Hence, when Elmer Sperry accepted the invitation of a group of financiers to come to Cleveland in the mid-1890s to develop an electric streetcar system, he set up shop at the Brush facility. He stayed on there until the turn of the century to work on other inventions, most notably an electric car and a related system of storage batteries that he sold, respectively, to the American Bicycle Company and the National Battery Company. Around the same time, Walter C. Baker also developed his electric car at Brush, and Alexander Winton worked

on his gasoline-powered automobile there. Both inventions led to the formation of companies bearing the inventors' names.

Other Cleveland enterprises played a similar role in incubating new firms. The overlapping networks that formed around the White Sewing Machine Company, for example, either directly spawned or facilitated the formation of companies that ranged from the machine-tool firm of Warner and Swasey to the White Motor Company, a producer of automobiles. The Brown Hoisting Machine Company and Wellman Seaver Engineering Company seem also to have functioned in this way, spawning startups and spin-offs in industries related to their core businesses, though our research on these companies is not as complete. As in other cities, moreover, telegraph facilities and hardware stores also functioned as gathering places for inventors and, as such, facilitated the same kinds of conversations and information flows as hub enterprises.

One might hypothesize that the networks to which these various hub enterprises gave rise were highly specific to the technologies in which each particular firm was engaged (electrical equipment at Brush, for example, and machine tools at White), and as such should be considered complementary institutions that might well have been rendered obsolete over time by technological progress. Two circumstances, however, suggest that that this kind of technological obsolescence was unlikely to be an important cause of Cleveland's decline. First, firms capable of performing this hub function emerged in a number of different industries in Cleveland during the late nineteenth century: electricity, machine tools, steel, chemicals, petroleum, and automobiles. As a result, the city could boast creative talent in virtually every area of Second Industrial Revolution technology. This diversity helped wealthy Cleveland investors develop an interest in investing in entrepreneurial ventures generally, not just in one "hot" sector. It also gave them the ability to learn about (that is, tap into the expertise needed to assess) new developments in a wide range of industries.

Second, in addition to the informal networks that coalesced around important enterprises, Cleveland could boast during this period an increasing number of more formal institutions that potentially served as ongoing supports for innovation. On the educational front, the most important was the Case Institute of Applied Science. Founded in 1880, it provided training to a number of important Cleveland inventors and had close connections to local entrepreneurs. Its first president, Cady Staley, took a personal interest in Herbert Dow during his undergraduate years and was a stockholder and member of the board of directors of the Dow Chemical Company from its founding in 1897. Case's second president, Charles S. Howe, was closely associated with two of Cleveland's most important inventor-entrepreneurs, Worcester Warner and Ambrose Swasey. Both served on Case's board. Their donations to Case financed its astronomy building (and a state-of-the-art

telescope built by Warner and Swasey), and the Warner Mechanics and Hydraulics Building, as well as endowed a chair in physics.[14]

Local engineering societies also provided forums at which inventors could discuss technical problems and assess the merits of new technologies. In 1880, a small group of engineers, who had been debating whether the country should adopt the metric system and other controversial topics, organized the Civil Engineers Club of Cleveland. By 1908, the club had transformed itself into the Cleveland Engineering Society, which published a journal intermixing reports on the doings of local engineers, minutes of the organization's bimonthly meetings, and serious articles on topics such as "The Electric Furnace and Its Use," "Some Recent Improvements in Electric Motor Control," "The Manufacture of Iron and Steel," and "Modern Machine Shop Milling Processes."[15] The city's growing numbers of patent attorneys also provided advice and technical expertise and sometimes helped to match inventors with buyers for their patents or recruit investors for entrepreneurial ventures.[16]

On the financial front, there were increasing numbers of banks and other similar financial institutions, many organized by the same men who founded startup companies. In 1870, the city was home to five banks and one savings institution. By 1920, there were thirty-eight banks, savings institutions, and trust companies with total deposits amounting to more than $800 million. The number of local brokerage houses and the amount of trading in local securities also grew during the late nineteenth century, leading in 1900 to the formal organization of the Cleveland Stock Exchange (CSE). From early on, the listings on the CSE included relatively more industrials than did its much larger counterpart in New York, and the number of manufacturing firms whose securities were traded on the CSE continued to grow, more than doubling between 1910 and 1914, for example. The newly listed manufacturers included some of the most successful of the innovative firms formed during the previous several decades, including National Carbon, Brown Hoisting Machine, Wellman-Seaver-Morgan (formerly, Wellman-Seaver Engineering), and the White Motor Company. One would expect that the creation of a formal exchange encouraged investors to put more money in cutting-edge enterprises,

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[14] C. H. Cramer, *Case Western Reserve: A History of the University* (Boston, Mass., 1976), 226, 242; Don Whitehead, *The Dow Story: The History of the Dow Chemical Company* (New York, 1968), 38, 43.

[15] See the Society's webpage for a history of the organization; viewed Oct. 11, 2007. URL: http://www.cesnet.org/about.asp. The articles are from, respectively, the *Journal of the Cleveland Engineering Society* 3 (Sept. 1910): 12-27; 4 (Sept. 1911): 17-27 and 46-64; and 4 (March 1912): 145-62.

[16] One of the organizers of the Brush Electric Company was a patent attorney and former U.S. Commissioner of Patents. For a history of patent attorneys in the city of Cleveland, see Hal D. Cooper and Thomas M. Schmitz, *A History of Inventions, Patents and Patent Lawyers in the Western Reserve* (Cleveland, Ohio 1993). For a more general discussion of patent attorneys' roles as intermediaries in the market for technology, see Lamoreaux and Sokoloff, "Intermediaries."

because the existence of an active equity market in local securities increased the liquidity of their investments.

Whether or not these various complementary institutions, both informal and formal, could have maintained Cleveland's innovative character over the long run is a hypothetical question. Even if they did play an ongoing role in encouraging investment in Second Industrial Revolution industries, moreover, it is still possible that their collective effect was to foster the growth of large firms that made the founding of new startups and spin-offs more difficult. It is also possible that these institutions were not sufficient to maintain Cleveland's position relative to other regions. In the next section, we examine data on trends in patenting rates and the assignment of patented inventions with the aim of exploring these possibilities.

## Data and Analysis

Our first step was to examine trends in patenting rates in Cleveland over time and compare them with those for the nation as a whole. We used Google Patent to count all patents issued to inventors living in Cuyahoga County between 1870 and 1930 (see Table 1 and Figure 1). The patenting rate in Cuyahoga was, not surprisingly for an urban manufacturing county, well above the national average. Over the whole period, Cuyahoga inventors patented at a rate almost 2½ times higher than that of the country as a whole. They continued to patent at very high rates during the 1920s, but the levels were more than 10 percent below the peak reached during the teens. The advantage that Cuyahoga County displayed over the rest of the country similarly appears to have declined during the 1920s (see Figure 2).

TABLE 1
Patenting in Cuyahoga County, Ohio, 1870 -1930

| Years | Cuyahoga County Patents | Mean Annual Patents/Million, Cuyahoga County | Mean Annual Patents/Million, United States |
|---|---|---|---|
| 1870-79 | 1,264 | 798 | 297 |
| 1880-89 | 2,336 | 961 | 360 |
| 1890-99 | 3,046 | 847 | 339 |
| 1900-09 | 4,345 | 835 | 376 |
| 1910-19 | 6,657 | 873 | 397 |
| 1920-29 | 8,173 | 777 | 384 |

*Sources:* Google Patent, viewed October 2007. URL: http://www.google.com/patents; Susan B. Carter, et al. eds., *Historical Statistics of the United States: Earliest Times to the Present*, Millennial ed., 5 vols. (New York, 2006), 3: Table Cg 27-37.

FIGURE 1
Cuyahoga County and U.S. Patenting Rate, 1870-1930 (per million population)

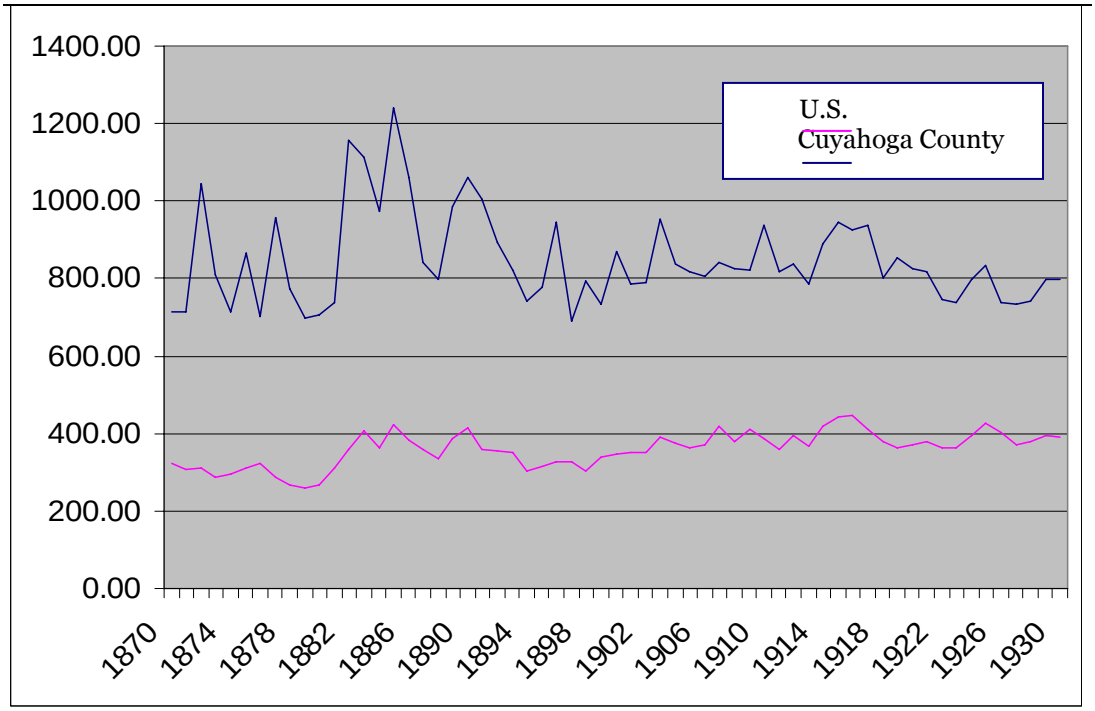
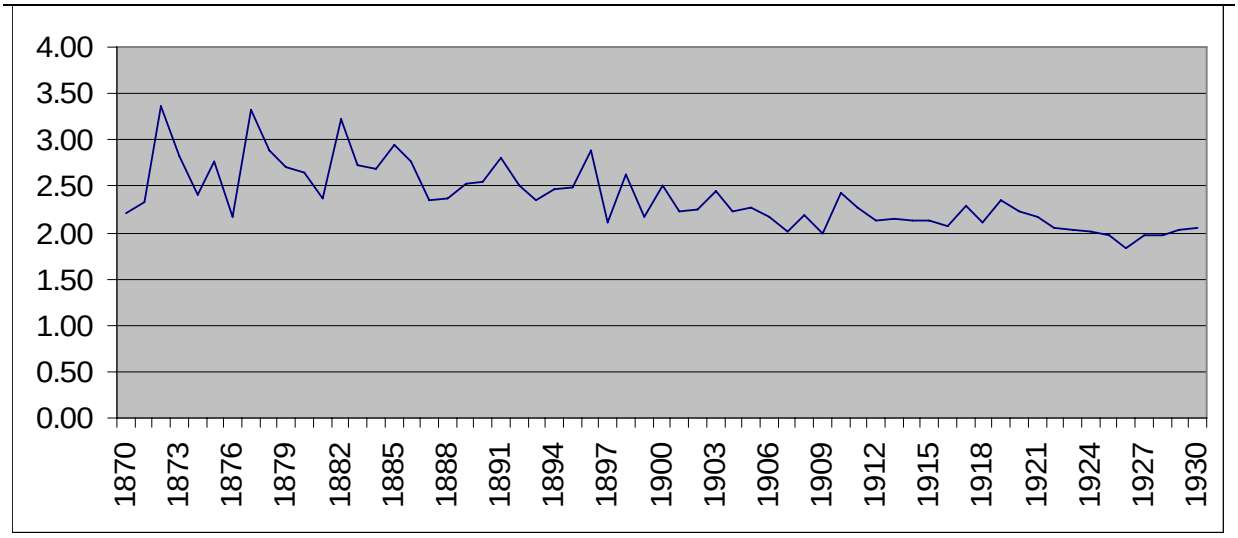



FIGURE 2 Ratio of Cuyahoga Patenting Rate to U.S. Patenting Rate, 1870-1930




*Sources* (for both Figs. 1 and 2): Google Patent, viewed October 2007. URL: http://www. google.com/patents; Susan B. Carter, et al. eds., *Historical Statistics of the United States: Earliest Times to the Present*, Millennial ed., 5 vols. (New York, 2006), 3: Table Cg 27-37.

We also examined the U.S. Census of Manufactures to compare trends in the size distribution of Cuyahoga County firms with those in the rest of the country. As Table 2 shows, the average size of firms in both the county and the country rose over time. From 1880 to 1900, Cuyahoga's manufacturing firms were roughly the same size or larger than those in other manufacturing counties. Over the next several decades, however, average firm size in Cleveland grew more slowly than in the country as a whole. Whether one looks at output or employment, firms in Cuyahoga County were decidedly smaller in 1930 than those in other manufacturing counties. This difference suggests that there were still many small- and medium-sized firms in the Cleveland economy, though it does not tell us anything about their innovative character.

To find out if Cleveland continued to be a center of innovative startups, we returned to patent data. Following the methodology we used in previous work for the period from 1880 to 1912, we collected data for the 1920s on inventions awarded to Cleveland patentees, on the patentees' occupations and other personal characteristics, and on the companies to which they assigned their patents.[17] We use these data to determine if patentees who were associated with startup enterprises still accounted for much of the inventive activity in the city, or if there was a shift toward patenting by employees of larger firms. We also looked for evidence that startup enterprises were facing greater difficulties than during previous periods.

We constructed the 1920s sample in essentially the same way as the earlier samples. We collected all patents issued to residents of Cleveland in 1925, 1928, and 1929; selected the patentees who had at least three patents during these years; and then collected all of the patents these inventors obtained for a set of additional years, in this case 1920, 1922, 1923, and 1930. For patents assigned at the time of issue, we collected the names of the individuals or firms to which the patent was transferred. We then looked up all the patentees and assignees in various issues of the Cleveland City Directory with the aim of understanding the nature of the relationship between the patentee and the assignee (for example, whether the patentee was a principal of the firm that obtained the patent). We also looked up the assignees in various issues of *Moody's Manual of Industrial Securities*. We classified assignees into categories in the following manner: If the assignee was a company, we first checked to see if the patentee was a principal in the company (that is, if the patentee was an officer or director of the company or if the company bore the surname of the patentee). We classified the remaining companies as "national" if financial information for them was reported in Moody's, "local" if there was no financial information reported in Moody's and the company was located in Cleveland, and "other" for the remaining cases.

In Table 3 we show the breakdown of assignments in the 1925-1929 sample, along with those in the 1884-1886, 1898-1902, and 1910-1912

[17] Lamoreaux et al., "Financing Invention"; and Lamoreaux et al., "Mobilizing Venture Capital."

samples. The most striking trend is the steady rise over time in the proportion of patents that Cleveland inventors assigned (sold or otherwise transferred to a new owner) by the time of the patent's issue. Inventors in the 1884-1886 sample had assigned only 22.3 percent of their

Table 2: Manufacturing in Cuyahoga County, Ohio, 1860-1930

| Year | Mean Manufacturing Output/Firm, Cuyahoga County | Mean Manufacturing Output/Firm, Top 100 Manufacturing Counties | Mean # of Workers/Firm, Cuyahoga County | Mean # of Workers/Firm, Top 100 Manufacturing Counties |
|---|---|---|---|---|
| 1870 | 23,541 | 28,942 | 8.8 | 13.79 |
| 1880 | 40,087 | 35,535 | 17.9 | 18.27 |
| 1890 | 48,027 | 41,929 | 21.5 | 16.43 |
| 1900 | 49,971 | 52,695 | 23.2 | 17.33 |
| 1910 | NA | NA | NA | NA |
| 1920 | 370,026 | 477,637 | 53.5 | 47.84 |
| 1930 | 488,789 | 737,254 | 58.0 | 75.60 |

*Notes:* NA = not available. All values are in current dollars. Because of changes in Census definitions from one census to the next, it is often more meaningful to compare county and national averages than to examine trends over time.
*Source:* U.S. Census 1870 to 1930; viewed 28 July 2006. URL: http://fisher.lib.virginia.edu/collections/stats/histcensus/index.html.

patents at issue. For the 1925-1929 group the figure was 74.4 percent. Table 4 breaks the same information down by type of patentee for the 1884-1886, 1898-1902, and 1925-1929 samples. We categorized patentees by the number of patents they had in the sample years and by whether they were a principal in an enterprise. Many patentees who were not principals were employees in firms, but the category "not a principal" also included professionals (such as attorneys and architects), independent inventors, and others who were more difficult to classify. In all three samples, non-principals with more than fifteen patents were the group with the highest assignment rate. By 1925-1929, patentees in this group were assigning more than 90 percent of their patents in advance of issue. Large-scale employers were more likely by this time to require their employees, especially those likely to engage in inventive activity, to sign contracts agreeing to transfer property rights to the employer for all their inventions. It is likely that this trend (along with an increase in the proportion of inventors who were employees) explains the rising assignment rates of patentees in this group.[18] The more dramatic change, however, was the

[18] Catherine L. Fisk, "Removing the 'Fuel of Interest' from the 'Fire of Genius': Law and the Employee-Inventor, 1830-1930," *University of Chicago Law Review* 65 (Fall 1998): 1127-98; Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Inventors, Firms, and

TABLE 3
Distribution of Patents Obtained by Cleveland Patentees by Type of Assignee

| Type of Assignee (if any) | 1884-1886 Sample | 1898-1902 Sample | 1910-1912 Sample | 1925-1929 Sample |
|---|---|---|---|---|
| Not Assigned at Issue | | | | |
| Number | 306 | 395 | 271 | 377 |
| Percent | (77.7) | (47.1) | (44.8) | (25.6) |
| Assigned to Individual | | | | |
| Number | 33 | 30 | 27.5 | 58 |
| Percent | (8.4) | (3.6) | (4.5) | (3.9) |
| Assigned to Company Where Patentee Is Principal | | | | |
| Number | 6 | 148 | 118.5 | 283 |
| Percent | (1.5) | (17.6) | (19.6) | (19.2) |
| Assigned to National Company | | | | |
| Number | 5 | 95 | 121 | 477 |
| Percent | (1.3) | (11.3) | (20.0) | (32.4) |
| Assigned to Local Company | | | | |
| Number | 25 | 77 | 58 | 224 |
| Percent | (6.3) | (9.2) | (9.6) | (15.2) |
| Assigned to Other Company | | | | |
| Number | 19 | 90 | 10 | 53 |
| Percent | (4.8) | (10.7) | (1.7) | (3.6) |
| Total # of Patentees | 42 | 36 | 107 | 157 |
| Total # of Patents | 394 | 839 | 606 | 1472 |
| #of Years in Sample | 7 | 18 | 3 | 7 |

*Notes and Sources:* For the 1884-1886 sample, we selected the 42 patentees who were Cleveland residents and who received three or more patents in 1884, 1885, and 1886 and then collected all of the patents they were awarded in those three years and in 1881, 1882, 1888, and 1889. The 36 patentees in the 1898-1902 sample include Cleveland residents who obtained a patent in 1900 and had at least three patents in 1898, 1900, and 1902. They also include several inventors resident in Cleveland who were prominent enough to be in the *Dictionary of America Biography*. We collected all patents these patentees received in 1892 through 1912, except for the years 1895, 1901, and 1904. The 1910-1912 sample consists of all patents received during 1910, 1911, and 1912 by the 107 Cleveland patentees who obtained a patent in 1912 and had at least 3 patents in those years. The 1925-1929 sample consists of all the patents obtained in 1920, 1922, 1923, 1925, 1928, 1929, and 1930 by the 157 patentees who obtained at least 3 patents in 1925, 1928, and 1929. We categorized the patents in the

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the Market for Technology in the Late Nineteenth and Early Twentieth Centuries," in *Learning by Doing in Firms, Markets, and Countries*, ed. Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin (Chicago, 1999), 19-57.

four samples by whether or not they were assigned at issue and to whom. An assignee as classified as a company in which the patentee was a principal if it bore the surname of the patentee or if the patentee was an officer or director of the firm. National companies were firms sufficiently important to have financial information reported in a national publication such as the *Commercial and Financial Chronicle* or *Moody's Manual of Industrial Securities*. Local companies were firms located in Cleveland for which there were no national financial reports. Other companies are firms located outside Cleveland for which there were no national financial reports.

TABLE 4
Distribution of Patents by Assignee Type, Patentee Productivity, and Relationship to Assignee for 1884-1886, 1898-1902, and 1925-1929 Cleveland Samples

| **1884-1886 Sample** | | | | | |
|---|---|---|---|---|---|
| | Category of Patentee | | | | |
| Type of Assignee | ≤ 15 Patents and a Principal | ≤ 15 Patents and Not a Principal | > 15 Patents and a Principal | > 15 Patents and Not a Principal | Total |
| **Not Assigned** | | | | | |
| Number | 76 | 87 | 131 | 12 | 306 |
| Percent | 90.5 | 63.0 | 97.0 | 32.4 | 77.7 |
| **Individual** | | | | | |
| Number | 4 | 26 | 0 | 3 | 33 |
| Percent | 4.8 | 18.8 | 0.0 | 8.1 | 8.4 |
| **Company where Patentee is Principal** | | | | | |
| Number | 3 | 0 | 3 | 0 | 6 |
| Percent | 3.6 | 0.0 | 2.2 | 0.0 | 1.5 |
| **National Company** | | | | | |
| Number | 1 | 4 | 0 | 0 | 5 |
| Percent | 1.2 | 2.9 | 0.0 | 0.0 | 1.3 |
| **Local Company** | | | | | |
| Number | 0 | 18 | 1 | 6 | 25 |
| Percent | 0.0 | 13.0 | 0.7 | 16.2 | 6.3 |
| **Other Company** | | | | | |
| Number | 0 | 3 | 0 | 16 | 19 |
| Percent | 0.0 | 2.2 | 0.0 | 43.2 | 4.8 |
| **# of Patents** | 84 | 138 | 135 | 37 | 394 |
| **% All Patents** | 21.3 | 35.0 | 34.3 | 9.4 | 100.0 |
| **# of Patentees** | 14 | 21 | 5 | 2 | 42 |
| **% All Patentees** | 33.3 | 50.0 | 11.9 | 4.8 | 100.0 |

| 1898-1902 Sample | | | | | |
|---|---|---|---|---|---|
| | Category of Patentee | | | | |
| Type of Assignee | 1-5 Patents | 6-15 Patents | >15 Patents and Principal | >15 Patents and Not a Principal | Total |
| **Not Assigned** | | | | | |
| Number | 9 | 41 | 269 | 76 | 395 |
| Percent | 60.0 | 49.4 | 61.1 | 25.3 | 47.1 |
| **Individual** | | | | | |
| Number | 2 | 6 | 14 | 8 | 30 |
| Percent | 13.3 | 7.2 | 3.2 | 2.7 | 3.6 |
| **Company where Patentee is Principal** | | | | | |
| Number | 0 | 21 | 119 | 11 | 151 |
| Percent | 0.0 | 25.3 | 27.0 | 3.7 | 18.0 |
| **National Company** | | | | | |
| Number | 0 | 0 | 9 | 86 | 95 |
| Percent | 0.0 | 0.0 | 2.0 | 28.7 | 11.3 |
| **Local Company** | | | | | |
| Number | 4 | 14 | 27 | 34 | 79 |
| Percent | 26.7 | 16.9 | 6.1 | 11.3 | 9.4 |
| **Other Company** | | | | | |
| Number | 0 | 1 | 2 | 85 | 88 |
| Percent | 0.0 | 1.2 | 0.5 | 28.3 | 10.5 |
| **# of Patents** | 15 | 83 | 440 | 300 | 838 |
| **% All Patents** | 1.8 | 9.9 | 52.5 | 35.8 | 100.0 |
| **# of Patentees** | 6 (1 Principal) | 9 (5 Principals) | 13 (all Principals) | 7 (no Principals) | 35 (19 Principals) |
| **% All Patentees** | 36.3 | 48.4 | 6.4 | 8.9 | 100.0 |

| 1925-1929 Sample | | | | | |
|---|---|---|---|---|---|
| | Category of Patentee | | | | |
| Type of Assignee | ≤ 15 Patents and a Principal | ≤ 15 Patents and Not a Principal | > 15 Patents and a Principal | > 15 Patents and Not a Principal | Total |
| **Not Assigned** | | | | | |
| Number | 153 | 146 | 51 | 27 | 377 |
| Percent | 37.5 | 29.6 | 20.6 | 8.4 | 25.6 |
| **Individual** | | | | | |
| Number | 15 | 23 | 11 | 9 | 58 |
| Percent | 3.7 | 4.7 | 4.4 | 2.8 | 3.9 |
| **Company where Patentee is Principal** | | | | | |
| Number | 166 | 4 | 113 | 0 | 283 |
| Percent | 40.7 | 0.8 | 45.6 | 0.0 | 19.2 |
| **National Company** | | | | | |
| Number | 18 | 173 | 56 | 230 | 477 |
| Percent | 4.4 | 35.1 | 22.6 | 71.2 | 32.4 |
| **Local Company** | | | | | |
| Number | 40 | 131 | 13 | 40 | 224 |
| Percent | 9.8 | 26.6 | 5.2 | 12.4 | 15.2 |
| **Other Company** | | | | | |
| Number | 16 | 16 | 4 | 17 | 53 |
| Percent | 3.9 | 3.2 | 1.6 | 5.3 | 3.6 |
| **# of Patents** | 408 | 493 | 248 | 323 | 1,472 |
| **% All Patents** | 27.7 | 33.5 | 16.8 | 21.9 | 100.0 |
| **# of Patentees** | 57 | 76 | 10 | 14 | 157 |
| **% All Patentees** | 36.3 | 48.4 | 6.4 | 8.9 | 100.0 |

*Notes and Sources:* See Table 3. The small number of assignments made by patentees classified as non-principals to firms in which the patentee was a principal involve cases where the patentee's status as a principal was brief.

rise in the assignment rate for principals with more than fifteen patents. In the 1898 to 1902 sample, inventors in this group assigned less than 40 percent of their patents, but in the 1925-1929 sample, they assigned nearly 80 percent. In previous work, we took the ability of principals in the 1898-1902 sample to maintain control of their intellectual property as evidence that they continued to have considerable bargaining power with respect to investors in

their enterprises.[19] If this interpretation is correct, then the fall in the assignment rate for this group indicates that these productive inventors had lost some of their autonomy by the 1920s.

Another striking trend in Table 3 is the sharp rise over time in the proportion of patents assigned at issue to companies categorized as national, from 11.3 percent in 1898-1902 to 32.4 percent in 1925-1929. The data in Table 4 show that the rise was particularly pronounced for non-principals with more than fifteen patents. Their assignments to national companies increased from 28.7 percent of their patents in 1898-1902 to 71.2 percent in 1925-1929. One might conclude from this combination of results that inventive activity was increasingly the domain of employees working for large-scale enterprises with R&D facilities, and there is certainly evidence for this interpretation. According to Table 5, slightly more than half of the patentees in the non-principals category were clearly employees, and another 12 percent were likely employees, or had some other kind of long-term relationship with their main assignee. These inventors transferred 78.8 and 90.1 percent, respectively, of their patents to their employers or main assignees. For the most productive category of patentees (those with more than fifteen patents), nine (64.3 percent) were either employees (8) or possible employees (1) of their assignees. The former assigned 89.0 percent of their patents to their employers; the latter 100 percent to the main assignee.

Nonetheless, although patentees in the non-principals category assigned some of their patents to important national companies with R&D facilities, such as GE and RCA (Radio Corporation of America), only about one-fifth of the sample patents obtained by non-principals went to companies that were listed by the National Research Council (NRC) as having an industrial research laboratory in 1927.[20] Moreover, the bulk of their patents (about two-thirds of the total) went to companies headquartered in Cleveland. Indeed, all of the companies with which the nine employees or possible employees in the most productive group were associated had headquarters in Cleveland. All had been startups formed during the late nineteenth or early twentieth century to exploit particular technological discoveries. Although most had achieved national importance by this period in the sense that Moody's included reports on them, and hence they presumably had access to national financial markets, only two were on the NRC's list of companies with research facilities in 1927.[21]

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[19] Lamoreaux et al., "Financing Invention" and Lamoreaux et al., "Mobilizing Venture Capital."

[20] National Research Council, "Industrial Research Laboratories of the United States Including Consulting Research Laboratories," *Bulletin of the National Research Council* 60 (July 1927).

[21] The companies were American Multigraph, Baker-Raulang, Grasselli Chemical, Lees-Bradner, National Acme, Perfection Stove, Thompson Products, Warner and Swasey, and Wellman-Seaver-Morgan. The two with industrial research facilities were Grasselli Chemical, acquired by DuPont in 1929, and Thompson Products, which became TRW.

TABLE 5
Distribution of Patents Obtained by Cleveland Patentees Who Were Not Principals in Firms, by Number of Patents Obtained, and Relationship to Assignee, 1925-1929 Sample

| Relationship of Patentee to Assignee | Number of Patents in Sample Years | | | |
|---|---|---|---|---|
| **Employee** | 3-9 | 10-15 | > 15 | Total |
| Number of Patentees | 36 | 2 | 8 | 46 |
| Number of Patents | 203 | 25 | 172 | 400 |
| Percent of Column Total of Patents | 55.9 | 19.2 | 53.3 | 49.0 |
| Number of Patents Assigned to Employer | 146 | 16 | 153 | 315 |
| Percent of Patents Assigned to Employer | 71.9 | 64.0 | 89.0 | 78.8 |
| **Likely Employee** | | | | |
| Number of Patentees | 8 | 2 | 1 | 11 |
| Number of Patents | 49 | 21 | 31 | 101 |
| Percent of Column Total of Patents | 13.5 | 16.2 | 9.6 | 12.4 |
| Number of Patents Assigned to Employer | 41 | 19 | 31 | 91 |
| Percent of Patents Assigned to Employer | 83.7 | 90.5 | 100.0 | 90.1 |
| **Other** | | | | |
| Number of Patentees | 5 | 4 | 1 | 10 |
| Number of Patents | 28 | 48 | 21 | 97 |
| Percent of Column Total of Patents | 7.7 | 36.9 | 6.5 | 11.9 |
| Unknown | | | | |
| Number of Patentees | 16 | 3 | 4 | 23 |
| Number of Patents | 83 | 36 | 99 | 218 |
| Percent of Column Total of Patents | 22.9 | 27.7 | 30.7 | 26.7 |
| **Number of Patents** | 363 | 130 | 323 | 816 |
| **Row Percent** | 44.5 | 15.9 | 39.6 | 100.0 |
| **Number of Patentees** | 65 | 11 | 14 | 90 |
| **Row Percent** | (72.2) | (12.2) | (15.6) | (100.0) |

*Sources:* See Table 3.

Even in cases where Cleveland inventors assigned patents to firms headquartered outside Cleveland, the firms typically had a significant local presence. For example, two of the most common non-Cleveland assignees were GE and Kemet Laboratories. GE had established a local presence when Thomson-Houston, which had acquired the Brush Electric Company, joined the GE merger in 1892. It maintained a local presence through its ownership of the National Electric Lamp Association (which operated in the former Brush

plant after 1902 and became a division of GE in 1911).[22] Kemet Labs also had Cleveland origins, as the National Carbon Company formed it in 1919 in order to acquire the Cleveland-based Cooper Research Company, a firm active in the development of high temperature alloys.[23]

Invention in Cleveland, it seems, was still largely a regional phenomenon. Not only did the most productive non-principals assign mainly to Cleveland firms, but the companies to which they assigned their patents acquired most of their technology locally. Figure 3 shows the number of patents that Cleveland enterprises acquired from non-Cleveland inventors. Although the figure rose over time, it remained quite low, never even reaching seventy patents a year before 1930. To give an example, one of the largest of the "national" enterprises based in Cleveland was American Multigraph. Its shares had been regularly and publicly traded since its incorporation in 1902. A multinational corporation, it owned both the International Multigraph Company and the Deutsche Multigraph Gesellshaft.[24] We were able to identify 147 patents assigned to American Multigraph between 1900 and 1929. Of these, Cuyahoga County inventors accounted for 92 percent, and there was no trend over time toward greater geographic dispersion. Between 1900 and 1909, all 7 patentees who assigned inventions to American Multigraph were from Cleveland. Of the 45 patents assigned to American Multigraph between 1910 and 1919, 89 percent were from Cuyahoga County inventors. During the 1920s, American Multigraph did receive two assignments from inventors located in Germany (one with the same last name as the firm's president, and the other the prolific inventor Henry Osborn), but fully 95 percent of its patents still came from inventors residing in Cuyahoga County.

Although the data in Table 3 show little change by the 1920s in the proportion of patents assigned to firms in which the patentee was a principal, this stability hides important trends. One of the most striking, evident in Table 4, is the tremendous growth in the sheer number of firms in which inventors were principals and in the number of patents awarded to those principals. In the 1898-1902 sample, there were only nineteen patentees who had at least three patents and were principals of firms; in the 1925-1929 sample there were sixty-seven. These sixty-seven patentees, moreover, obtained 656 patents in the years sampled—nearly (almost 80 percent) as many as those obtained by all patentees during the years from 1898 to 1902, even though for the latter group we sampled many more years.

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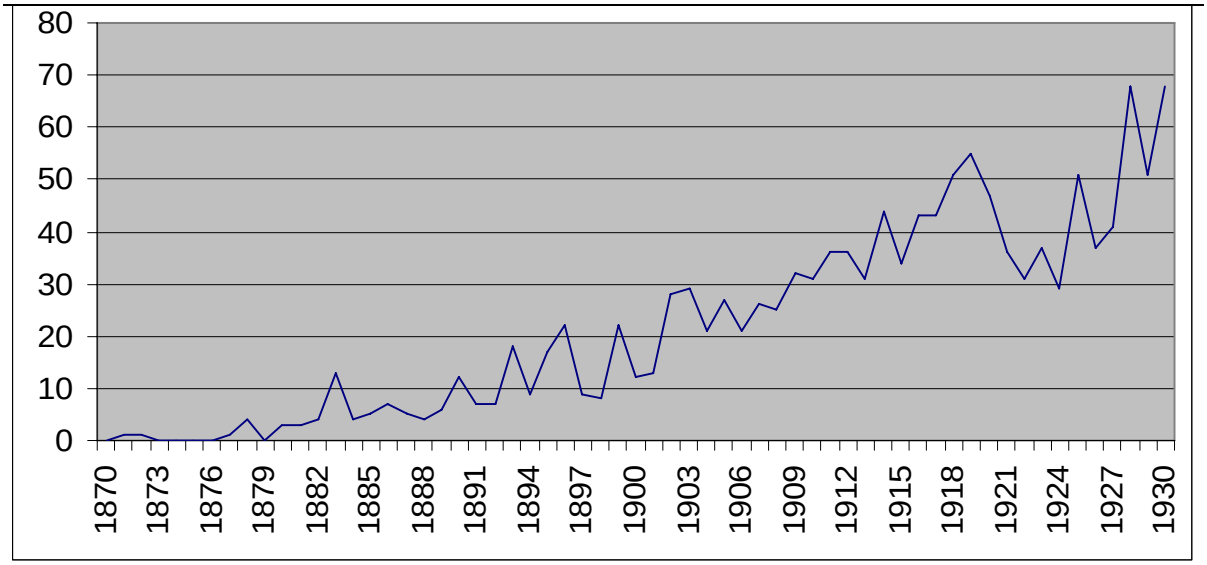
[22] "General Electric," *Encyclopedia of Cleveland History*; viewed 23 May 2007. URL: http://ech.case.edu/.

[23] "History of Kemet," Kemet Corporation website; viewed May 23 2007. URL: http://www.kemet.com/kemet/web/homepage/kechome.nsf/weben/about%20us.

[24] Fred S. Borton and T. E. Borton, *Borton's Pocket Manual of Cleveland Securities* (Cleveland, 1926).

FIGURE 3
Acquisition of Non-Cleveland Patents by Cleveland Firms, 1878-1930




*Sources*: Google Patent, viewed October 2007. URL: http://www.google.com/patents; Susan B. Carter, et al. eds., *Historical Statistics of the United States: Earliest Times to the Present*, Millennial ed., 5 vols. (New York, 2006), 3: Table Cg 27-37.

Not all of the firms in which patentees were principals were new startups. To get a sense of the age of the patentees' firms, we checked to see if the Dun Mercantile Agency's credit rating book for 1910 listed them.[25] At least 25 percent of the firms in which patentees were principals were on the list, indicating that they were founded before 1910 (see Table 6). The most productive patentees (those with more than 15 patents) seem to have been associated with the youngest firms, with only about 10 percent clearly established by 1910. For the middle group of patentees (10-15 patents), the proportion was 14 percent, and for the least productive group (3-9 patents), the proportion was 32 percent.

We also looked up the principal-patentees in the 1920 population census and were able to locate 52 of the 67. Their average age was approximately 39 years, and intriguingly there was little difference across the three productivity groups. Of the least productive group, only three of the 35 inventors we were able to trace were younger than age 25, suggesting that the small number of patents cannot be attributed to their being in the early stages of their careers. Indeed, 54 percent were 40 years or older. The least productive patentees seem to have been the most rooted in the community. Fifty-five percent of

[25] Dun Mercantile Agency, *Record Book* (1910).

those we could locate in the census owned their homes, contrasted with only 17 percent of the most productive inventors. We interpret these findings as indicating that many of the inventors in our large group of less productive patentee-principals were not entrepreneurs in the sense of organizing new firms to exploit cutting-edge technological discoveries. They were, however, active managers of companies founded in an earlier period, and they continued to generate new inventions. The large numbers of patents awarded to these inventor-principals is testimony to the continuing technological dynamism of Cleveland enterprises.

TABLE 6
Characteristics of Inventor-Principals and Their Firms, by Number of Patents Obtained, 1925-1929 Sample

| | Number of Patents in Sample Years | | | |
|---|---|---|---|---|
| | 3 to 9 | 10 to 15 | > 15 | Total |
| # of Patentee-Principals | 43 | 14 | 10 | 67 |
| # of Patents/Patentee-Principals | 242 | 166 | 248 | 656 |
| Mean # of Patents per Patentee | 5.6 | 11.9 | 24.8 | 9.8 |
| % of Patents Assigned | 59.0 | 68.0 | 79.0 | 77.0 |
| Mean # of Different Assignees | 1.1 | 1.6 | 2.6 | 1.5 |
| # of Assignments to Company in which Inventor is Principal | 69.7 | 54.0 | 65.1 | 64.8 |
| % of Assignees in 1910 | 32.6 | 14.3 | 10 | 25.4 |
| Mean Age of Inventors (in 1920) | 40.0 | 38.3 | 38.2 | 39.4 |
| % of Inventors Born in Ohio | 64.7 | 45.5 | 66.7 | 62.7 |
| % of Inventors Owning Home | 54.3 | 36.4 | 16.7 | 46.2 |

*Notes and Sources:* Dun Mercantile Agency, *Record Book* (1910); U.S. Census. *Fourteenth Census of the United States, 1920*. United States Federal Census On-line Database. URL: http://www.ancestry.com; and the sources described in Table 3. All percentages are unweighted averages of the values for individual patentees.

If one excludes this bottom group of low-productivity principals from the count, the increase in the absolute numbers of principal-patentees was much lower—from 18 in the 1898-1902 sample to 24 in the 1925-1929 sample.[26] Perhaps more important was the sharp fall in the proportion of patents awarded to inventors who were principals of firms. For the productive group, the drop was dramatic. Principal-inventors accounted for nearly 60 percent of patents awarded to inventors with more than 15 patents in 1898-1902. By 1925-1929, the proportion had fallen to almost 40 percent. Inventors who were

[26] We show a decrease in the number of patents awarded to principal inventors with more than 15 patents in our tables, but this difference may be a result of the many more years in the 1898-1902 sample.

not principals were accounting for a much larger fraction of inventions during the 1920s.

In itself, this shift does not necessarily mean that the world was becoming more difficult for those who wanted to start their own firms. Cleveland was now home to a substantial number of innovative manufacturing firms founded in earlier periods, and it is not surprising that inventors who worked for these firms were generating increasing numbers of new patents and therefore accounting for a greater share of the inventive activity going on in the city. There is also evidence, however, that by the 1920s, principal-inventors were losing some of their bargaining power, or at least some of their autonomy. We have seen that the proportion of their patents that they continued to control (that is, did not assign at issue) had dropped precipitously. As we show in Table 6, by the 1920s principal-inventors had relatively few different assignees and, indeed, assigned the bulk of their patents to their own firms. These numbers, moreover, would look respectively smaller or larger if we reclassified two enterprises into the category of companies in which the patentee was a principal. These enterprises had acquired firms associated with two of the most productive patentees in the principals group. The two patentees continued to assign large numbers of patents to them, and it is likely that they retained an ownership stake.

Without more information about the histories of individual firms during this period, we are not yet able to determine if the networks for creating new firms around inventors that we observed for earlier periods continued to thrive during the 1920s. One intriguing change, however, was the relatively high proportion of patents assigned to firms in which the inventor was a principal located outside the region. For the patentees in the most productive group, the proportion was 32.8 percent (46.7 percent if we include the one of the two acquiring firms located outside the region). Despite the regional character of much of Cleveland's inventive activity, its most productive inventors were assigning an increasing share of their patents outside the region. This shift in the location of firms in which Cleveland inventors were principals may be an indication that the city's economic environment no longer offered the opportunities and advantages that allowed it to host an earlier generation of inventor-entrepreneurs.

Moreover, to the extent that the earlier networks persisted, they no longer seemed to exert an attractive force on inventors from outside the region. As Table 6 shows, regardless of productivity class, Cleveland's principal-patentees did not come from far away. Most were born in Ohio, and those who were not came disproportionately from other parts of the Midwest. Data collected by Khan and Sokoloff for a somewhat older birth cohort of "great inventors" (those born between 1860 and 1885) show that 64.5 percent of those awarded in the Midwest went to great inventors born in the region and 33.1 percent went to inventors born in the Middle Atlantic. Conversely, 29.1 percent of the patents awarded in the Middle Atlantic went to inventors born in the

Midwest.[27] Our data on productive inventors in Cleveland in the 1920s suggest that the Midwest was no longer exerting much pull on creative individuals from other regions.

## Conclusion

From the 1880s at least through the first decade of the twentieth century, Cleveland was a hotbed of high-tech startups. Many of the new enterprises formed during these years were unsuccessful, and firms based in other regions sometimes acquired those that did survive. However, a significant number grew into local companies that were important enough to show up in *Moody's Manual of Industrial Securities* , which we consider evidence of their ability to raise funds on the national capital markets. Few of these important local companies had formal R&D laboratories (according to the NRC listings), but they remained innovative in the sense of continuing to generate large numbers of patented inventions, and they accounted by the 1920s for a growing proportion of the inventive activity in the city of Cleveland.

At the same time, Cleveland continued to spawn large numbers of new enterprises. Although the total number of patents that these new firms generated was collectively large, individually their contributions to the stock of patented technology were small. Most of the patentee-principals in our sample obtained less than ten patents in the sampled years, and the firms with which these low-productivity principals were associated do not appear to have been significant acquirers of patents from other inventors, whether employees or not. It seems likely, then, that the failure of most of these firms to generate significant numbers of patented inventions is behind the slippage in Cleveland's patent rate during the 1920s.

The question, then, is why so many of Cleveland's entrepreneurial enterprises generated so few patents. The industries in which the firms operated spanned a broad range of the manufacturing sector, but they were especially concentrated in Second Industrial Revolution industries such as electrical machinery and products, other machinery, automobiles, and chemicals. These industries were still on the leading edge during the 1920s, so it seems doubtful that Cleveland's institutions and resources had suddenly become obsolete. They may have become relatively less attractive, however. Here the high proportion of inventor-principals who were born in Ohio or nearby states offers an important clue. Inventors from other regions no longer seemed to be attracted to Cleveland for its entrepreneurial opportunities. The decline in the city's patenting rates relative to the national average suggests that inventors were going to other regions, although we cannot tell from the Cleveland data if they perceived the economic environment elsewhere to be better for startups or if they were taking employment positions in large firms. We plan to explore these alternative explanations in future research. The data

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[27] Khan and Sokoloff defined great inventors as those important enough to be included in the *Dictionary of American Biography*; see Khan and Sokoloff, "Institutions."

on the inventors' state of birth suggest another possibility to explore. Cleveland's inventor-principals may have produced fewer inventions because they were less talented—that is, because inventors who were more technologically creative were migrating to regions where economic opportunities were greater.

Yet another possibility is that local inventors were finding it more difficult to raise the capital they needed to make productive use of their ideas and, at the same time, continue their R&D work. Perhaps the successful Cleveland firms founded earlier were absorbing the bulk of the capital that was available locally to the detriment of new startups. The significant number of patents going to outside firms in which Cleveland patentees were principals is consistent with such a view. Alternatively, Cleveland investors may have put more of their funds in securities traded on the national capital markets,rather than invest in local startups. The Great Bull Market of the late 1920s may have left local enterprises in Cleveland (and presumably elsewhere in the Midwest) increasingly starved for funds.

A further possibility is that Cleveland's purported decline in innovativeness is an artifact of our reliance on patent data. If entrepreneurial enterprises during this period relied increasingly on trade secrets or some means of protecting intellectual property other than patents, the drop in the number of patents they obtained may not be good evidence of a fall in innovativeness. We could interpret such a shift, however, as evidence that entrepreneurs found their environment increasingly hostile. Firms tend to rely on trade secrets rather than patents when they fear they will lose out in patent disputes to firms with greater legal resources or that their patent specifications will reveal too much information to firms with greater R&D capabilities.[28] Moreover, such a shift could also explain the apparent failure of Cleveland's entrepreneurial enterprises to grow. The signals that patents send investors are important for raising capital.[29] As Tom Nicholas has shown using data on market evaluations of firms traded on the New York Stock Exchange, by the 1920s investors were paying close attention to companies' stocks of patents in evaluating the worth of their shares.[30]

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[28] Josh Lerner, "Patenting in the Shadow of Competitors," *Journal of Law and Economics* 38 (Oct. 1995): 463-95; Joshua Gans and Scott Stern, "The Product Market and the Market for 'Ideas': Commercialization Strategies for Technology Entrepreneurs," *Research Policy* 32 (Feb. 2003): 333-50.

[29] Kenneth J. Arrow, "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Economic Activity: Economic and Social Factors, Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Council* (Princeton, N.J., 1962), 609-25; Ashish Arora, Andrea Fosfui, and Alfonso Gambardella, *Markets for Technology: The Economics of Innovation and Corporate Strategy* (Cambridge, Mass., 2001); David H. Hsu and Rosemarie H. Ziedonis, "Patents as Quality Signals for Entrepreneurial Venture," unpublished paper (Ann Arbor, Mich., 2007).

[30] Tom Nicholas, "Stock Market Swings and the Value of Innovation, 1908-1929," in *Financing Innovation*, ed. Lamoreaux and Sokoloff, 217-45.

We still have much work to do to understand the patterns in our data. In addition to getting a better grasp of the national context for our findings, we need to study the complementary institutions that previously had supported entrepreneurial enterprises in Cleveland, especially the hub firms that had played so central a role in creating, vetting, and commercializing important new technologies. Whatever the explanation, however, it does seem that by the 1920s, Cleveland's economic environment was not as supportive of new high-tech enterprises as it had been earlier around the turn of the century.