The Decline of an Innovative Region: Cleveland, Ohio, in the Twentieth Century

Naomi Lamoreaux
University of California, Los Angeles and NBER

Margaret Levenstein
University of Michigan

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This paper aims to advance our knowledge of the dynamics of technological innovation by studying patenting and the commercialization of patents in Cleveland, Ohio during the period following World War I. As we have shown in earlier work, at the turn of the century Cleveland was a center of technological innovation in a wide range of "Second Industrial Revolution" industries (Lamoreaux et al. 2006 and 2007a). It was also an important entrepreneurial center, with well-developed, largely informal, networks linking inventors to new sources of capital and to product markets. Cleveland was not able to maintain its leadership position in innovation and entrepreneurship through the twentieth century. To the contrary, today it exemplifies the problems of deindustrialization, population decline, and entrenched poverty faced by many Midwestern cities. Our goal is to understand how Cleveland lost its entrepreneurial character and, more generally, acquire insight into the larger processes behind the emergence, growth, and decline of innovative regions in economic history.

Much of what scholars know (or think they know) about such regions has been based on observations of another important case—Silicon Valley. Our study of Cleveland allows us to test some of the influential hypotheses that have grown out of that literature and determine whether they have application beyond northern California. Of course, our study of Cleveland raises questions of generality as well, but the advantages of such an in-depth investigation outweigh the disadvantages. By focusing on a particular location, we can gather data on networks of inventors, entrepreneurs, and investors, and on the institutions that support them, that would not be feasible to collect for a macro, national-level study. Moreover, Cleveland has one significant advantage over other cities as a case to be studied: because its economy was diversified across the leading industries of the period, we can eliminate the confounding problem of the life cycle of a particular industry (such as computers in Silicon Valley or autos in Detroit) and focus attention on trends in innovative activity more generally.

At the heart of our project is a detailed database of Cleveland's most prolific inventors and the firms with which they were associated. Built up from patent records, city directories, Census records, newspaper articles, credit reports, and manuscript collections, including those of a number of financial institutions, the database allows us to determine the timing of the decline of innovativeness in the region and the factors behind it. More specifically, we use these data compare the implications of life cycle models of regional growth and decline, of explanations that give a leading role to increases in firm size and market concentration, and of explanations that focus on the quality of complementary financial and educational institutions. Our preliminary results suggest that the Cleveland area remained technologically dynamic through the 1920s and that region's subsequent decline was more likely a consequence of the financial shocks of the Great Depression and perhaps also of government policies developed in response to the depression and the Second World War.

Theory and Literature

There are well-established theories that predict that regions which are particularly innovative at a point in time should maintain their innovative character into the future (see, for example, Krugman 1991, Murphy, Shelifer and Vishny 1989, and Romer 1986). One important reason is that the fixed, complementary investments that foster innovation can continue to supply services to the region over time at relatively small incremental cost. For example, entrepreneurs require access to finance, which in turn requires that institutions exist for providing potential investors with information about new ventures and assessing their potential profitability.[1] There are a variety of institutions that can solve such information problems. Because building these institutions is largely a fixed cost, once they are created they can be tapped repeatedly. These institutions increase the returns to entrepreneurship, so they encourage investment of time, energy, and capital to generating and commercializing new technologies. Moreover, would-be entrepreneurs are likely to be attracted to regions where the institutions for financing innovative activities are well established. As a consequence, regions that develop such institutions can gain an advantage in innovation that persists over time.

Silicon Valley's remarkable success in maintaining its innovative character over half a century has often been attributed to such complementary institutions. The venture capital firms that clustered along Sand Hill Road have a long track record of vetting new projects and channeling funds to entrepreneurs deemed worthy of support (Saxenian 1994, Kenny 2000, Kortum and Lerner 2000, Castilla 2003). Moreover, other institutions, most notably educational establishments such as Stanford University, have provided the region with a steady supply of highly skilled personnel capable both of generating and evaluating innovations. They have also given Valley entrepreneurs ready access to knowledge on the technological frontier (Leslie 1993, Leslie and Kargon 1996, Lowen 1997, Adams 2003 and 2005, Gillmor 2004, Lécuyer 2006).

But if complementary institutions are the critical element in the innovativeness of a region, why would places such as Silicon Valley ever decline? One possibility is that these institutions may be specific to a particular technology; once that technology is superseded, the region loses its advantage. For example, the financial intermediaries that channel funds to

[1] Economic historians long focused on the importance of institutions for amassing capital to support innovation and economic growth (e.g. Gerschenkron 1962). But it has become clear that it is at least as important to have institutions that *direct* that capital toward innovative projects by providing the necessary information and incentives (Hoffman, Rosenthal, and Postel-Vinay 2000; Lamoreaux 1986 and 1994).

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 new industries. Similarly, educational institutions may be focused on technologies most relevant to those same industries and may be unable to provide innovators with an adequate foundation in newer technologies. Such industry-specific investments might explain, for instance, the relative decline of New England in the early twentieth century. The region had long had patenting rates per capita that were well above the national average, and even though textile and shoe production was leaving the region, it continued to dominate patenting in those industries. It did not do as well, however, in new industries like electricity that required command of a substantially different body of technological knowledge (Sutthiphisal 2006).

Another possibility is that a region's very success sows the seeds of its decline. The region may initially be a fertile environment for startup enterprises, but as the most successful of these enterprises grow big or are acquired by large firms, two things may occur. First, with increasing size, these enterprises may themselves become less innovative as managers become more bureaucratic or excessively enamored of the particular technologies on which their success was founded (Schumpeter 1934). Second, the emergence of large firms may affect the local environment in ways that make it less conducive to startup enterprises. Large firms may arrogate to themselves most local capital or talent, or their entrenched relationships with customers may make it difficult for new firms to gain a foothold (see Klepper 2002 and 2007 on Detroit).

Saxenian's (1994) comparison of semi-conductor enterprises in Silicon Valley and Route 128 argues that the latter region declined as its firms became larger and less cooperative with one another. Differences between the two high tech regions in terms of firm size and the movement of personnel among firms have been documented by other studies (for example, Almeida and

Kogut 1999), but the rise of large firms in the Boston area cannot be the whole story. Silicon Valley itself is home to large firms that have tried to restrict the movement of employees to competitors, and yet its innovative character shows no signs of dampening.[2] Writing primarily with other cases in mind, some scholars have added lack of local manufacturing to the list of factors that dampen innovative activity (Thomson 1989, Graham and Pruitt 1990, and Trescott 1981). But again the case of Silicon Valley suggests that a region can maintain its innovative character even as production migrates elsewhere.

A third possibility is that the sources of decline are external to the region. One region's economic position can deteriorate simply because another surpasses it in some way that proves economically salient. For example, Midwestern cities such as Cleveland may have suffered because Eastern cities developed superior educational institutions. 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 (Khan and Sokoloff 2006). Similarly, technological innovation in these industries required much greater amounts of capital for both research and commercialization than had ever been the case before. It is likely that this increase favored regions that had deeper pools of savings and 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 facilities because the latter were better able to tap formal financial markets for funds (Lamoreaux and Sokoloff 2009).

A final possibility is that macroeconomic shocks, like the Great Depression (or the current credit crisis) can destroy the complementary institutions, especially financial ones, that give a region its advantage. In the case of Cleveland, the Great Depression may have struck a

[2] However, California law may have made it much more difficult than Massachusetts law for firms to keep employees from taking jobs with competitors or from starting their own firms. See Gilson (1999), Hyde (2003), and Hamasaki.

double blow. In the first place, it destroyed the local investors and financial institutions that had supported entrepreneurial startups; in the second, the financial regulations imposed by the federal government in its wake may have given New York's financial institutions such a competitive advantage that local capital markets never recovered. It is also possible that the policies pursued by the federal government during the war to disperse manufacturing capacity undermined recovery by increasing economic opportunities in other regions or even giving them a competitive edge. The effect of the shocks of the middle third of the twentieth century on the subsequent trajectory of the economy is a subject of growing importance in its own right. For years scholars have been primarily interested in understanding the causes of these catastrophes. Now there is increasing interest in their long-term effects—for example on income inequality, economic geography, and institutions.

Cleveland's rise as a center of manufacturing and invention

Located on Lake Erie at the terminus of the Ohio Canal, Cleveland had long been the commercial center of northeastern Ohio. Its first heavy industrial enterprise, a firm that produced steam furnaces, was founded in the 1830s, and its first iron rolling mills were built in the 1850s, but the city's rise as a manufacturing center was largely a post-Civil War phenomenon (Miller and Wheeler 1990). As late as 1870 Cuyahoga County, where Cleveland is located, ranked number twenty-two in manufacturing output among counties nationwide; by 1920 it had risen to fourth place; over the same period Cleveland's ranking in terms of population rose from twenty to seven. Intriguingly, although the average size of firms in the county rose over the same period, the local economy continued to be characterized by relatively small enterprises. In 1870 the county ranked sixty-sixth among the hundred largest manufacturing counties in terms of the average number of workers per establishment. In 1920 its rank on this scale was still only fifty-two. Although some Cleveland enterprises grew very large, the average size of firms remained relatively low (Lamoreaux et al 2006 and 2007a).

Many of the firms founded in Cleveland during the late nineteenth and early twentieth centuries were in industries associated with the Second Industrial Revolution. Cleveland's location gave it convenient access to Lake Superior iron ore, so it is not surprising that iron and steel was the city's leading industry (in terms of value of output) throughout the nineteenth century (see Table 1). Machine tool manufacturing was also among the city's top three industries throughout the period 1870 to 1920. By 1910, however, automobile manufacturing was the third largest industry, and it would climb to number one by 1920. During that same decade electrical machinery rose to fourth place, so that the city's top industries by 1920 were automobiles, machine tools, iron and steel, and electrical machinery. Another industry with a major presence in the city and its surrounding areas was chemical products, such as paints and varnishes (Lamoreaux et al 2006 and 2007a).

In the late nineteenth and early twentieth centuries, Cleveland was a center for the creation of new technology. 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 of the period, Cleveland was the fifth most technologically important city in the country (Fogarty, Garofalo, and Hammack undated). Assignments of patents in the Midwest in the late nineteenth and early-twentieth century followed a distinctive pattern. While the most productive patentees on the East Coast increasingly assigned their patents to large, integrated firms (which may well have been their employers), Midwestern inventors were much more likely to assign patents to firms that bore their name. That is, Midwestern inventors were forming businesses as vehicles for financing their continuing innovative activity and the commercialization of the resulting inventions (Lamoreaux and Sokoloff 2009). In previous work, using a preliminary sample of Cleveland patents, we found that Cleveland inventors conformed to this pattern; a substantial portion of the patents awarded to residents of the city went to inventors who were officers in local manufacturing startups (Lamoreaux et al 2006, 2007a).

One of the first and most important of the Cleveland startups was the Brush Electric Company.[3] 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 businessmen) 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 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—not primarily because it generated large numbers of new inventions for the firm itself (though Brush continued to patent new ideas), but as the hub of an overlapping network of inventors and financiers. The inventors' part of the network included Brush employees who obtained valuable technological training in the course of

[3] The remainder of this section is based on Lamoreaux, Levenstein, and Sokoloff 2006 and 2007a. See those articles for the sources underpinning this discussion.

their work, learned about opportunities for spinoff enterprises, and launched their own companies.[4] Brush foreman 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. The Brush location enabled Short to tap appropriate human capital, such as employee John C. Lincoln. Moreover, 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 ones were likely to prove economically valuable—provided the financiers who plugged into these networks the information they needed to decide where to invest 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 benefitted from building their experimental electric aluminum smelting furnace at Brush. Brush had originally scoffed at their

[4] The Brush Electric Company had a formal training program in which young men, such as John C. Lincoln (see below), participated.

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 institutions, albeit informal ones, that facilitated the development and economic exploitation of new technologies. Intriguingly, it continued to function as a hub even after the Brush enterprise was acquired by Thomson-Houston and the factory shut down. 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 which he sold respectively to the American Bicycle Company and the National Battery Company. Around the same time, Walter C. Baker 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 spinoffs 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 functioned as gathering places for inventors and, as such, facilitated similar conversations and information flows as hub manufacturers.

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 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—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. For example, 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 Warner and Swasey served on Case's board, and 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.

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 in 1880. 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."[5] 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 round up investors for entrepreneurial ventures.[6]

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,

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[5] See the Society's webpage for a history of the organization: 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): and 17-27 and 46-64; 4 and (March 1912): 145-62.

[6] One of the organizers of the Brush Electric Company was a patent attorney and former U.S. Commissioner of Patents. For a more general discussion of patent attorneys' role as intermediaries in the market for technology, see Lamoreaux and Sokoloff 2003.

savings institutions, and trust companies with total deposits amounting to more than $800 million. The number of local brokerage houses and 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 because the existence of an active equity market in local securities increased the liquidity of their investments.

Data Sources

Despite the complex of formal and informal institutions that Cleveland's entrepreneurs put in place to support their activities, the city lost its innovative character sometime in the decades that followed World War I. Our aim is to understand when and why. One possibility is that Cleveland declined as a result of the shocks of the Great Depression and World War II. Although we will present some data on long-run trends in patenting in the Ohio compared to other regions that suggest the turning point was during the Great Depression, it is difficult to test that hypothesis directly. Hence our approach is to look for signs that Cleveland's economy was already changing in the 1920s in ways that made it less conducive to entrepreneurial activity. Following an empirical strategy similar to the one we used in previous work for the period 1880-

1912 (Lamoreaux et al. 2006 and 2007a and b), we collected data for the 1920s on inventions awarded to Cleveland patentees, on the occupations and other personal characteristics of the patentees, and on the companies to which they assigned their patents. We use these data to see whether patentees who were associated with startup enterprises still accounted for much of the inventive activity in the city or whether there was a shift toward patenting by employees of larger firms. We also look for evidence that startup enterprises were facing greater difficulties than was the case in previous periods.

More specifically, using Google Patent and LexisNexis, we identified every patent issued to an inventor resident in Cuyahoga County and every patent assigned to an individual or firm located in Cuyahoga County during the years 1928 to 1930. We then selected the patentees who had at least three patents during these years. For each of these frequent inventors, we are collecting a range of additional data from the manuscript records of U.S. Decennial Census of Population available at Ancestry.com, the Cleveland City Directory, the *Bulletin* of the National Research Council, the *Commercial and Financial Chronicle*, *Poor's* and *Moody's* manuals, and newspapers and magazines, as well as manuscript collections and secondary sources. This data includes age, place of birth, occupation, residence, educational attainment, home ownership, and relationship to assignee (for example, whether the patentee was a employee of, a principal in, or had some other relationship to the company acquiring his/her patents). We are also in the process of collecting all of the patents these frequent inventors obtained over their careers. Thus far we have collected the career patents for the inventors who received six or more patents during the years 1928-30. In future work we will also follow Tom Nicholas's lead (2003 and 2007) and use data on patent citations since 1970 to weight patents in our sample by quality.

We are also collecting a range of data (using the above sources, as well as Cleveland Stock Exchange records and handbooks, incorporation records, annual reports, issues of the R. G. Dun's *Mercantile Agency Reference Book*, and lending records of financial institutions) on all Cuyahoga County businesses that were assigned a patent during a sample years, as well as non-Cuyahoga County businesses who received an assignment from one of our frequent inventors. This information includes the identities of founders, officers and directors, year of establishment, capitalization, bond issues, other business units, merger history, stock prices and stock market affiliation, credit rating, and whether the firm has a research and development facility.

Preliminary analysis of the data[7]

One of most important explanations for the decline of innovative regions is that their success inevitably leads to, and is undermined by, the growth of large firms. Our first step, therefore, was to compare trends in the size distribution of firms in Cuyahoga Country with those in the rest of the country using the U.S. Census of Manufactures. As Table 2 shows, the average size of firms in both the county and the country as a whole 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 (SMEs) in the Cleveland economy, though it does not tell us anything about their innovative character.

[7] Our data collection is ongoing, so the findings we report in this section may change.

To determine whether Cleveland's SMEs were as innovative in the 1920s as they were in earlier periods we turn to patent data. Figure 1 uses state-level data published in the Annual Reports of the Commissioner of Patents to compare patenting rates for Ohio with those for several of the most important regions of the U.S. over the period 1921-43. During the 1920s, patenting rates per capita were very similar in the nation's three main patenting regions (New England, the Middle Atlantic and the East North Central), both in terms of level and rate of increase. There is no evidence that Ohio, or the East North Central, was losing ground during that decade. Indeed, patenting in Ohio seems to have increased somewhat more rapidly during the 1920s than in any of these three regions, though it also fell off more rapidly in the 1930s.

We obtained patent counts for Cuyahoga County from Google Patent by searching on the county name and also on the names of cities and towns located in the county. Because Google's optical character recognition capabilities are highly imperfect, these searches inevitably miss some patents awarded to Cuyahoga County residents. The problem is especially serious after 1925, when the Patent Office stopped recording the patentee's county of residence, so the trends for the 1920s should be interpreted with caution.[8] As Figures 2 and 3 display, the number of patents awarded to residents of the Cleveland region increased more or less steadily over the period but dropped relative to population during the 1920s. Of course the city's population was growing rapidly during this period, and it is possible that the decline in patenting rates resulted at least in part from an influx of unskilled workers. But we can also compare Cuyahoga County's patenting rate with that of Ohio and several other high patenting states that also experienced similar in-migration. The annual figures bounce around a lot, so for ease of interpretation, we

[8] For years before 1925 we have at least two chances to pick up a particular patent: when we search on the name of the county and when we search on the name of the city or town. After 1925 we only have one chance. We know we are missing patents for the late 1920s because when we search on the names of patentees (which can appear multiple times in a patent record), we pick up patents that we missed when searching on location.

present decadal averages in Table 3. It was perhaps inevitable that Cuyahoga County's position would slip relative to Ohio. Cleveland was on the leading edge of a regional industrial boom, and its development encouraged more economic activity and more patenting in the surrounding counties. Thus Cleveland's distinctiveness within Ohio decreased over time. More interesting is the region's position compared to Massachusetts and New York. Cuyahoga County's ability to maintain its position relative to Massachusetts, home to Harvard, MIT, and many other important colleges and universities, suggests that the innovativeness of Cleveland's economy was not hampered during this period by weaknesses in this type of complementary institution. Its decline relative to New York, however, suggests that other kinds of complementary institutions—perhaps the financial markets that induced large firms to locate there—may be part of the story.

Aggregate trends can only take us so far, however. Our sample of frequent inventors (that is, inventors resident in Cuyahoga county who received at least three patents during the years 1928-30) allows to get a much better idea of circumstances under which new technology was being generated and the extent to which (and by whom) it was being exploited. Table 4 sets these inventors in a long-run context by comparing them to earlier samples of Cleveland inventors. Our new sample differs from the earlier ones in that, in order to take account of increased suburbanization during the 1920s, it encompasses the whole of Cuyahoga County, rather than just the city of Cleveland. There are a number of other differences in the samples (for details, see the note to the table and Lamoreaux et al. 2006 and 2007a and b), so comparisons have to be made with caution.[9] In particular, because of differences in the number of years of patent data we collected for each patentee, they cannot be used to track changes in the number of patents per inventor. Nonetheless, certain trends stand out so clearly they cannot be dismissed as an artifact of the different characteristics of the samples. The proportion of patents that the

[9] We are in the process of redoing the earlier samples so they are all fully comparable.

patentees assigned (that is, sold or otherwise transferred to another owner) by the time of issue increased steadily and rapidly from 22.3 percent in 1884-86 to 74.4 and 84.4 percent for the two 1920s samples. The proportion of these assignments that went to companies (as opposed to individuals) also increased but with a somewhat different time pattern, rising from 62.5 percent in 1884-86 to 93.2 percent in 1898-1902 and remaining at a high level through the 1920s. The proportion of patents that were assigned to companies in which the inventors were principals (officers, directors, or proprietors) followed a similar trend, increasing between 1884-85 and 1898-1902 and then holding fairly steady thereafter. As a proportion of total assignments, however, assignments to such companies fell from 1910-12 to the late 1920s.

The increase in the fraction of patents that were assigned (and the decreasing fraction of assignments going to companies in which the patentee was a principal) suggests that over time patenting was more and more the work of employees.[10] But employees' assignments of patents to the companies for which they worked still accounted during the 1920s for only about 30 percent of total patents (about 35 percent of total assignments). As the first two columns of Table 5 show, nearly 40 percent of the patents assigned at issue during the 1920s went to companies in which the patentee was neither a principal nor an employee, and if one focuses on the most productive inventors (those who obtained six or more patents during the years 1928-30), the figure was more like 50 percent.

Table 5, moreover, overstates the amount of patenting by employees because patentees who were principals were much less likely to assign their patents to their companies than were patentees who were employees. This difference can be seen in Table 6. The patentees to whom we were able to assign an occupation for the years 1928-30 were almost evenly divided between

[10] Most of this change probably resulted from an increase in the proportion of inventors who were employees, but some also resulted from the increased prevalence during this period of contracts requiring employees to assign all patents to their employers. See Fisk (1998) and Lamoreaux and Sokoloff (1999).

principals (52) and employees (55), and patentees in the two groups obtained roughly the same number of patents on average (5.6 and 5.4 respectively). Principals, however, had lower assignment rates than employees, were much less likely to assign their patents to the companies with which they were associated, and assigned their patents to a greater number of different assignees.[11]

Some of the difference we observe in the assignment behavior of principals and employees was simply a result of their respective positions. Employees were often contractually obligated to assign their patents to their employers. Some principals were under similar obligations, but in other cases they demonstrated considerable independence and were able to retain ownership of their inventions (for examples from an earlier period, see Lamoreaux et al. 2006 and 2007a). Principals also had more leeway to work on technologies not directly connected with their business and thus to obtain patents that could be assigned to other parties or even to other businesses of their own. For example, Morris I. Howard's 1928-30 inventions included an "electric switch," an "apparatus for and process of making tire casings," and a "writing device." He assigned his patents to three different businesses, in at least two of which he had an ownership interest. Similarly, Theodore A. Willard invented a "radio apparatus" that he assigned to the Radio Corporation of America (RCA), as well as inventions related to batteries that he transferred to his own Willard Storage Battery Company. Not surprisingly, principals who were more productive at patenting (obtained more patents in a given period) seemed to have had more freedom and bargaining power. As Table 7 shows, principals with six or more patents in 1928-30 assigned on average only about 40 percent of their patents to the company with which they were associated.

[11] City directories typically listed only one occupation for each individual, so it is possible that an inventor we observe to be an officer in one firm was also an officer in another. To the extent that we miss such connections, our data understate the proportion of patents assigned to companies in which the patentee is a principal.

Another source of the different assignment behavior of principals and employees was that some principals were in the business of inventing. That is, the goal of their business was to develop new technologies that they could exploit by selling or licensing the patent rights to other companies. Several inventors in our sample listed their occupation as patent attorney in the Cleveland city directory. Patent attorneys helped inventors by shepherding their applications through the Patent Office's examination process, representing them in interference and infringement proceedings, and finding buyers or licensees for their patents, but they typically had more technical than legal training and were often in the business of inventing themselves (Lamoreaux and Sokoloff 2003). Six of our frequent Cuyahoga inventors were patent attorneys, and in the three years of the sample they obtained 41 patents (11, 10, 9, 8, 5, 3, and 3), all but 3 of which were assigned by the time of issue to fourteen different assignees, including firms in the electrical, machinery, iron and steel, and automobile industries.

Four other inventors in our sample were principals in independent research laboratories that sprang up during the 1920s—one in Alpax Research Laboratories (4 patents in 1928-30), one in Cosma Labs (6 patents), and two in Brush Laboratories (8 patents). Although they provided testing and engineering services to other firms, these laboratories seem to have been vehicles for the inventors involved to finance their creative activities. Judging from the assignment data, each had a somewhat different business model. The inventor associated with Alpax retained title to his inventions; the one associated with Cosma assigned his patents to three different firms, including one in New York and one in Tennessee. The Brush inventors assigned their patents to the lab.[12] We know the most about the last of these ventures, because it was founded by Charles F. Brush, Jr., the son of Cleveland's famous arc-lighting

[12] After Charles F. Brush, Jr. died in 1929, several assignments went to the Cleveland Trust Company, which had responsibility for Brush's estate.

inventor/entrepreneur. Brush and his associates aimed to pay their bills, at least initially, by selling their services to small firms that lacked in-house research capabilities, but the firm's corporate charter described its purpose to be "scientific research, testing, and engineering including the manufacture or dealing in the patents, inventions and processes of scientific research," and the proprietors focused most of their attention on developing and promoting their own discoveries in the areas of radio technology, brake linings, and beryllium alloys.[13]

The substantial number of patentees in the 1928-30 sample who were principals (52 compared to 55 employees), the large number of patents attributable to them (289 compared to 295 for employees), the significant fraction of principals whose business it was to invent, and the high degree of autonomy that principals seem to have exercised in deciding whether and to whom to transfer their property rights all suggest that Cleveland continued to be a hospitable environment for innovative enterprises in the late 1920s. The question, however, is whether it was becoming less so over time. Comparing the data in Table 6 with information from our earlier Cleveland samples suggests that both the proportion of patentees who were principals and the proportion of total patents awarded to principals declined by the 1920s (Table 8). But such a result does not necessarily mean that it was becoming more difficult to form start-up enterprises. One would expect that, as entrepreneurial ventures from earlier periods established themselves, expanded, and continued to generate new technologies, their employees would account for an increasing proportion of patents. The sheer growth in the number of patentees who were principals may be a more important indicator of the continuing innovative character of the region's economy than their proportion of either patentees or total patents.

[13] Articles of Incorporation of the Brush Laboratories Company (1921), Box 1, Folder 1, Charles Baldwin Sawyer Collection, Kelvin Smith Library, Special Collections, Case Western Reserve University. See also the correspondence between T. C. Brown and Charles Brush, Jr., in 1919 and 1921 about the formation of the lab in Box 16, Folder 6 of the same collection and the late 1920s reports to directors in Box 1, Folder 6.

Information we have collected on inventors' migration patterns suggests that the Cleveland region continued to attract technologically creative people. The proportion of patentees in our youngest group who were born outside Ohio was about the same as for those in our oldest group, though they were slightly more likely to come from other East North Central states than from elsewhere in the United States (Table 9). To learn when the migrants arrived in Cleveland, we looked them up in earlier population censuses and are also retrieving all their career patents (each patent records the location of the patentee at the time she or he applied for the patent). Thus far we have finished collecting this information for all Cuyahoga patentees who obtained at least six patents during 1928-30. For those born outside Ohio, the modal decade when we first observe them in the state is the 1920s (Table 10). This result is another indication that talented individuals continued to be attracted to Ohio and to the Cleveland region more specifically (the vast majority of the patents place them in Cuyahoga County). For the most part, moreover, this highly productive group of investors finished their patenting careers in the region. Only five out of the 35 inventors with more than six patents in these years later applied for patents from other regions. Two of these had left the Cleveland area by 1930, but the other three first applied for patents from other locations in 1938, 1939, and 1943 respectively.

Of course, it is possible that migrants came for the jobs rather than the entrepreneurial opportunities that would come to them down the pike and that the latter were becoming rarer over time. Tables 6 and 7 show that patentees who were principals in companies were about six years older on average than patentees who were employees, and the age gap was greater for patentees with six or more patents in 1928-30 than it was for those with three to five patents. However, this age difference is exactly what one would expect to find, given that inventors typically have to establish a reputation before they can attract financial backing for a venture, whereas firms often hired young men right out of university to work in their research and development facilities (Lamoreaux and Sokoloff 2009). Moreover, one might expect that young workers would discover on the job that they had a talent for coming up with new technological ideas and only later quit to start their own businesses. Such expectations are borne out by the patterns in Table 11, which breaks the 1928-30 sample of Cuyahoga inventors into three age categories. Eighteen of the 30 patentees in the youngest group (age 39 or below) were employees, and only eight were principals. The balance began to tip in the middle group, and for the oldest group it completely reversed. Fully 15 of the 20 patentees aged 50 or older were principals, and only four were employees.

But was it becoming more difficult to start one's own business? The literature on Silicon Valley versus Route 128 (especially Saxenian 1994) suggests that as entrepreneurial enterprises establish themselves and grow large, they can make it more difficult for small innovative enterprises to get a foothold. There are three main mechanisms by which this happens: first, large firms provide employment opportunities that can be more attractive, in terms of pay, job security, and resources for technological discovery, than starting a business; second, they can absorb investment funds that might otherwise go to new firms; and third, by vertically integrating they destroy the upstream and downstream market opportunities that often stimulate the formation of new enterprises. Certainly, the availability of upstream and downstream opportunities was very important in earlier periods; hub firms like Brush Electric and White Sewing Machine encouraged entrepreneurs looking to start related business to locate in Cleveland, sometimes even providing them with production space and capital (Lamoreaux et al. 2006 and 2007a). We do not yet have the evidence that enables us to determine whether these kinds of opportunities were disappearing during the 1920s, but we know that some at least of the enterprises in which our frequent inventors were principals produced parts or other types of intermediate goods and could well be in vertical relationships with area firms.

As for the first mechanism, there is evidence that established Cleveland firms were employing growing numbers of technically skilled personnel during the 1920s. According to surveys conducted by the National Research Council, the number of firms in the city with industrial research laboratories mushroomed from 5 in 1920 to 38 in 1931, and the number of employees who worked in these labs soared as well (see Table 12). Moreover, as many as 40.1 percent of the patents assigned by employee-inventors in the 1928-30 sample went to firms that the NRC listed as having labs (Table 13). However, there does not seem to have been an obvious drain of inventors from entrepreneurial business into large firms with in-house R&D facilities. Eight of the firms with inventor-principals had their own research labs (15 percent of the total); the number for firms with employee-inventors was only slightly more (13), though it was about a third of the total (see Table 14). Moreover, as Table 13 shows, even for the most productive inventors (those receiving six or more patents in 1928-30), the proportion of patents going to firms with research labs was not quite a third.

As Table 14 indicates, firms with inventor-principals were considerably smaller on average than those with inventor-employees. This difference could indicate that they were more capital-constrained; they were also less likely to be listed in *Moody's Manual*, which we take to be evidence of access to broader financial markets. But these differences could also simply be a function of their (on average) considerably younger age. There is anecdotal evidence that at least some inventors thought the grass was greener elsewhere. Glenn Martin, founder of the aircraft firm of Glenn L. Martin Company (a predecessor of today's Lockheed Martin), moved his business to Baltimore in 1929. Charles Van Dusen, another principal in the same firm, also left the city to pursued his aviation ventures.[14] The fact of the matter, however, is that the vast majority of the most productive inventors in the 1928-30 sample (those with at least six patents during those years) did not leave the region to invent elsewhere. If, unlike those of an earlier generation, the businesses that our 1920s inventor-principals founded did not grow into enterprises we have heard of today, the fault may lie with the Great Depression. Not surprisingly the patenting careers of almost all the productive patentees who remained in the city ended during the 1930s.

Lastly, the overwhelming majority (86.9 percent) of the patents assigned by inventors in the 1928-30 sample went to firms located in Ohio and fully 80.7 percent went to firms in Cuyahoga county itself. Moreover, Cleveland-area companies relied almost completely on technology generated in the region. Of the 905 patents acquired by Cuyahoga County firms during the years 1928-30, a whopping 95.0 percent came from inventors resident in the county (see Table 15). The Cleveland region may have remained technologically vibrant during the 1920s, but the wellsprings of its creativity were almost exclusively local. This reliance on local invention may reflect the vitality of the local technological community. But it probably also made the regional economy less resilient when local networks were disrupted by financial shocks and by depression- and war-induced migrations

Conclusion

Our examination of the patenting record of Cuyahoga County inventors has uncovered little evidence to suggest that the innovative character of the region's economy was already in decline during the 1920s. Although the county's patenting rate may have slipped somewhat,

[14] Rose (1950), Ch. 15; "History of NADC, 1941-1980," http://www.navairdevcen.org/nadchistory2a.html, retrieved 8 September 2008.

Cleveland-area inventors generated substantially more patents during that decade than they had ever done before. Moreover, nearly 45 percent of them were attributable to inventors who were principals (officers, directors, or proprietors) in firms—about the same share as were attributable to employee-inventors. Many of the firms with which these principals were associated seem to have been entrepreneurial ventures. They were generally young. They were small relative to other firms in the area that were acquiring patents, and only a small proportion had formal R&D facilities.

Many of the firms with employee-inventors on staff had once upon a time had similar entrepreneurial profiles. Some, such as the White Motor Company, Lincoln Electric, Thompson Products, and National Acme, had survived their growing pains to become established enterprises able to tap broader capital markets for funds. Others, such as National Carbon, Grasselli Chemical, and U.S. Aluminum, became constituent elements in giant national firms such as Union Carbide, Du Pont, and Alcoa. Although these erstwhile startups had by the 1920s grown large, they do not seem to have been dominant enough in the local economy to choke off opportunities for additional startups. Indeed, as late as 1930 manufacturing establishments in Cuyahoga County were considerably smaller on average than those in other industrial counties.

Although Cuyahoga County's large numbers of SMEs may have helped maintain it as a hospitable spawning ground for new entrepreneurial ventures, they may also have made its economy more vulnerable to catastrophic shocks such as the Great Depression. Most of the entrepreneurial enterprises of the late 1920s did not survive the prolonged downturn, but all the large firms listed above did. Not only did they survive, they expanded their investments in in-house R&D. Given the severity and duration of the depression, large firms had little incentive to devote resources to new productive capacity, so many of them increased their investments in research instead. It is well known that the number and size of the nation's industrial research laboratories increased dramatically during the 1930s (Bernstein 1987; Mowery and Rosenberg 1989). In Cleveland the number of firms with such facilities grew from 23 in 1927 to 38 in 1931 to 53 in 1940 (see Table 12), but the National Research Council surveys show that the growth was even greater in the Middle Atlantic, where most of the nation's largest enterprises had built their headquarters. The difference was already apparent in the 1920s in the relative rise of patenting rates in the Middle Atlantic region,[15] and the gap would widen during the Great Depression, when patenting rates fell dramatically everywhere but in the Middle Atlantic (Figure 1).

Whether this differential experience during the Great Depression was in itself enough to account for the Cleveland region's subsequent decline as a center of innovation is not clear. But it would help to explain why Cleveland's industrial diversity—certainly relative to cities like Detroit—did not protect it from a similar "rust belt" fate. Additional contributing factors may include the destruction of the complementary financial institutions that had supported entrepreneurial ventures in the region and changes in the regulatory regime that advantaged New York and made it difficult for regional capital markets like Cleveland's to recover their earlier vibrancy. They may also include policies adopted by the federal government during the Second World War to disperse manufacturing capacity in order to make the country's industry less vulnerable to attack. Sorting out the relative importance of these factors is a task for further research. We think this research is particularly compelling to undertake in the current economic environment. The U.S. economy is suffering financial shocks of a magnitude not seen since the Great Depression, and it is important to understand the effects that such events can have on

[15] Data being collected by Lamoreaux and Dhanoos Sutthisphisal shows that patenting in the Middle Atlantic in the late 1920s was disproportionately attributable to large firms in the Middle Atlantic region.

regions, like Silicon Valley, whose innovative character largely depends on the continuous spawning of new firms.

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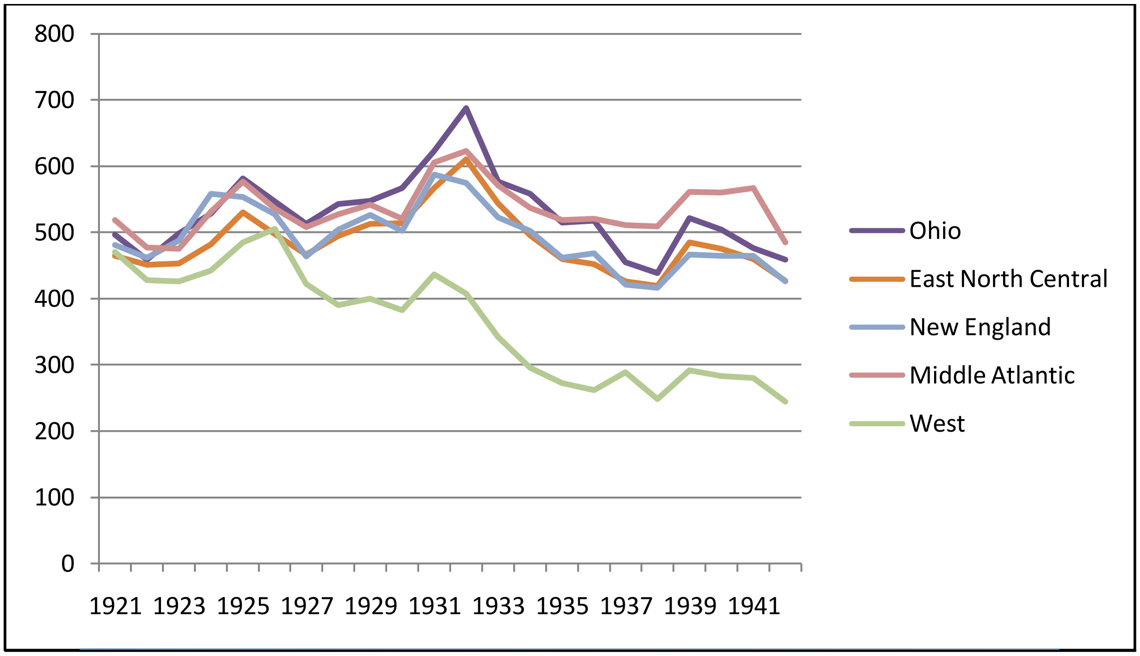
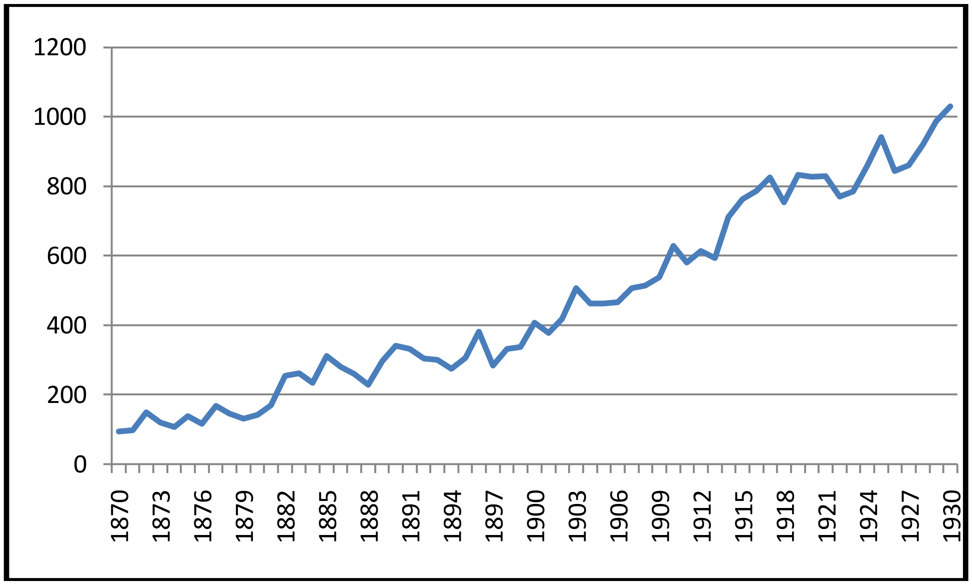
Figure 1. PATENTING RATES FOR OHIO AND SELECTED REGIONS
(PER MILLION POPULATION)



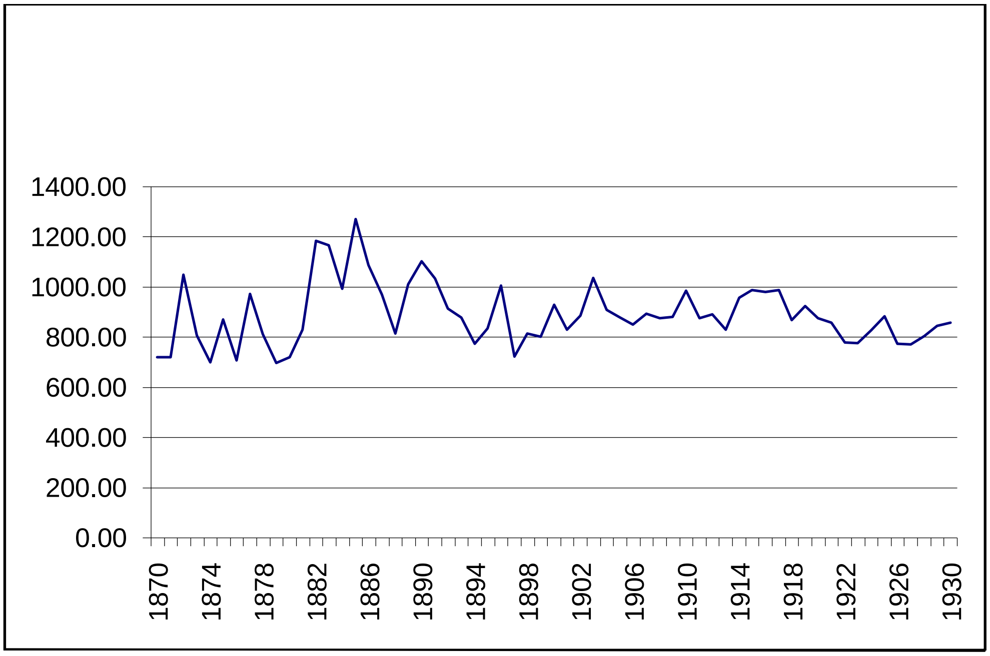
Source: U.S. Commissioner of Patents, *Annual Report*, 1921-25, 1946; Carter et al. (2006), 28-29.

FIGURE 2. PATENTS ISSUED TO CUYAHOGA COUNTY, OHIO INVENTORS, 1870 -1930



Sources: See text.

FIGURE 3. CUYAHOGA COUNTY PATENTING RATE 1870-1930
(PER MILLION POPULATION)



Sources: See text and Figure 1.

Table 1. CLEVELAND'S LARGEST INDUSTRIES, 1870-1920

Industry Rank	1870*	1880	1890	1900	1910	1920
1	Coal, rectified	Iron and steel	Iron and steel	Iron and steel	Iron and steel, steel works, and rolling mills	Automobiles
2	Iron, forged and rolled	Slaughtering and meatpacking	Foundry and machine-shop products	Foundry and machine-shop products	Foundry and machine-shop products	Foundry and machine tools
3	Flour-mill products	Foundry and machine-shop products	Petroleum Refining	Slaughtering and meatpacking, wholesale	Automobiles	Iron and steel
4	Meat, packed pork	Clothing, men's	Slaughtering and meatpacking, wholesale	Clothing, women's factory product	Slaughtering and meatpacking	Electrical Machinery
5	Iron, castings (not specified)	Liquors, malt	Carpentering	Liquors, malt	Clothing, women's	Clothing, women's

*1870 data are for Cuyahoga County. All other years are for the city of Cleveland.

Sources: U.S. Census Office, *Census of the United States*, 1850-1910; and U.S. Bureau of the Census, *Census of the United States*, 1920.

Table 2. MANUFACTURING IN CUYAHOGA COUNTY, OHIO, 1860 -1930

Year	Cuyahoga County Average Manufacturing Output per Firm	Average Manufacturing Output per Firm, Top 100 Manufacturing Counties	Cuyahoga County Average Number of Workers per Firm	Average Number of Workers per 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

Note: 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. Bureau of the Census, Historical Census Browser. Retrieved 28 July 2006, from the University of Virginia, Geospatial and Statistical Data Center: http://fisher.lib.virginia.edu/collections/stats/histcensus/index.html.

Table 3. CUYAHOGA COUNTY PATENTING RATES RELATIVE TO OHIO, NEW YORK, AND MASSACHUSETTS

Year	Cuyahoga County/ Ohio	Cuyahoga County/ New York	Cuyahoga County/ Massachusetts
1871-80	2.42	1.32	0.94
1881-1890	2.36	1.44	1.06
1891-1900	2.25	1.59	1.21
1901-10	1.84	1.62	1.47
1911-20	1.89	1.53	1.52
1921-30	1.55	1.37	1.53

Sources: See text and Figure 1.

Table 4. ASSIGNMENT OF PATENTS OBTAINED BY CLEVELAND AREA PATENTEES

Assignment Information	1884-86 Cleveland sample	1898-1902 Cleveland sample	1910-12 Cleveland sample	1925-29 Cleveland sample	1928-30 Cuyahoga sample
Assignments at Issue					
Percent of Patents	22.3	52.9	55.3	74.4	84.4
Assigned to Companies					
Percent of Patents	14.0	49.3	50.8	70.4	82.7
Percent of Assignments	62.5	93.2	91.9	94.7	96.8
Assigned to Companies where the Patentee was a Principal					
Percent of Patents	1.5	17.6	19.6	19.2	18.4
Percent of Assignments	6.8	33.3	35.5	25.8	21.5
Total Number of Patentees	*42*	*36*	*107*	*157*	*125*
Total Number of Patents	*394*	*839*	*606*	*1472*	*624*
Number of Years in Sample	*7*	*18*	*3*	*7*	*3*

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 (we excluded John Walker because his name was too common for us to make precise matches) and then collected all of the patents they were awarded in those three years and also 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 a total of at least three patents in 1898, 1900, and 1902. They also include several inventors resident in Cleveland who were prominent enough to be profiled in the *Dictionary of America Biography*. We collected all the 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 three 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 Cleveland patentees who obtained at least three patents in 1925, 1928, and 1929. The 1928-30 sample consists of all the patents obtained in 1928, 1929, and 1930 by the 130 residents of Cuyahoga County who obtained at least three patents in 1925, 1928, and 1929. An assignee was classified as a company in which the patentee was a principal if the company bore the surname of the patentee or if the patentee was an officer, director, or proprietor. To avoid double counting, we counted a patent as 0.5 if the inventor was one of two co-inventors and 0.333 if he was one of three co-inventors. For ease of interpretation we present rounded numbers for patent counts in the table.

Table 5. ASSIGNMENT OF PATENTS BY PATENTEES IN THE 1928-30 SAMPLE

Assignment Information	1925-29 Cleveland sample	Patents obtained in 1928-30 by patentees with at least three patents in Cuyahoga County in 1928-30	Patents obtained in 1928-30 by patentees with at least six patents in Cuyahoga County in 1928-30
Assignments at Issue			
Percent of Patents	74.4	84.4	87.6
Assigned to Companies where the Patentee was a Principal			
Percent of Patents	19.2	18.4	12.6
Percent of Assignments	25.8	21.5	14.4
Assigned to Companies where the Patentee was an Employee			
Percent of Patents	27.6	30.7	30.5
Percent of Assignments	37.1	36.0	34.9
Total Number of Patentees	*157*	*125*	*35*
Total Number of Patents	*1472*	*624*	*306*
Number of Years in Sample	*7*	*3*	*3*

Notes and Sources: See Table 4.

Table 6. ASSIGNMENTS IN 1928-30 BY CUYAHOGA COUNTY INVENTORS WITH AT LEAST THREE PATENTS DURING THOSE YEARS

	Principals	Employees	Unknown
Number of patentees	52	55	18
Number of patents	289	295	80
Number of assignments	235	281	54
Average percent of patents assigned	81.5	95.3	66.9
Average percent of patents assigned to the company where the patentee is a principal	50.5	---	---
Average percent of patents assigned to the company where the patentee is an employee	---	77.8	---
Average number of different assignees for patentees that assigned at least three patents	1.56	1.20	1.42
Average age in 1929	46.8	41.3	42.7

Notes and Sources: For this table we used occupational information collected primarily from Cleveland city directories to classify patentees as principals or employees during the years 1928-30. Each patentee is weighted equally in the table. Patents issued to multiple inventors are counted in each co-inventor's tally, so the total number of patents exceeds that in Tables 4 and 5. Age is from the 1930 Census. We were able to obtain this information for 41 out of 56 of the patentees classified as employees, 35 of the 51 patentees classified as principals, and 10 of the 18 patentees classified as unknown.

Table 7. ASSIGNMENTS IN 1928-30 BY CUYAHOGA COUNTY INVENTORS WITH 3-5 AND 6+ PATENTS DURING THOSE YEARS

	Principals		Employees	
	3-5 patents	6+ patents	3-5 patents	6+ patents
Number of patentees	36	16	38	17
Number of patents	133	156	136	159
Number of assignments	107	128	130	151
Average percent of patents assigned	80.8	82.9	95.2	95.0
Average percent of patents assigned to the company where the patentee is a principal	56.9	41.1	---	---
Average percent of patents assigned to the company where the patentee is an employee	---	---	78.7	71.8
Average number of different assignees for patentees that assigned at least three patents	1.54	2.29	1.16	1.35
Average age in 1929	45.9	48.8	41.4	41.3

Notes and Sources: See Table 6. To save space we dropped patentees categorized as unknown in Table 6 from this table.

Table 8. PRINCIPALS' SHARE OF ALL SAMPLE PATENTEES AND PATENTS

	Principals	All Others
1884-86 Cleveland Sample		
Percent of Patentees	45.2	54.8
Percent of Patents	55.6	44.4
1898-1902 Cleveland Sample		
Percent of Patentees	54.3	45.7
Percent of Patents	58.4	41.6
1925-29 Cleveland Sample		
Percent of Patentees	42.7	57.3
Percent of Patents	44.6	55.4
1928-30 Cuyahoga Sample		
Percent of Patentees	41.6	58.4
Percent of Patents	43.5	56.5

Notes and Sources: See Tables 4 and 6.

Table 9. STATE OR COUNTRY OF BIRTH FOR PATENTEES WITH 3+ PATENTS IN 1928-30

	Ohio	Other ENC	Other US	Foreign	Total
Occupational Category					
Principals					
Number	17	2	13	3	35
Row Percent	(48.6)	(5.7)	(37.1)	(8.6)	(100.0)
Employees					
Number	16	5	11	8	40
Row Percent	(40.0)	(12.5)	(27.5)	(20.0)	(100.0)
Unknown					
Number	2	0	5	2	9
Row Percent	(22.2)	(0.0)	(55.6)	(22.2)	(100.0)
Age Group					
39 or less					
Number	10	5	10	4	29
Row Percent	(34.5)	(17.2)	(34.5)	(13.8)	(100.0)
40-49					
Number	18	0	11	7	36
Row Percent	(50.0)	(0.0)	(30.6)	(19.4)	(100.0)
50 or more					
Number	7	2	8	2	19
Row Percent	(36.8)	(10.5)	(42.1)	(10.5)	(100.0)

Notes and Sources: See Table 6.

Table 10. CUYAHOGA PATENTEES WITH 6+ PATENTS 1928-30 WHO WERE BORN OUTSIDE OHIO: YEAR FIRST OBSERVED IN OHIO

Date first known to be living in Ohio	Born Outside Ohio	Place of Birth Unknown	Total
1900s	4	1	7
1910s	6	1	6
1920s	7	5	13
Total	17	7	26

Notes and Sources: Using LexisNexis and Google Patent, we collected all the career patents of patentees who obtained at least six patents in Cuyahoga County in 1928-30. In most cases, the year in which we first observe patentees in Ohio who were born elsewhere is the first year in which they applied for a patent from Ohio, but sometimes we found them there in the 1910 or 1920 Census.

Table 11. THE RELATIONSHIP BETWEEN AGE AND OCCUPATION: PATENTING IN 1928-30 BY CUYAHOGA COUNTY INVENTORS WITH 3+ PATENTS DURING THOSE YEARS

		Age in 1929	
	39 or less	40-49	50 or more
Number of Patentees	30	36	20
Number of Patents	162	184	119
Patents per Patentee	5.4	5.1	6.0
Employees			
Number of Patentees	18	19	4
Number of Patents	112	93	28
Patents per Patentee	6.2	4.9	7.0
Principals			
Number of Patentees	8	12	15
Number of Patents	32	65	87
Patents per Patentee	4.0	5.4	5.8
Unknown			
Number of Patentees	4	5	1
Number of Patents	18	26	4
Patents per Patentee	4.5	5.2	4.0

Notes and Sources: See Table 6.

Table 12. NUMBER OF CLEVELAND FIRMS WITH INDUSTRIAL RESEARCH LABORATORIES

Year	Number of Firms	Average Number of Research Lab Employees	Average Employees, excluding GE
1920	5	53.4	10.5
1921	7	95.0	22.5
1927	23	68.4	39.1
1931	38	74.5	39.5
1933	38	68.9	41.8
1938	42	93.1	57.9
1940	53	98.2	67.0
1946	45	174.6	174.6

Source: *Bulletin of the National Research Council*, 1920, 1921, 1927, 1931, 1933, 1938, 1940 and 1946.

Note: In most cases, where a firm, such as General Electric, has research laboratories in more than one location, the number reported here reflects research laboratory employment for the entire firm, not just Cleveland. In 1946, General Electric's research employment was not reported, so excluding it does not change the average. The 1946 number is inflated, however, by the inclusion of firms such as Dow Chemical Company, Radio Corporation of America, and B.F. Goodrich, all of which had substantial research employment outside Cleveland.

Table 13. SHARE OF PATENTS GOING TO FIRMS WITH INDUSTRIAL RESEARCH LABS, 1928-1930

	Percent of Patents Issued to "Frequent Inventors" that were Assigned to Cleveland Firms with R&D Labs
All patents assigned by 3+ inventors	29.1
Patents assigned by employee-inventors	40.1
Patents assigned by principals	21.4
Inventors with 6+ patents	32.1
Inventors with 3-5 patents	26.0

Notes and Sources: See Tables 6 and 12.

Table 14. CHARACTERISTICS OF FIRMS RECEIVING ASSIGNMENTS FROM CUYAHOGA COUNTY INVENTORS, 1928-1930

	Principals	Employees
Number of patentees	52	55
Number of associated firms	55	40
Average age of firm in 1930	13.9	23.7
Percent of firms in existence by 1915	36.4	72.5
Percent of firms in existence by 1925	78.2	87.5
Percent of firms listed in Moody's in 1933	10.9	35.0
Percent of firms worth more than $500,000 in 1925	18.2	50.0
Percent of firms worth more than $50,000 in 1925	34.5	75.0
Percent of firms reported to have an industrial research lab	14.5	32.5

Notes and Sources: See Table 12; the *Encyclopedia of Cleveland History*; Rose (1950); individual company websites, *Dun's Mercantile Agency Record Book* (various years),the *Bulletin* of the National Research Council (various years), and Moody's *Manual of Investments*. The average age of firm in 1930 is an underestimate because in some cases our observation of age is truncated. In some cases we observe the year in which the firm was founded, but if we do not have this information, we estimate the year of establishment as the first year the firm appears in our database.

Table 15. CUYAHOGA COUNTY FIRMS RECEIVING PATENTS, 1928-1930

Residence of Inventor	Percent of patents acquired
Ohio	96.9%
Cuyahoga County	95.0%
Other Midwest	1.3%
Mid Atlantic	1.2%
Total number of patents acquired by Cuyahoga County firms, 1928-1930	905

Notes and Sources: See text.