

Patenting in an Entrepreneurial Region during the Great Depression:

The Case of Cleveland, Ohio

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Abstract

This paper investigates the effect of a major macroeconomic shock, the Great Depression, on patenting in an innovative region. Cleveland, Ohio, was a vibrant industrial city in the 1920s, a hotbed of inventive activity and small-scale startups in a range of important Second Industrial Revolution industries. One might expect a shock of the magnitude of the Great Depression to have taken a serious toll on inventive activity, especially in a region such as Cleveland's, where there were so many small firms dependent on external finance. We explore this issue by comparing the career patenting records of two cohorts of Cleveland patentees who obtained a threshold number of inventions during the years 1910-12 and 1928-30 and find remarkably little effect of the Depression on patenting. We then look at the patenting careers of graduates from the Case School of Applied Science. Only when we focus on the students who graduated in the midst of the Depression do we find a significant effect. We conclude that an important negative consequence of the Depression was to prevent a new generation of inventors from forming to carry on the region's innovative tradition.

Patenting in an Entrepreneurial Region during the Great Depression:

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This paper investigates the effect of a major macroeconomic shock, the Great Depression, on patenting in an innovative region. Cleveland, Ohio, was a vibrant industrial city in the 1920s—a hotbed of inventive activity in such important Second Industrial Revolution industries as open-hearth steel, electrical machinery, chemicals, machines tools, and automobiles. At a time when large-scale enterprises and their in-house research laboratories were coming to dominate technological discovery in the Middle Atlantic region of the country, small-scale enterprises and independent inventors remained a major source of innovation in the East North Central states (Lamoreaux, Sokoloff, and Sutthiphisal 2011). Cleveland epitomized this Midwestern dynamic. Much like Silicon Valley today, its success drew on networks of entrepreneurs and financiers that funneled investment into new firms and technologies. Although by the 1920s some of city's manufacturing firms had grown (or merged) into large national corporations, the average size of firms in the city remained small relative to other manufacturing centers, and startup enterprises continued to be an important means of exploiting new technological discoveries (Lamoreaux, Levenstein, and Sokoloff 2007b).

Patenting generally declines during depressions. Because the expected returns from commercializing a new technology fall when demand and incomes drop, there is less incentive to invest in technological discovery during downturns (Schmookler 1966). In addition, invention and patenting are costly endeavors that are likely to be more difficult to finance in periods when revenues, incomes, and prices are falling. One might expect, therefore, that a shock of the magnitude of the Great Depression would have taken a serious toll on patenting rates and that the

shock would have been particularly severe in a region such as Cleveland's, where there were so many small firms dependent on external finance. As Figure 1 shows, the aggregate evidence is generally consistent with these expectations. Patenting rates dropped everywhere in the U.S. during the Great Depression, but they fell longer and farther in the East North Central region than in the Middle Atlantic. Unfortunately, we do not have a separate time series for patenting in the Cleveland area, but we can see that the fall was even sharper in Ohio than in the East North Central region as a whole.

Other patterns, however, are not consistent with this story of decline. We know from David Mowery and Nathan Rosenberg's analysis of the surveys of industrial research laboratories conducted by National Research Council (NRC) that large firms' investments in R&D facilities and personnel actually rose during the Depression (Mowery and Rosenberg 1989). That increase in turn might explain why patenting rates dropped less in the Middle Atlantic than elsewhere, but we have no comparable studies of firms that organized technological discovery more informally, and we have no direct information about how patenting by inventors in different kinds of enterprises and settings was affected by this macroeconomic shock. Alexander Field (2011) argues that total factor productivity in manufacturing grew rapidly during the Great Depression. The rate of increase was lower than in the 1920s, but still high by any other standard of comparison, including the post-war "golden age" of American business. Although Field attributes some of the growth to complimentary investments in transportation and distribution, the overall picture is one in which manufacturing firms were continuing to push out the production possibility frontier. Little is known, however, about the sources of these productivity gains and the extent to which they derived from new technological discoveries.

The purpose of this paper is to begin to fill these gaps in our knowledge by investigating the effect of the Great Depression on patenting activity in the Cleveland region. We examine the patenting record of two different populations of individuals in the Cleveland region before, during, and after the Great Depression. The first consists of two cohorts of Cleveland patentees who obtained a threshold number of inventions during the years 1910-12 and 1928-30 respectively. Some of these “frequent inventors,” as we call them, were employees in established firms, often with R&D labs, but many others were entrepreneurs who founded and led their own firms. Comparing the patenting behavior of the frequent inventors who were active on the eve of the Great Depression with that of the earlier cohort, at similar ages, stages of their careers, and occupations, we find remarkably little effect of the Depression. The 1928-30 inventors maintained patenting rates through the worst years of the Depression at levels that were remarkably similar to those achieved by the 1910-12 cohort under the much more favorable macroeconomic conditions of the build-up to the First World War.

To examine the effect of the Depression on inventors who had not necessarily already established themselves, we collected a second dataset consisting of graduates of the Case School of Applied Sciences from the 1920s and 1930s. The Case School had been founded in Cleveland in 1880 to educate young men to “apply pure science to unlock the secrets of nature and to develop the nation’s abundant resources” (Cramer 1976, 203). Graduates of Case had the human capital to engage in technological discovery, and fully one quarter of the students who finished during these years obtained at least one patent during their lifetime. We find that the record of Case graduates prior to the onset of the Depression looks much like that of the frequent inventors in the sense that the Depression does not seem to have decreased their patenting. Those who came of age during the Depression were different, however. Not only did their patenting activity

suffer during the Depression, but the shock seems to have had a long-term negative effect on their inventive careers.

These findings, which we supplement with additional biographical and archival evidence, lead to two general conclusions. First, patenting was rewarding enough that successful inventors and their firms were willing to do whatever they could to sustain their technological creativity despite the Depression. The fall in patenting that occurred during the downturn mainly resulted from a decline in applications by casual inventors and by those who had not yet established themselves. Second, an important negative effect of the Great Depression on patenting was to prevent the next generation of inventors from following in the footsteps of their predecessors. We speculate that this generational effect was greater for economies like Cleveland's that depended on networks and the formation of new enterprises and that it may have contributed to the region's subsequent technological stagnation.

Cleveland's Innovative Ecology on the Eve of the Great Depression

Cuyahoga Country, where Cleveland was located, was a booming manufacturing region in the late nineteenth and early twentieth centuries. In 1900 the county was the fourteenth largest in the nation terms of total value of manufacturing output, surpassed in the Midwest only by Chicago, Cincinnati, and St. Louis, and, by 1920 it had catapulted itself into seventh place.¹ Although the average Cuyahoga manufacturing plant more than doubled in size over these two decades, from 23 to 53 workers, the county remained a hospitable environment for small firms, and its national ranking in terms of average plant size actually fell from seventh to eleventh.

¹ The figures in this paragraph come from the U.S. Census of Manufactures for 1900, 1920, 1930, and 1940, as reported in the Historical Census Browser at <http://mapserver.lib.virginia.edu/>.

Cuyahoga's plants in the 1920s were larger on average than those of mercantile centers such as Chicago, New York, and San Francisco, but they were considerably smaller than other Midwestern cities, such as Detroit and Akron and Gary, which specialized in particular mass-production industries. Like the mercantile centers, moreover, Cuyahoga's manufacturing sector was highly diversified (Simon and Nardinelli 1992). Virtually all the key industries of the Second Industrial Revolution figured prominently in its industrial landscape (see Table 1). Cleveland's location gave it convenient access to Lake Superior iron ore, so it is not surprising that iron and steel attained top billing early on. Machine-tools, another regionally important industry, gave rise to automobiles, one of the city's top three industries by 1910. Electrical machinery attained a similar rank by the late 1920s, and chemical products, such as paints and varnishes and oil refining, though not listed among the top group until 1947, long had a major presence in the area.

Cleveland was also a center for the development of leading-edge technologies, ranking eighth out of all U.S. cities in 1900 in the total number of patents granted to residents. If that calculation is limited to patents deemed by official examiners to have made a significant contribution to the industrial art of the period, Cleveland was the fifth most technologically important city (Fogarty, Garofalo, and Hammack n.d.). Local firms built their success almost exclusively on technologies developed in the area. More than 90 percent of the patents acquired by Cuyahoga County firms during the years 1910 to 1912 were awarded to inventors resident in the county, and in 1928 to 1930 the proportion was almost the same (Tables 2A and B).

In previous work (Lamoreaux, Levenstein, and Sokoloff 2006 and 2007a and b), we demonstrated that the story of Cleveland's emergence as a center of innovation bears a strong resemblance to the histories of regions like Silicon Valley, where local networks of firms and

complementary technological and financial institutions helped to initiate and sustain waves of start-up enterprises.² New firms such as the Brush Electric Company and White Sewing Machine not only served as models for ambitious entrepreneurs to emulate but were gathering places for overlapping networks of inventors and financiers. Some of the inventors who congregated at these enterprises were employees, but others were entrepreneurs who set up shop in or near the factory with the aim of developing complementary technologies. Financiers with ties to these business could “listen in” on the conversations the inventors had about each other’s discoveries—which ones were likely to work, which to prove economically valuable—and thus gain the information they needed to decide where to invest their funds.

In addition to these informal networks, Cleveland quickly developed an increasing number of more formal institutions that served as ongoing supports for innovation. On the educational front the most important was the Case School of Applied Science, which played a role in the region much like that of Stanford University in Silicon Valley.³ Founded in 1880, Case provided training to a number of important Cleveland inventors and had close connections with local entrepreneurs. For example, its first president, Cady Staley, took a personal interest in undergraduate Herbert Dow and served as a 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), the Warner Mechanics and Hydraulics Building, and an endowed chair in

² On Silicon Valley, see Saxenian 1994; Castilla 2000; Kenney and Florida 2000; Hyde 2003; Lécuyer 2006. See also Trescott (1981) for a similar pattern in late nineteenth-century Pittsburgh.

³ On Stanford’s role in Silicon Valley, see Leslie and Kargon 1996; Lowen 1997; Adams 2003 and 2005; and Gillmor 2004.

physics. Many Case students found employment in the region's high-tech enterprises and some like Walter C. Baker, an automotive engineer, founded important start-ups.

Local engineering societies also provided regular forums at which inventors could discuss technical problems and assess the merits of new technologies. The same year that Case was founded, a small group of engineers who had been debating whether the country should adopt the metric system 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."⁴

On the financial front, Cleveland was home in 1920 to thirty-eight banks, savings institutions, and trust companies with total deposits amounting to more than \$800 million. The city was well "banked" in comparison to its peers. Of the 25 largest manufacturing counties in the country in 1920, Cleveland had the fourth highest bank deposits per capita, behind only New York, Boston, and Pittsburgh. In the Midwest, Cleveland had bank deposits of 61 cents per person, compared to 55 cents in Chicago, 39 cents in Milwaukee, and only one cent in Detroit.⁵ Trading in local securities led in 1900 to the organization of the Cleveland Stock Exchange (CSE). From its beginning, the CSE listed relatively more industrials than its much larger counterpart in New York, and the number of manufacturing firms whose securities traded on the

⁴ See the Society's webpage for a history of the organization: <http://www.cesnet.org/about.asp>, accessed on 8 December 2013. 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.

⁵ Note that, although we refer to the cities, these data are actually measured at the county level. Bank deposit data are from ICPSR-0007 (Federal Deposit Insurance Corporation Data on Banks in the U.S. (1920-1936)). Population data are from the 1920 U.S. Decennial Census.

CSE continued to grow, more than doubling between 1910 and 1914. Newly listed manufacturers included some of the most successful of the innovative firms formed in Cleveland during the previous decades, including National Carbon, Brown Hoisting Machine, Wellman-Seaver-Morgan, and the White Motor Company. In addition, the city's growing numbers of patent attorneys provided advice and technical expertise and sometimes helped to match inventors with buyers for their patents or round up investors for entrepreneurial ventures.⁶

As Cleveland's economy developed and some of the early innovative firms became more established, older enterprises accounted for a growing fraction of the patents assigned at issue to Cuyahoga firms (compare Tables 3A and 3B). Some of these firms built their own in-house R&D laboratories. In 1920 the National Research Council (NRC) began to survey firms to find out whether they had R&D facilities and, if so, where the labs were located and how many researchers they employed. Table 4 shows that a growing number of firms reported having laboratories in Cleveland. Most of these firms were headquartered locally, but a few were large national companies that also had extensive R&D operations elsewhere. The most important of these was General Electric, whose main laboratory was in Schenectady, New York, but which operated the National Electric Lamp Association (NELA) research facility in Cleveland.

The growth of large firms and the spread of industrial R&D laboratories meant that Cleveland's industrial ecology was changing in the early twentieth century, but the region retained its innovative character, and start-ups continued to flourish alongside more established enterprises.⁷ Although by the 1920s an increasing fraction of the county's patentees were

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, Sokoloff, and Sutthisphisal 2013.

⁷ In this respect, Cleveland was very different from Detroit, where as Klepper (2007) has shown, the large automobile manufacturers closed off opportunities for newcomers during the 1920s.

employees, inventors who operated independently or who were principals in companies formed to exploit their technological discoveries continued to generate large numbers of patents. In 1910-12 employees and principals each accounted for about the same proportion of patents (45.4 percent for employees and 46.5 percent for principals), and most of the rest went to independent inventors or patent attorneys (Table 5A). By 1928-30 the fraction going to employee-inventors had increased to 52.0 percent (Table 5B), but nearly half of all patents still went to principals (39.2 percent) and independents/patent attorneys (8.5 percent). Table 6 sets these patterns in long-run context by comparing the 1928-30 and 1910-12 data to samples of Cleveland inventors for earlier periods. When we combine principals and independents, we find, as one might expect, that their proportion of both patentees and patents peaked around the turn of the century and then fell off with the rise of large-scale manufacturing and industrial R&D in the twentieth century. Nonetheless, the share of inventive activity attributable to these two categories of patentees remained substantial, both in absolute terms and relative to their historic highs.

Following national trends (see Lamoreaux and Sokoloff 1999), Cleveland inventors assigned an increasing proportion of their patents at issue and also made a growing share of those assignments to companies (see Table 6). Employees often had contracts that obligated them to turn their inventions over to their employers, so their patents were generally more likely than those of other inventors to be assigned at issue (Fisk 1998). Over time, however, the gap between employees and other inventors narrowed, perhaps because principals faced more pressure from investors to transfer their technology or perhaps because companies were attaching greater importance to controlling patented technology.⁸ Interestingly, however, for both principals and employees the average number of different individuals and companies to which

⁸ Tom Nicholas (2007) has shown that intellectual property played a dramatically more important role in market evaluations of companies in the 1920s than it had in the preceding decade.

they assigned their patents increased between 1910-12 and 1928-30—from 1.05 to 1.21 for employees and from 1.16 to 1.18 for principals (Table 5A and 5B). Neither group of inventors was automatically assigning their inventions to the firms with which they were associated.⁹ As late as 1928-30, principals transferred only about 60.7 percent of their patents to their companies, retaining control of 17.5 percent and assigning 12.5 percent to other individuals or firms. Employees transferred nearly 30 percent of the patents they received in these years to parties other than their employers, suggesting that, whatever their contractual obligations, they were still behaving quite entrepreneurially.

Indeed, although some employee inventors spent their entire careers working for established firms, others used their jobs as stepping stones to start their own businesses. This path from employee to employer seems to have become somewhat more difficult to navigate by the 1920s. Although the age distribution of employees and principals was very similar in the 1910-12 cohort, employee-inventors in the 1928-30 cohort were younger on average than principal-inventors (Tables 7A and 7B). Either the probability of employees starting their own businesses was dropping or they were making this transition later in their careers. Nonetheless, it was certainly still possible in the 1920s to make the transition from employee to principal, and a number of the inventors in our sample did. For example, Wilbur Burke was listed in the 1920 U.S. Census as the manager of an electrical company, but by 1926 he was president of the startup Electric Vulcanizing Rubber Co. Lee Chadwick was a mechanical engineer working in an auto works company in 1910, but president of the Cleveland Metal Products Company in 1923. Anthony Fricker was a machinery salesman in 1910, but president of the A. Fricker Manufacturing Company in 1923. Inventor-entrepreneurs were not disappearing—nearly half of

⁹ This trend rise might reflect entrepreneurial behavior, but it could also reflect increased mobility across firms or movement in and out of employment and self-employment.

the 1928-30 frequent inventors were principals or independents and about 20 percent were under age 40—but they were aging relative to employees.

There was a similar change over time in the proportion of principals and employees who came from outside the region. In the 1910-12 cohort, principals and employees were equally likely to be born outside of Ohio (Table 7A). By the 1928-30 cohort, however, principals were more likely than employees to be from Ohio, suggesting that inventors without local connections had a harder time finding support to start a business, particularly in the early stages of their careers. In both periods, moreover, principals were less likely than employees to come from foreign countries, perhaps because immigrants were less likely to have the skills or relationships necessary to establish a firm (Tables 7A and 7B). Even so, the Cleveland region remained a magnet for innovative migrants. Although there was decline between the 1910-12 and 1928-30 cohorts in the proportion of inventors born abroad (Tables 7A and 7B), this trend is consistent with overall patterns of migration during the Teens and Twenties. Moreover, the decline in foreign migrants was largely offset by an influx of inventors born in other regions of the U.S., a flow that continued during the 1920s. Over 50 percent of the American-born inventors in the 1928-30 cohort who came from outside Ohio were first observed in the state in the ten preceding years, about the same proportion as in the 1910-12 sample (Table 8A and 8B).

As the continued importance of principals in the population of inventors suggests, the growing presence of large firms in the region's economy does not seem to have choked off entrepreneurial innovation. The proportion of patents accounted for by more established enterprises rose over time, but this pattern is exactly what one might expect to find in an innovative region that had been generating new firms for an extended period of time. Some of the successful startups from previous periods hired staffs of inventors, and their employees

accounted for an increasing share of the patents produced in the region. But migrants continued to flow into the region, new firms continued to form, and the inventors who were principals of startups still accounted for a large proportion of the area's output of patents.

In this context, the Great Depression was a severe shock to Cleveland's economy. Although Cuyahoga County entered the downturn with a more extensive financial system than most manufacturing counties (it also had its own Federal Reserve Bank), the Depression hit its banking sector particularly hard. Figure 2 shows bank deposits in Cuyahoga County (on the right axis) and total deposits in the 24 other largest manufacturing counties in the country (on the left axis). Cuyahoga's bank deposits grew at essentially the same rate as those in the rest of the manufacturing areas from 1920 to 1929, and then fell at the same rate from 1929 to 1931. However, the county's decline from 1931 to 1933 was much sharper than comparable areas across the nation. Similarly, it suffered a greater fall in the total number of banks (Figure 3).

Although Cleveland entered the Depression an integral part of the new Midwestern manufacturing belt with a more diversified industrial base than most large manufacturing cities in the East North Central region, neither its location nor its industrial mix seem to have been an advantage. Wallis (1989) calculates regional employment rates and finds larger declines in the East North Central than in other regions of the country or in the country as a whole (Figure 4), and Simon and Nardinelli (1992) find that industrial diversity on the eve of the Great Depression was associated with relatively larger declines in employment. Local historians have estimated that fully a third of the city's workers were unemployed by 1933 and that over 30,000 families were receiving direct relief in that year.¹⁰

¹⁰ See Encyclopedia of Cleveland History (<http://ech.case.edu/>) entries for "Timeline" and "Homeless, vagrants, and tramps."

The question then is, what were the long-term consequences of this severe shock for the innovative character of the region? Did the disruptions of the Great Depression slow technological change by decreasing the returns to innovation? By making it difficult for innovators to finance their creative activities? Were small networked enterprises more adversely affected than larger firms with internal sources of capital? Did the shock have long-lasting effects on the organization and productivity of inventors in the region?

Data Sources

In order to examine the effect of the Great Depression on Cleveland's inventors and their enterprises, we analyze data on two groups of inventors. The first consists of two cohorts of "frequent inventors": all inventors resident in Cuyahoga County who obtained at least three patents during the years 1928-30; and, for comparative purposes, all inventors resident in Cuyahoga County who received at least three patents during the years 1910-12. Whereas the first cohort suffered through a long debilitating depression in the years immediately following the sample years, the second experienced a boom when the outbreak of war in Europe stimulated American industrial production. For both cohorts of inventors, we collected additional data on occupations, patenting careers, and other personal characteristics, as well as information on the companies to which they assigned their patents.

More specifically, using Google Patent, LexisNexis, and the U. S. Patent and Trademark Office (USPTO) website, we identified every patent issued to an inventor resident in Cuyahoga County or assigned to a Cuyahoga County firm during the years 1910-12 and 1928-1930. We then selected the patentees who received at least three patents during these years. For these frequent inventors, we collected (from the same sources) all the patents they obtained over their

lifetimes. The patent records provide us with the name and city of residence of the patentee(s), as well as the name and location of any individuals or companies to which the inventor(s) assigned the patent at the time of issue. We then searched for additional information on the patentees and assignees in a variety of other sources, including the manuscript U.S. Decennial Census of Population, military draft records, and social security death records available at Ancestry.com, Cleveland (and other) city directories, the surveys of industrial research laboratories published in the *Bulletin* of the NRC, the *Commercial and Financial Chronicle*, *Poor's* and *Moody's* manuals, issues of the R. G. Dun's *Mercantile Agency Reference Book*, incorporation records, company annual reports, newspapers and magazines, and a large variety of secondary sources. We exploit as well manuscript collections that are extant for a number of Cleveland firms and financial institutions.

The resulting dataset allows us to categorize the relationship between inventors and the companies to which they assigned their patents and determine whether the patentee was an employee of the assignee or a principal (proprietor, partner, officer) in the business, or whether the relationship between the patentee and the assignee was arm's length. It also enables us to follow the careers of the patentees (for example, their migration decisions and their movements into and out of employment positions and into and out of their own businesses) and the histories of companies that acquired their patents (when they were founded and dissolved or otherwise disappeared, their growth and credit ratings over time, how they created or acquired new technologies, including whether they built in-house R&D laboratories, their sources of capital, and whether and where their securities traded). We compare the careers and the patenting records of the 1910-12 cohort of inventors with that of 1928-30 cohort in order to isolate the impact of the macroeconomic shock of the Great Depression on the latter's patenting activity.

The second group for which we collected data consists of graduates of the Case School of Applied Science from 1920 to 1939. Members of this group had the requisite technical skills and human capital to become inventors, but only some did. Of the 2,401 graduates receiving a Bachelor of Science degree during this period, fully one-quarter (622 alumni) obtained a patent at some point during their lifetimes. We are interested in comparing the propensity to invent by graduates who came of age during the Great Depression with those who finished their degrees earlier. As we did for the “frequent inventor” sample, we collected all patents issued to these graduates over their lifetimes, as well as occupational and other information from the sources described above. We supplemented this data with information from Case commencement programs, including information on the graduates’ majors, thesis topics, and honors, and an Alumni Directory that Case compiled in 1958 that reported graduates’ place of employment and residence.¹¹

It is important to note that neither of our datasets allows us to observe in any systematic way the direct effect of the Great Depression on inventors’ or firms’ access to finance, though we have anecdotal evidence indicating that funding for entrepreneurial projects became much more difficult, if not impossible, to obtain during the early 1930s. Our metric is instead the effect of the downturn on inventors’ patenting activity relative to that of other groups that did not suffer from macroeconomic shock or that experienced it at a different stage in their careers. As we will show, the Depression does not seem to have had much effect on patenting by those who had already established themselves as inventors by the late 1920s, but it seems to have stunted the careers of those who were just coming of age when the crisis hit.

¹¹ The commencement programs for 1920-39 and the 1958 Alumni Directory are from the Case Western Reserve University Archives.

The Effect of the Great Depression on Frequent Inventors and their Enterprises

To assess the effect of the Great Depression on Cleveland's inventive community, we estimate the probability that patentees in our 1910-12 and 1928-30 frequent-inventor samples obtained a patent in each year of their patenting careers. We compare the patenting of the 1928-30 inventors during the Great Depression with the patenting of the 1910-12 inventors during the equivalent time period.¹² This comparison enables us to control for changes in the probability of patenting over the life cycle and hence to ask whether inventors patented less than one might otherwise expect during the Great Depression. For each cohort of inventors, we compare the probability of patenting in three-year time intervals before and after the selection period, controlling for age. We also check to see whether the probability of patenting was higher for inventors who were principals in companies, or who were independents and patent attorneys, relative to those who were employees. Tables 9A and 9B report descriptive statistics for these two samples.

Because we selected the frequent inventors on the basis of their having received at least three patents during the sample years, including the patents from these (high patenting) years in the analysis might bias our results. In particular, we expect that patenting will, on average, be lower before and after the selection years. For the 1928-30 frequent inventors, the years after coincided with the onset of the Depression. So we need to take care that our comparisons do not conflate this selection-generated decline with the impact of the Depression itself. We deal with this selection problem in three ways. First, although we chose the sample on the basis of the year the patents were *issued*, the estimates are computed on the basis of the year the inventor *applied*

¹² We also ran estimates using the number of patents obtained in each year as the dependent variable, with very similar results.

for the patent. The year of application corresponds much more closely to the time in which the patentee was engaged in the inventive activity. Second, we compute the estimates both with and without the patents from the selection years so as to obtain what are effectively upper- and lower-bound estimates for the coefficients on adjacent periods. Finally, the effect of the selection bias on the two cohorts should have been much the same, so the change in patenting by the 1928-30 group during the Depression years *relative* to the change in patenting by 1910-12 group during the comparison period is the focus of our analysis.

Tables 10A and B present logit estimates of the probability that the 1910-12 and 1928-30 frequent inventors would apply (successfully) for at least one patent in any given year. Columns 1 through 5 in each table include patents issued in the selection years; columns 6 through 10 exclude them.¹³ For both cohorts, patenting increased with age until about the time the inventor turned 48 and then declined. This relationship between patenting and age was stable across all specifications. It does not seem, therefore, that there were any large changes in the life cycle pattern of inventing in the interval between the two samples.

The third column in each table adds dummies for the various three-year time intervals, with the omitted category being 1904-06 for the 1910-12 sample and 1922-24 for the 1928-30 sample.¹⁴ If one focuses on the estimates for the 1928-30 cohort (Table 10B), one sees that the inventors' probability of patenting, controlling for age, was significantly higher during the period

¹³ The corresponding tables in the Appendix report marginal effects, evaluated at the mean for continuous variables and at a value of 1 for dummy variables. The first column in each table reports the basic estimate of the effect of an increase of one year in the inventors' age on the probability of obtaining a patent in any given year. The second column in each table can be compared to the seventh column. It includes a dummy for the years immediately prior to the "sample selection period" when we expect that applications were submitted for the patents issued during that period. Most patent applications were submitted two to three years before they were issued (2.19 years on average for the 1910-12 patents; 3.32 years on average for the 1928-30 patents). As expected, there is a large positive coefficient on that dummy when patents issued during the sample selection periods are included (column 2) and an insignificant or marginally significant coefficient when those patents are excluded.

¹⁴ We chose the omitted periods to be similarly prosperous and to be as close as possible to the sample years without including many of the patents on which the sample was selected.

1928-30 than during the base years and that it then tailed off, as might be expected, during the Depression. Note that this pattern is not simply an artifact of the sample selection criteria, as the positive and significant coefficient on the years 1928-30 is still present in column 8, where the estimation excludes patents issued in that period. In other words, the sample inventors were applying (successfully) for large numbers of patents in 1928-30 that were not actually issued until later. Given the way we chose the sample, it makes sense that these years were productive ones in the inventors' lives.

What is more surprising, however, is how minimal the drop in patenting was during the Depression years. Focusing in Table 10B on column 8, which excludes the selection patents, we do not see any significant difference between patent applications during the Depression years and the boom years of 1922-1924. When the selection patents are included (column 3) the point estimates are negative following the selection period, but they are not statistically significant until the mid-1930s. By contrast, for the 1910-12 group (Table 10A), the decline over comparable intervals was steeper and the coefficients all statistically significant (even when the selected patents were excluded). In other words, it appears that the 1910-12 inventors fared worse after their selection period than the 1928-30 inventors, even though they faced more favorable macroeconomic conditions. Using the least favorable (column 3) estimates, evaluated at the average values for all the inventors in their cohort, the 1928-30 inventors were about 2.8 percent less likely to patent in 1931-33 than in 1922-24, whereas the 1910-12 inventors were about 5.2 percent less likely to patent in 1913-15 than in 1904-1906 (see Appendix Tables 10A and 10B). Figure 5 shows the comparison graphically, with the blue dots showing the increased or decreased probability of patenting (that is, the marginal effects) for the 1910-12 inventors (relative to the years 1904-06) and the red diamonds showing the same for the 1928-30 inventors

(relative to 1922-24). The bars represent 95 percent confidence intervals around these estimates for each cohort. For the early periods in the cohorts' careers, the dots are close together and well inside the confidence intervals of the other cohort. For the later periods, the blue dots for the 1910-12 inventors are below the red diamonds and at the edge of the confidence intervals, suggesting that the 1910-12 inventors had a steeper drop-off in patenting than did the 1928-30 cohort.

Returning to Tables 10A and B, we can see some changes over time in patenting by members of the different occupational categories (see columns 4 and 9 of each table). Among the 1910-12 group, principals and independent inventors had significantly higher probabilities of patenting over their careers than employees. Among the 1928-30 group, principals were somewhat more likely to patent than employees, but independent inventors were less likely to patent (though the latter estimates are not statistically significant), suggesting that principals and inventors were no longer very different from employees in their patenting. These results are consistent with the changes in Cleveland's economy we discussed in the previous section. Although the inventor-entrepreneurs who drove Cleveland's early growth continued to have a strong incentive to invent and patent, their relative position in the local economy had slipped. Controlling for occupation does not, however, change the time pattern of patenting for either cohort (columns 5 and 10). The minimal impact of the Great Depression is still striking.

Undoubtedly there were other differences between the two cohorts (and also between the time periods in which they were active) that should make us cautious about the precision of these comparisons. One worry is that the Patent Office became more lenient about approving applications during the 1930s, both in absolute terms and relative to standards imposed on the earlier cohort. After 1929, the total number of applications for patents fell quite dramatically.

Applications began to rise again after 1933, but the average for 1937-1939 was still only about 73 percent of what it had been in 1927-29. Over the same period there was also a drop in the number of patents granted, but it was much smaller, so that the total number of patents issued in 1937-39 was 92 percent of what it had been in 1927-29. During the 1910s, by contrast, the number of patent applications generally increased (except for 1918), but so generally did the number of patents granted (with some fall off beginning in 1917) (Carter et al. 2006, Table Cg27-37). It is possible, therefore, that the lack of an observed Depression effect for the 1928-30 cohort may be an artifact of greater leniency on the part of Patent Office examiners during the Great Depression. Alternatively, it is also possible that the financial stringency reduced the number of low-quality applications, leading to a fall in the total number of applications but also a rise in the proportion that passed the Patent Office examination. To assess these possibilities we examined the number of times patents obtained by our 1928-30 frequent inventors were cited in later applications for patents. Citation counts have often been used as a measure of patent quality (Trajtenberg 1990; Nicholas 2003), and we check to see if patents that members of the cohort applied for before the Depression struck were different in quality by this measure than patents they applied for during the Depression.¹⁵ As Figure 6 shows, patents applied for during the 1930s were *more heavily* cited on average than those from earlier years. Hence reweighting the estimations in Table 10B by this measure of patent quality would only have further reduced our estimate of the Depression's impact. It should be noted that Figure 6 suggests a large drop-off during the Depression of the share of patents with zero citations. Almost 25 percent of the patents that the 1928-30 inventors applied for between the years 1924 and 1928 had no citations,

¹⁵ Patent applications only began regularly to cite prior art in 1949. Because the frequency of citation after 1949 is likely to be systematically different for patents obtained in 1910-12 compared to 1928-30, we do not compare across cohorts.

whereas fewer than 10 percent of those that they applied for during 1934-38 had no citations. If the behavior of inventors more generally can be inferred from this group, this result suggests that the observed decline in applications and the increase in the rate of issue were the result of inventors choosing not to patent inventions with lower expected value.

In order better to understand how the frequent inventors coped with the impact of the Depression and maintained their patenting activity over these difficult years, we have reconstructed their biographies using the genealogical information available in Ancestry.com and the other sources listed above. The information we have collected about the inventors' experiences during these years is consistent with the quantitative data. Most frequent inventors remained in the region and most maintained relationships with the same firms they had been associated with on the eve of the Depression. The vast majority of the frequent inventors who were employees in 1930 were still working for the same companies in 1940. The principals changed companies a bit more (and since they were older to begin with, a greater proportion of them died), but most of the survivors were still principals at the end of the decade and still relatively well off. The 1940 Census includes data on income that was top-coded at a level of \$5,000 a year. The modal (and median) income for the frequent inventors we have been able to locate in the Census was above this threshold (see Table 11). Of the 34 principals we were able to find, 19 (56 percent) had top-coded incomes, and only 5 (15 percent) earned less than \$5,000 in 1939. Only 7 of the total cohort of 61 principals could not be located in any source circa 1940, and it is possible that these seven did very poorly during the 1930s. However, supplementary evidence that we have found for the rest of the survivors (those whom we were able to locate in city directories and other sources, those who refused to report their income to the Census, and those who retired) indicates that most emerged from the Depression in good

financial shape. The experience of the independent inventors and patent attorneys was similar. The frequent inventors who were employees in 1928-30 seem to have had a somewhat more difficult time in that nearly a third of those located in the 1940 census earned less than \$5,000 in 1939. Nonetheless, about the same proportion of employees as principals were top-coded in the 1940 Census.

These results by no means eliminate the possibility that Depression had a negative effect on the careers of these inventors. Principals might have done considerably better in a more favorable macroeconomic environment, and employees who stayed with a firm might under other circumstances have been able to move on to better jobs or start their own businesses. What the results do suggest, however, is that the established position of these frequent inventors prior to the Depression's onset enabled most of them to pursue strategies that maintained both their livelihood and their inventive activities during this difficult period. Of course, there are contrary accounts of failure or bad fortune. Inventor Anthony Fricker was president of the A. Fricker Manufacturing Company in the late 1920s and founded Universal Specialties in 1929, but by 1935 he was living on a farm in Pennsylvania. Harold D. Church, vice president of the White Motor Company, lost his position after a strike during the late 1930s. James W. Howell worked as an employee at White when the downturn began, but then started an auto repair shop during the 1930s, perhaps because he was laid off from his job.

What is most striking, however, is how few such stories our biographical research has turned up. Only when we have archival records that allow us actually to see what was going on inside firms during this time period do we get a sense of the financial pressures the city's enterprises faced and the enormous risks that owners took in order to maintain their commitment to technological innovation. The Lees-Bradner Company, developer of machines to manufacture

gears for automobiles, was in such bad shape during the early years of the Depression that it was down to three employees by 1934, the year it developed an innovative rotary hobbing machine. Bradner, who owned the majority owner of the company's shares, voted himself the power "to invest the funds of this Company in such stocks, bonds and other securities as he, in his sole discretion, shall deem advisable," and essentially gambled with the company's remaining funds in a desperate effort to keep the company afloat. He succeeded, and the company survived the Depression to make about half of the thread milling machines used by the Allies during World War II.¹⁶

The Towmotor Company, inventor of fork lifts, did a similarly booming business during the Second World War, acquired other companies during the post-war expansion, and ultimately merged with the Caterpillar Tractor Company in 1963. During the Depression, however, the company barely managed to keep going. The company's officers took pay cuts, pleaded with shareholders to buy more of the company's shares or lend it money, and ultimately took on a sales manager (who proved disastrous) because he was willing to lend the enterprise \$4,000. The company managed to bring out new models of "towmotors" despite the stringency, but in the end the shareholders lost faith and dissolved the company. The inventor-entrepreneurs behind the enterprise continued to run it as a partnership from 1937 to 1942. Then, thanks to wartime demand for its products, it was able once again to find investors and reorganize as a corporation.¹⁷

¹⁶ Resolution adopted at the Directors' meeting of 2 June 1933, Container 1, Folder 4—Corporate Proceedings, Lees-Bradner Company Records, 1906-1992, Ms. 4653, Western Reserve History Society Library; "Lees-Bradner Co.," *Encyclopedia of Cleveland History*, <http://ech.case.edu/cgi/article.pl?id=LC2>, accessed 21 Jan. 2014.

¹⁷ Towmotor Corporation Records, Mss. 4593, Western Reserve Historical Society Library. See especially the documents in Container 1, Folder 2.

A final example of a company that survived extraordinary financial stringency to prosper during the Second World War is the Brush Beryllium Company. If any startup was well connected to the networks that had sustained Cleveland's innovative economy, it was this one, for the firm was a spinoff of Brush Laboratories, a company founded in 1921 by Charles Brush, Jr. and Charles Baldwin Sawyer with backing from Charles Brush, Sr., the arc lighting pioneer who had sparked the region's development (Lamoreaux, Levenstein, and Sokoloff 2007 and 2007a). The untimely death of Brush, Jr. in 1927, followed by the death of Brush, Sr. in 1929 disrupted the company's initial financing, and the onset of the Depression made it difficult to raise funds, but members of the Brush and Sawyer extended families came through with subscriptions for \$35,000 of the firm's \$50,000 capital stock. The company faced a number of difficult technological challenges, however, and found it harder and harder to raise the funds it needed to surmount them. To conserve cash Sawyer agreed to take his salary in stock. All of the company's employees agreed to pay cuts, its patent attorney accepted stock for a substantial part of his compensation, and other outside contractors made similar arrangements. Nonetheless, with sales of the company's products "in these times ... disappointing," the company had to let most of its employees go. By December 1932, it was down to two key researchers and had only \$2000 left in the bank, enough to continue with the patent work and keep the men employed for about two months.¹⁸

Sawyer and other company officials pressed shareholders to increase their investment and, at the same time, conducted a desperate effort to "interest outside capital." "Because of the

¹⁸ See the letters from Charles Baldwin Sawyer to Roger G. Perkins on 6 July 1931, 28 July 1931, 4 Dec. 1931, 13 July 1932, and 8 Dec. 1932, Charles Baldwin Sawyer Collection, Brush Laboratories, Series II, Box 11, Folder 2, Special Collections, Kelvin Smith Library, Case Western Reserve University. See also the letters from Sawyer to Roselyn Weir on the same dates, Box 12, Folder 7; and the letter to Dorothy H. Dick, 25 May 1933, Box 14, Folder 5. Letter from Sawyer to Perkins, 8 Dec. 1932, Box 11, Folder 2; letter from Sawyer to Charles Brush Perkins, 30 Jan 1933, Box 11, Folder 1; letters from Sawyer to R. T. Sawyer, 31 Jan. 1933, 3 Feb 1933, and 8 Feb. 1933, Box 11, Folder 6; and letter from R. T. Sawyer to Sawyer, 8 Feb. 1933.

extreme times,” however, money was difficult to raise. The Cleveland Trust Company, which administered the Brush estates, refused to help, and the company would probably have gone under if Roger G. Perkins, a shareholder who belonged to the Brush extended family, had not come through in February 1933 with a modest additional investment of \$1,500 from himself and another member of the family (he invested another \$2000 in August).¹⁹ During the next few months, installment payments on these new investments enabled the Beryllium Company to buy ore and pay its bills. In April, 1934, the company managed to secure an investment of \$2,000 from Roy E. Larsen, an executive at Time, Inc., which Sawyer immediately used to buy more ore.²⁰ It was still strapped for cash, however, and Sawyer sent shareholders another round of begging letters that do not seem to have generated any new funds. A bigger break came in August, when the company landed an investment of \$5,000 from John Sherwin and his brother Francis, a Cleveland financier, for the express purpose of supporting “further work on the metal.” In this hand-to-mouth way, the company survived the worst years of the Depression.²¹ Sales increased beginning in 1934, and the resulting revenues gave the company the funds it needed to commercialize its process of refining pure beryllium, putting it in a position later on to

¹⁹ Letter from Sawyer to Roger G. Perkins, 8 Dec. 1932, and from Perkins to Sawyer, 5 Aug. 1933, Box 11, Folder 2; letter from Sawyer to Charles Brush Perkins, 30 Jan 1933, Box 11, Folder 1; letters from Sawyer to R. T. Sawyer, 31 Jan. 1933, 3 Feb 1933, and 8 Feb. 1933, Box 11, Folder 6; and letter from R. T. Sawyer to Sawyer, 8 Feb. 1933, 14 Feb. 1933; letter from Sawyer to Maurice Perkins, 8 Feb. 1933, Series II, Box 11, Folder 1; letter from Sawyer to R. T. Sawyer, 8 Feb. 1933, Box 11, Folder 6 Charles Baldwin Sawyer Collection, Brush Laboratories, Series II. See also letters from Sawyer to I. F. Freiburger, 8 Feb. 1933 and 10 Feb. 1933, Box 14, Folder 2. Cleveland Trust did, however, allow the Brush estate to lend \$3,000 to Brush Laboratories in 1933. See letter from G. F. Karch to Sawyer, 11 Jan. 1933, Box 14, Folder 2.

²⁰ Letters from Sawyer to Perkins, 15 Mar 1933; 11 Apr. 1933; 9 May 1933, Box 11, Folder 2; letters between Sawyer and Larsen dated 10 Apr. 1934 and 16 Apr. 1934, Charles Baldwin Sawyer Collection, Brush Laboratories, Series II, Box 10, Folder 3. Larsen was also strapped for funds. He also brought stock in another spinoff from Brush Labs, the Brush Development Company, and had to request an extension on his payments. See the exchange between Sawyer and Larsen dated 21 Apr. 1934 and 23 Apr. 1934, Box 10, Folder 3.

²¹ Letter from Sawyer to Maurice Perkins, 14 May 1934, Series II, Box 11, Folder 1; letter from Sawyer to R. G. Perkins, 14 May 1932, Box 11, Folder 2; letter from Sawyer to Roselyn Weir, 15 May 1934, Box 12, Folder 7; letter from Sawyer to Larsen, 21 Aug. 1934, Box 10, Folder 3, Charles Baldwin Sawyer Collection, Brush Laboratories, Series II. Intriguingly Francis Sherwin was at that time an officer of the Cleveland Trust Company. He later became a director of Brush Beryllium. See “Sherwin, Francis McIntosh,” *Encyclopedia of Cleveland History*, <http://ech.case.edu/ech-cgi/article.pl?id=SFM>, accessed 26 October 2010.

win important contracts from the federal government during the Second World War and to prosper in the postwar era, producing beryllium in various forms for use in consumer electronics, aerospace, and other industries.²²

The histories of firms like Lees-Bradner, Towmotor, and Brush Beryllium show the lengths to which inventor-entrepreneurs were willing to go in order to continue their innovative activities during the Great Depression. Undoubtedly some similar efforts were unsuccessful, but the quantitative evidence from the sample of frequent inventors is more consistent with a narrative of success than of failure and highlights the extraordinary resilience of the region's networks of inventors and entrepreneurs. It is only when we turn our attention to an analysis of the next generation that we begin to see the toll that the Great Depression's took on Cleveland's innovative community.

The Effect of the Depression on Graduates of Case School of Applied Science, 1920-1939

If the Great Depression did not dramatically dampen the patenting activity of Cuyahoga County's established inventors, it may nonetheless have made it more difficult for young would-be inventors to pursue careers in the region that gave them scope for technological creativity. In order to explore this possibility we collected information about the patenting activity of a set of young men who we know started their careers with the human capital necessary to engage in technological discovery: the 2,480 students who graduated with Bachelor of Science degrees from the Case School of Applied Science between 1920 and 1939. As Table 12 shows, about a

²² *Seventy-Five Years of Taking Technology Where It Has Never Been Before: The History of Brush Engineered Materials Inc. and its Predecessor Companies, Brush Wellman Inc. and Brush Beryllium Company* (Cleveland: Brush Engineered Materials, 2008). See also Bengt Kjellgren, "History of the Brush Beryllium Company," Engineering Training Meeting No. 2, 31 July 1952. The Brush Engineered Materials Company kindly supplied us with a copy of this document. Brush Engineered Materials is now Materion Corporation.

quarter of the Case graduates from these two decades obtained at least one patent during their lifetimes, and many of these inventors were quite prolific. Inventing was not evenly distributed among graduates from different fields of study (Table 13). Although the average number of lifetime patents per graduate was 5.45, physicists patented at almost twice that average (9.38 lifetime patents) and civil engineers at only about half (2.81).

As we did for the samples of frequent inventors, we estimate the probability that members of the Case graduating classes obtained a patent in each year of their careers. Table 14 reports summary statistics and Tables 16 and 17 report Logit estimates of the probability that different groupings of Case graduate obtained patents in each of a range of years. In both sets of Logit estimations we first control for age and find the familiar inverted u-shaped relationship between age and patenting, with maximum inventiveness at about 40 years of age (column 1). Because patenting varied so much across majors, we controlled for that as well (column 2). It is, of course, possible that the type of student who attended Case during the Great Depression differed in important ways from the type of student enrolled during earlier boom years. If the Depression graduates were less talented on average than earlier cohorts, the Logit results might reflect this difference in selection rather than a change in the opportunities that the students faced after graduation. Table 17 presents what systematic information we have on the graduates: their age; the proportion who came from Cuyahoga County, and whether they had already earned a bachelor's degree before attending Case. There was a slight downward trend over time in age, so that Case graduates were about a year younger in the 1930s than in the 1940s. The share of students who came with a bachelor's degree from another institution increased during the second half of the 1920s, but then fell off again with the onset of the Depression. The percentage of students who came from Cuyahoga County increased during the 1930s, as might be expected

during a period of economic hardship. Overall, there were no dramatic changes in the student body at Case during the Depression that might explain a change in patenting behavior, but we control for these observables in our estimations.

Table 15 examines students who graduated during the 1920s, most of whom had started to establish themselves in their careers before the Depression struck. We find that the patenting record of these 1920s graduates resembles that of the 1928-30 frequent inventors in that they applied successfully for significantly more patents in the early years of the Great Depression than at any other time in their careers. Table 16 pools Case graduates from both the 1920s and 1930s.²³ It is only when we compare students who entered the labor market during the depths of the downturn with the rest of the graduates that we see a significant effect of the Depression. Students who graduated in 1931-1937 obtained significantly fewer patents over their entire patenting careers than those who graduated in other years. This result is not at all surprising. Recent studies have shown that young people who had the bad fortune to enter the labor market during a severe downturn fared worse than other cohorts and that the disadvantage persisted over their careers.²⁴ What is more surprising, given the unusual severity of the Great Depression, is that we have not been able to observe a negative effect of the downturn on the patenting of any of the other groups we have studied.

Finally, we examine the effect of the Great Depression on the subsequent locational decisions of Case graduates. Figure 7 depicts the residence of those graduates who could be located in the 1930 and 1940 censuses or in the 1958 alumni directory. As might be expected, the proportion of graduates from any particular class who resided in Cuyahoga County fell over

²³ In this set of estimates, we do not include dummies for patent applications during the Depression, because the 1930s graduates were still in school.

²⁴ See, for example, Oreopolous et al. (2012).

time. But it appears that the Depression also propelled an exodus of graduates from the region. In the first place, students who obtained their degrees during the 1930s were less likely to live in the county in 1940 than were 1920s graduates in 1930, a contrast that is all the more striking when it is recalled that the 1930s graduates were more likely to come from Cleveland in the first place. Second, there was a large outmigration of 1920s graduates during the Depression years so that, relative to 1930s graduates, considerably fewer of them remained in the region in 1940. Third, the close spacing of the 1940 and 1958 lines indicates that most of the movement of graduates out of the area occurred during the Depression and not, for example, during the Second World War or its aftermath.²⁵

Conclusion

Our most striking and also most surprising finding is how little effect the Great Depression had on the patenting careers of inventors who had already established themselves by the late 1920s. Whether they were principles in businesses established to commercialize their technological discoveries or employees in established firms, the 1928-30 frequent inventors sample continued after the onset of the Depression to patent at rates that were the same or greater than the 1910-12 inventors of comparable ages, even though the latter operated in a much more favorable macroeconomic environment. Moreover, the biographical data we have collected on the 1928-30 cohort suggests that the frequent inventors came through the Depression remarkably well, with a large proportion earning incomes in 1940 that were above the threshold for the Census's highest reported category. If one were to rely on the obituaries or other biographical

²⁵ We have run regressions to check whether the patenting records of the migrants were significantly different from those of the non-migrants and found that they were not.

sources later published about these men, one would not even know there was a depression.

Thus Charles Baldwin Sawyer's obituary in the *New York Times* on March 26, 1964 reported that Sawyer "developed modern uses for beryllium in nuclear physics and in space rockets" and founded the Brush Beryllium Company in 1931. The article skipped over the Depression years entirely, focusing instead on company's role in the production of the first atomic bomb. It is only when we are able to dig more deeply into the archival records of individual companies such as Brush Beryllium that we can see the financial distress to which they were subject and get some sense of the extraordinary value their owners must have ascribed to patenting to be able to continue to invent and apply for patents during these difficult times.

Mowery and Rosenberg (1989) show that large firms increased their investments in R&D during the Depression, taking advantage of their pool of retained earnings to develop new technologies at a time when it did not make much sense to invest in production facilities. Our finding that inventors in our frequent inventors sample maintained their commitment to patenting over the same years is consistent with Mowery and Rosenberg's view but extends it by suggesting that R&D was also a critical part of business strategies of smaller, more entrepreneurial, more financially constrained firms—so much so that they kept it going despite the great sacrifices it entailed. These sacrifices, which included substantial cuts in employment at firms like Brush Beryllium, meant that would-be inventors who came of age during the Great Depression faced diminished prospects. The result, as we have seen, was that students who graduated from the Case School of Applied Science during the Depression patented significantly less over their entire careers than students who graduated during the 1920s. Moreover, a large proportion of Case graduates from both decades left the region during the Depression years, seeking better opportunities elsewhere.

In the end, therefore, it is likely that the Depression helped to shift the locus of inventive activity in favor of the kinds of large firms Mowery and Rosenberg studied. As young would-be inventors left innovative regions like Cleveland's in search of jobs, they would find them disproportionately in the R&D labs that large firms were building and expanding at such a rapid pace. Cleveland's factories would experience a resurgence in demand during the boom years that followed World War II, but innovative economies require continuous regeneration. What was missing in the postwar prosperity was the next wave of startups that those out-migrants might have founded—startups that could have carried the region into the next technological transformation.

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TABLE 1. CLEVELAND'S LARGEST INDUSTRIES, 1870-1947
(RANKED BY AVERAGE EMPLOYMENT)

Industry Rank	1870	1880	1890	1900	1920	1930	1940	1947
1	Coal, rectified	Iron and steel	Iron and steel	Iron and steel	Iron and steel, steel works, and rolling mills	Auto	Foundry and machine tools	Foundry and machine tools
2	Iron, forged and rolled	Slaughtering and meat-packing	Foundry and machine-shop products	Foundry and machine-shop products	Foundry and machine-shop products	Foundry and machine tools	Auto	Auto
3	Flour-mill products	Foundry and machine-shop products	Petroleum Refining	Slaughtering and meat-packing, wholesale	Auto-mobiles	Iron and steel	Electrical machinery	Electrical machinery
4	Meat, packed pork	Clothing, men's	Slaughtering and meat-packing, wholesale	Clothing, women's factory product	Slaughtering and meat-packing	Electrical machinery	Iron and steel	Chemicals
5	Iron, castings (not specified)	Liquors, malt	Carpentering	Liquors, malt	Clothing, women's	Clothing, women's	Printing and publishing	Iron and steel

Notes: The 1870 and 1930 data are for Cuyahoga County. The 1929 data are for the Cleveland Industrial Area, comprising Cuyahoga and Lorain counties. The 1947 data are for the Cleveland metropolitan area, consisting of Cuyahoga and Lake Counties. All other years are for the city of Cleveland.

Sources: *Census of the United States*, 1870-1910; U.S. Bureau of the Census (1923, 1933, and 1947).

TABLE 2A. RESIDENCE OF INVENTORS ASSIGNING PATENTS TO CUYAHOGA FIRMS, 1910-12

Residence	Percent of inventors	Percent of patents
Cleveland	86.2	87.7
Elsewhere in Cuyahoga County	4.6	6.5
Elsewhere in Ohio	3.9	2.4
Elsewhere in the U.S.	5.3	3.5
Foreign Country	0	0
<i>Total number</i>	282	547

TABLE 2B. RESIDENCE OF INVENTORS ASSIGNING PATENTS TO CUYAHOGA FIRMS, 1928-30

	Percent of inventors	Percent of patents
Cleveland	81.2	87.2
Elsewhere in Cuyahoga County	3.4	2.1
Elsewhere in Ohio	4.0	3.5
Elsewhere in the U.S.	10.0	6.3
Foreign Country	1.3	0.8
<i>Total number</i>	670	1246

Notes: The inventor's residence is at the time of application for the patent. Only patents assigned at issue to companies located in Cuyahoga County are included in the table. Patents awarded to multiple inventors are divided by the number of inventors. For example, if two inventors jointly applied for a patent, each inventor is counted as receiving 0.5 patents. We exclude design patents from this analysis.

Sources: We searched Google Patent, LexisNexis, and the USPTO website for all patents assigned at issue during these years to companies located in Cuyahoga County.

TABLE 3A. AGE OF CUYAHOGA COUNTY FIRMS OBTAINING PATENT ASSIGNMENTS IN 1910-12

Age Definition	Year established		Year first sighted		First year using previous (acquired) firm's info, if it is formed earlier	
	Percent of Firms	Percent of Patents	Percent of Firms	Percent of Patents	Percent of Firms	Percent of Patents
Prior to 1883	25.5	36.6	10.1	22.5	10.8	22.7
1883-1892	9.8	8.6	9.5	8.4	10.8	9.3
1893-1902	33.3	34.8	21.6	36.0	21.6	40.6
1903-1912	31.4	20.0	58.8	33.1	56.8	27.4
<i>Total number for which firm age could be established</i>	<i>51</i>	<i>325</i>	<i>148</i>	<i>547</i>	<i>148</i>	<i>547</i>
<i>All Cuyahoga County firms receiving patent assignments</i>	<i>148</i>	<i>547</i>	<i>148</i>	<i>547</i>	<i>148</i>	<i>547</i>

TABLE 3B. AGE OF CUYAHOGA COUNTY FIRMS OBTAINING PATENT ASSIGNMENTS IN 1928-30

Age Definition	Year established		Year first sighted		First year using previous (acquired) firm's info, if it is formed earlier	
	Percent of Firms	Percent of Patents	Percent of Firms	Percent of Patents	Percent of Firms	Percent of Patents
Prior to 1901	39.4	42.1	21.9	31.5	26.5	38.7
1901-1910	25.0	18.1	19.2	21.6	18.5	22.1
1911-1920	19.2	25.0	26.2	25.0	24.2	20.5
1921-1930	16.4	14.8	32.7	21.9	30.8	18.7
<i>Total number for which firm age could be established</i>	<i>104</i>	<i>745</i>	<i>260</i>	<i>1246</i>	<i>260</i>	<i>1246</i>
<i>All Cuyahoga County firms receiving patent assignments</i>	<i>260</i>	<i>1246</i>	<i>260</i>	<i>1246</i>	<i>260</i>	<i>1246</i>

Notes and Sources: See Tables 2A and 2B. Where possible, we determined the year the current firm was established using Cleveland city directories, the annual reports of incorporations issued by the Ohio Secretary of State, company histories, financial statements, and newspaper articles. For firms whose year of establishment could not be determined, we calculate “first sighted” as the first year for which we have a record of the firm’s existence, based on city directories, reports of stock trades or quotations, patent assignments, or other mentions of the firm’s existence. Although there is no missing data for “first sighted,” this measure underestimates the age of firms. “Year established,” by contrast, suffers from missing data and also overstates average age, because firms with short life spans are more likely to be missing.

TABLE 4. NUMBER OF FIRMS LOCATED IN CLEVELAND 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

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

Notes: In most cases where a firm, such as General Electric, had 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 5A. PATENTS AND ASSIGNMENTS BY OCCUPATIONAL CATEGORY,
1910-12 FREQUENT INVENTORS

	Employees	Principals	Independent Inventors and Patent Attorneys	Retired
Number of patentees	56	55	12	1
Number of patents	291.5	298.7	48.5	4
Row Percent of patentees	45.2	44.4	9.7	0.8
Row Percent of patents	45.4	46.5	7.5	0.6
Row Percent of high-tech patents (20.9% of all patents)	39.5	50.1	10.4	0.0
Row Percent of assignments (48.7% of all patents)	54.5	40.7	4.8	0.0
Column percent of patents in each occupational category				
Percent of patents assigned	58.5	42.6	30.9	0.0
Percent assigned to company where patentee is principal		79.2		
Percent assigned to company where patentee is employee	54.0			
Average number of different assignees for inventors who assigned at least two patents	1.05	1.16	1.05	1.00
Average age of patentee in 1911	45.0	44.6	47.6	63.0

TABLE 5B. PATENTS AND ASSIGNMENTS BY OCCUPATIONAL CATEGORY,
1928-1930 FREQUENT INVENTORS

	Employees	Principals	Independent Inventors and Patent Attorneys	Deceased
Number of patentees	100	65	14	1
Number of patents	494.1	373.0	81	3
Row Percent of patentees	55.6	36.1	7.8	0.6
Row Percent of patents	52.0	39.2	8.5	0.3
Row Percent of high-tech patents (18.5% of all patents)	44.3	41.5	13.6	0.6
Row Percent of assignments (84.1% of all patents)	54.9	37.3	7.5	0.3
Column percent of patents in each occupational category				
Percent of patents assigned	88.9	80.0	74.1	66.7
Percent assigned to company where patentee is principal		60.7		
Percent assigned to company where patentee is employee	67.8			
Average number of different assignees for inventors who assigned at least two patents	1.21	1.18	1.05	1.00
Average age of patentee in 1929	43.2	48.7	44.5	63.0

Sources: Using Google Patent, LexisNexis, and the USPTO website, we identified every patent issued to an inventor resident in Cuyahoga County during the years 1910-12 and 1928-1930. We then selected the patentees who received at least three patents during these years. The 1910-12 panel includes 124 inventors and 725 patents, and the 1928-30 includes 180 inventors and 989 patents. The patent records provided the name and city of residence of the patentee(s), as well as the name and location of any individuals or companies to which the inventor(s) assigned the patent at the time of issue. We then searched for additional information on the patentees and assignees in a variety of other sources, including the manuscript records of U.S. Decennial Census of Population available at Ancestry.com, directories for Cleveland and other cities, the surveys of industrial research laboratories published in the *Bulletin of the National Research Council*, the *Commercial and Financial Chronicle*, *Poor's* and *Moody's* manuals, issues of the R. G. Dun's *Mercantile Agency Reference Book*, incorporation records, company annual reports, newspapers and magazines, and a large variety of other primary and secondary sources.

Notes: Patents with multiple inventors are assigned fractional weights, so that the frequent inventor is credited with his fractional share of the patent. Assignments include only assignments made at the time the patent issued. An inventor is considered a principal of a firm if he was ever a principal of that firm. He is considered an employee of the firm if he was ever an employee and was never a principal of that firm. This protocol was adopted because we do not have annual observations of employment in most cases. It is also often the case that a person whom we classify as a principal because he was the founder or officer of a firm was also sometimes

reported to be an employee. This procedure does treat as principals those employees who began their careers as employee-inventors but moved into the executive offices of the company and therefore does somewhat overstate the importance of principals in this sample. Patents awarded to multiple inventors are divided by the number of inventors. High-tech patents are those in USPTO patent classes corresponding to Chemical/ Computers & Communications/ Drugs & Medical/ Electrical & Electronic Industries, based on “Classification of patent classes into technological categories and sub-categories.” Appendix 1, Hall, Jaffe and Trajtenberg (2001).

TABLE 6. COMPARING NINETEENTH AND TWENTIETH CENTURY PATENTING IN CLEVELAND

	1884-86 Cleveland sample	1898-1902 Cleveland sample	1910-12 Cuyahoga sample	1928-30 Cuyahoga sample
Occupational Category				
Percent of Patentees Who Were Principals, Independents and Patent Attorneys	45.2	54.3	54.0	43.9
Percent of Patents Awarded to Principals, Independents and Patent Attorneys	55.6	58.4	54.0	47.7
Assignment Behavior				
Assignments at Issue Percent of Patents Assigned to Companies	22.3	52.9	52.9	86.4
Percent of Patents	14.0	49.3	48.7	84.1
Percent of Assignments	62.5	93.2	91.9	97.3
Sample				
<i>Total Number of Patentees</i>	42	36	124	180
<i>Total Number of Patents</i>	394	839	656	989
<i>Number of Years in Sample</i>	7	18	3	3

Sources and Notes: The comparisons over time must be made with caution because these samples were collected in different ways. See Table 5 for a description of the 1910-12 and 1928-30 samples. Note that the 1910-12 and 1928-30 samples differ from the earlier ones in that, in order to take account of increased suburbanization, they encompass the whole of Cuyahoga County, rather than just the city of Cleveland. For the 1884-86 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. For more information, see Lamoreaux et al. (2006 and 2007a). For the purposes of this table, we do not count patent attorneys but only independent inventors. We also do not apportion patents with multiple inventors. If at least one of the co-inventors was a principal or an independent inventor, then the patent is counted in that category.

TABLE 7A. AGE AND PLACE OF BIRTH BY OCCUPATIONAL CATEGORY,
1910-12 FREQUENT INVENTORS (PERCENT)

	Employees	Principals	Independent Inventors and Patent Attorneys	All inventors
Place of birth				
Ohio	39.3	40.0	8.3	36.3
Other ENC	8.9	5.5	16.7	8.1
Other US	19.6	29.1	50.0	26.6
Foreign	26.8	20.0	25.0	24.2
Age Group in 1911				
39 or less	32.1	32.7	25.0	31.4
40-49	35.9	36.5	25.0	34.8
50 or more	32.1	30.8	50.0	33.9

TABLE 7B. AGE AND PLACE OF BIRTH BY OCCUPATIONAL CATEGORY,
1928-30 FREQUENT INVENTORS (PERCENT)

	Employees	Principals	Independent Inventors and Patent Attorneys	All inventors
Place of birth				
Ohio	35.0	43.1	42.9	38.9
Other ENC	17.0	10.8	0.0	13.3
Other US	30.0	32.3	57.1	32.8
Foreign	17.0	13.8	0.0	14.4
Age Group				
39 or less	27.0	20.0	35.7	25.0
40-49	56.0	32.3	28.6	45.0
50 or more	17.0	47.7	35.7	30.0

Notes: “All inventors” includes inventors in the “unknown” occupational category. Other ENC (East North Central) includes anyone born in the states Illinois, Indiana, Michigan, and Wisconsin. Other US includes anyone born in a US state outside the ENC region. The year and place of birth are unknown for six of the frequent inventors in the 1910-12 cohort and one in the 1928-30 cohort.

Sources: See Table 5A and 5B.

TABLE 8A. IN-MIGRATION OF 1910-12 FREQUENT INVENTORS:
YEAR FIRST OBSERVED IN OHIO (PERCENT)

Date first known to be living in Ohio	Born in Other State than Ohio	Born in Foreign Country
Before 1880	7.0	23.3
1880-1889	9.3	23.3
1890-1899	30.2	33.3
1900-1909	53.5	20.0
Total number	43	30

TABLE 8B. IN-MIGRATION OF 1928-30 FREQUENT INVENTORS:
YEAR FIRST OBSERVED IN OHIO (PERCENT)

Date first known to be living in Ohio	Born in Other State than Ohio	Born in Foreign Country
Before 1898	3.5	4.4
1898-1907	22.1	21.7
1908-1917	23.3	34.8
1918-1927	51.2	39.1
Total number	86	23

Sources and Notes: See Tables 5A and 5B.

TABLE 9A. SUMMARY STATISTICS FOR THE PROBABILITY THAT A FREQUENT INVENTOR WOULD PATENT IN EACH YEAR, 1910-12 SAMPLE

Variable name	Definition	Mean	Standard Deviation	Minimum	Maximum
Patenting1	= 1 if an inventor applied for a successful patent in the year	0.225	0.418	0	1
Patenting2	= 1 if an inventor applied for a successful patent in the year, excluding patents issued in the years 1910-12	0.192	0.394	0	1
Age	= Year minus year of birth	47.154	17.474	18	95
Principal	= 1 if inventor was a principal in 1910-12	0.417	0.493	0	1
Independent or Patent Attorney	= 1 if inventor was an independent inventor or patent attorney in 1910-12	0.107	0.309	0	1
Dummies for particular period					
Years before 1895		0.194	0.395	0	1
Year 1895-97		0.050	0.218	0	1
Year 1898-00		0.053	0.224	0	1
Year 1901-03		0.054	0.226	0	1
Year 1904-06		0.054	0.226	0	1
Year 1907-09		0.054	0.226	0	1
Year 1910-12		0.054	0.226	0	1
Year 1913-15		0.053	0.225	0	1
Year 1916-18		0.051	0.220	0	1
Year 1919-21		0.050	0.218	0	1
Year after 1921		0.333	0.471	0	1

Table 9B. SUMMARY STATISTICS FOR THE PROBABILITY THAT A FREQUENT INVENTOR WOULD PATENT IN EACH YEAR, 1928-30 SAMPLE

Variable name	Definition	Mean	Standard Deviation	Minimum	Maximum
Patenting1	= 1 if an inventor applied for a successful patent in the year	0.215	0.411	0	1
Patenting2	= 1 if an inventor applied for a successful patent in the year, excluding patents issued in the years 1928-30	0.184	0.388	0	1
Age	= Year minus year of birth	46.725	17.529	18	95
Principal	= 1 if inventor was a principal in 1928-30	0.354	0.478	0	1
Independent or Patent Attorney	= 1 if inventor was an independent inventor or patent attorney in 1928-30	0.075	0.263	0	1
Dummies for particular period					
Years before 1913		0.209	0.406	0	1
Year 1913-15		0.050	0.219	0	1
Year 1916-18		0.052	0.221	0	1
Year 1919-21		0.052	0.223	0	1
Year 1922-24		0.053	0.224	0	1
Year 1925-27		0.053	0.223	0	1
Year 1928-30		0.052	0.222	0	1
Year 1931-33		0.051	0.220	0	1
Year 1934-36		0.050	0.218	0	1
Year 1937-39		0.048	0.213	0	1
Years after 1939		0.331	0.471	0	1

Sources and Notes: See Tables 5A and 5B. For this analysis, we collected all the patents that each of the 1910-12 and 1928-30 frequent inventors obtained over their lifetimes from Google Patent and the LexisNexis patent database. We consider each inventor to be “at risk” for patenting from the year in which he turned 18 until his death. Where birth year was missing, it was imputed as the average year of birth for inventors in that sample. Where death year was missing, it was imputed as 75 or the last year in which a patent application was submitted, whichever was greater. For the 1910-12 group, 6 people were missing year of birth and 59 were missing year of death. For the 1928-30 group, one person was missing year of birth and 53 were missing year of death. Inventors are counted only when they are over 18 and alive.

TABLE 10A. LOGIT ESTIMATES OF THE PROBABILITY OF PATENTING IN EACH YEAR BY THE 1910-12 FREQUENT INVENTORS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Includes Patents Granted in 1910-12					Excludes Patents Granted in 1910-12				
Age	0.343** (0.0298)	0.325** (0.0292)	0.256** (0.0318)	0.346** (0.0297)	0.257** (0.0321)	0.310** (0.0291)	0.306** (0.0293)	0.253** (0.0327)	0.313** (0.0290)	0.255** (0.0329)
Age squared	-0.00374** (0.000330)	-0.00351** (0.000320)	-0.00264** (0.000332)	-0.00377** (0.000329)	-0.00266** (0.000335)	-0.00336** (0.000318)	-0.00332** (0.000319)	-0.00260** (0.000335)	-0.00339** (0.000317)	-0.00262** (0.000336)
Years before 1895			-1.252** (0.215)		-1.275** (0.211)			-1.136** (0.220)		-1.155** (0.215)
Year 1895-97			-0.997** (0.214)		-1.016** (0.215)			-0.883** (0.219)		-0.899** (0.218)
Year 1898-00			-0.634** (0.183)		-0.647** (0.185)			-0.521** (0.182)		-0.531** (0.184)
Year 1901-03			-0.169 (0.143)		-0.175 (0.144)			-0.0838 (0.145)		-0.0877 (0.146)
Year 1907-09		1.498** (0.140)	0.803** (0.155)		0.818** (0.157)		0.244+ (0.146)	-0.467** (0.163)		-0.468** (0.165)
Year 1910-12			0.475* (0.196)		0.489* (0.199)			-0.326+ (0.186)		-0.323+ (0.188)
Year 1913-15			-0.419* (0.188)		-0.413* (0.191)			-0.318+ (0.186)		-0.312+ (0.189)
Year 1916-18			-1.048** (0.220)		-1.044** (0.224)			-0.949** (0.218)		-0.946** (0.222)
Year 1919-21			-0.951** (0.237)		-0.941** (0.239)			-0.874** (0.234)		-0.864** (0.237)
Years after 1921			-1.441** (0.278)		-1.415** (0.274)			-1.440** (0.274)		-1.414** (0.271)
Principals				0.418** (0.158)	0.426* (0.173)				0.429* (0.171)	0.415* (0.175)
Independents/ Patent Attorneys				0.451* (0.191)	0.482* (0.205)				0.467* (0.199)	0.460* (0.199)
Observations	6554	6554	6554	6554	6554	6554	6554	6554	6554	6554

+ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$

Notes and sources: See Table 5A and 9A. The omitted occupational categories are employees and unknowns/deceased, and the omitted years are 1904-06. Standard errors are in parentheses. Errors are clustered by individuals.

TABLE 10B. LOGIT ESTIMATES OF THE PROBABILITY OF PATENTING IN EACH YEAR BY THE 1928-30 FREQUENT INVENTORS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Includes Patents Granted in 1928-30					Excludes Patents Granted in 1928-30				
Age	0.420** (0.0305)	0.398** (0.0296)	0.307** (0.0324)	0.421** (0.0303)	0.302** (0.0329)	0.383** (0.0294)	0.381** (0.0297)	0.293** (0.0337)	0.384** (0.0292)	0.287** (0.0342)
Age squared	-0.00457** (0.000348)	-0.00430** (0.000337)	-0.00321** (0.000348)	-0.00458** (0.000346)	-0.00319** (0.000350)	-0.00412** (0.000331)	-0.00409** (0.000334)	-0.00307** (0.000355)	-0.00412** (0.000329)	-0.00305** (0.000357)
Years before 1913			0.824** (0.137)		0.838** (0.137)			-0.164 (0.152)		-0.153 (0.152)
Year 1913-15			-1.142** (0.223)		-1.228** (0.227)			-0.882** (0.239)		-0.973** (0.244)
Year 1916-18			-0.919** (0.172)		-0.962** (0.170)			-0.515** (0.185)		-0.560** (0.184)
Year 1919-21			-0.882** (0.162)		-0.912** (0.161)			-0.470** (0.171)		-0.500** (0.170)
Year 1925-27		1.459** (0.115)	-0.407** (0.119)		-0.422** (0.119)		0.141 (0.127)	-0.0847 (0.124)		-0.0988 (0.125)
Year 1928-30			0.358* (0.153)		0.384* (0.152)			0.389** (0.147)		0.418** (0.146)
Year 1931-33			-0.237 (0.155)		-0.202 (0.154)			0.211 (0.155)		0.252 (0.153)
Year 1934-36			-0.726** (0.176)		-0.680** (0.177)			-0.273 (0.180)		-0.222 (0.180)
Year 1937-39			-0.719** (0.190)		-0.659** (0.190)			-0.263 (0.196)		-0.197 (0.196)
Years after 1939			-1.394** (0.217)		-1.295** (0.212)			-0.942** (0.225)		-0.836** (0.219)
Principals				0.289* (0.138)	0.304* (0.149)				0.296* (0.147)	0.317* (0.150)
Independents/ Patent Attorneys				-0.0186 (0.258)	-0.0195 (0.273)				-0.0883 (0.297)	-0.0850 (0.306)
Observations	10239	10239	10239	10239	10239	10239	10239	10239	10239	10239

+ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$

Notes and sources: See Tables 5B and 9B. The omitted occupational categories are employees and unknowns/deceased, and the omitted years are 1922-24. Standard errors are in parentheses. Errors are clustered by individuals.

TABLE 11. 1940 INCOMES OF 1928-30 FREQUENT INVENTORS

Occupation	Number with top-coded annual income of \$5,000 or more in the 1940 Census	Number with annual income <\$5000 in the 1940 Census	Number whose income was not given in the 1940 Census	Number who were retired (worked zero weeks and had zero income in 1939)	<i>Total number found in the 1940 Census</i>	Number who were dead by 1940	Number not found in the 1940 census but found in other sources c1940	Number not found in any source c1940	<i>Grand total</i>
Principal	19	5	6	4	34	11	9	7	61
Employee	38	22	6	3	69	5	22	3	99
Attorney	1	1	4	0	6	1	2	0	9
Independent	1	0	1	1	3	2	1	0	6
<i>Total</i>	59	28	17	8	112	19	34	19	175

Notes and Sources: Information on income is from the 1940 Decennial Census of the U.S. Other biographical income comes mainly from city directories, World War II draft cards, death records, and other sources available on Ancestry.com. The table excludes five members of the initial cohort of 1928-30 frequent inventors who died, retired, or otherwise disappeared before 1930.

TABLE 12. LIFETIME PATENTING BY CASE SCHOOL OF APPLIED SCIENCE GRADUATES

Year of Grad	Total Number of Graduates	Number of Patentees	Total # Patents	Avg. Patents per graduate	Avg. Patents per patentee
1920	79	16	187	2.37	11.69
1921	106	24	116	1.09	4.83
1922	139	34	161	1.16	4.74
1923	132	22	104	0.79	4.73
1924	100	16	112	1.12	7.00
1925	103	25	188	1.83	7.52
1926	116	29	97	0.84	3.34
1927	103	20	129	1.25	6.45
1928	120	27	103	0.86	3.81
1929	100	28	265	2.65	9.46
1930	114	34	265	2.32	7.79
1931	139	37	201	1.45	5.43
1932	165	48	187	1.13	3.90
1933	148	33	139	0.94	4.21
1934	146	41	167	1.14	4.07
1935	120	32	174	1.45	5.44
1936	124	31	123	0.99	3.97
1937	123	35	140	1.14	4.00
1938	132	42	254	1.92	6.05
1939	171	41	242	1.42	5.90
All years	2,480	615	3,354	1.35	5.45

Notes and Sources: The table includes graduates from the Case School of Applied Science who were awarded the degree of Bachelor of Science in the years 1920-39. We culled their names from the Case School's Annual Commencement Programs, which we obtained from the Case Western Reserve University Archives. We then searched the Google Patent database to find all the patents obtained by these graduates over their lifetimes.

TABLE 13. PATENTING BY MAJOR, CASE GRADUATES 1920-39

Major	Number of Graduates	Number of Patentees	Average Lifetime Patents per Patentee
Civil	330	33	2.81
Mechanical	786	199	5.47
Electrical	465	119	5.03
Mining	46	7	2.86
Metallurgical	300	64	3.61
Physics	118	52	9.38
Chemical	427	141	5.93
Not Listed	8	1	2.00
Total	2,480	615	5.45

Sources: See Table 12.

TABLE 14. SUMMARY STATISTICS FOR THE PROBABILITY THAT A CASE GRADUATE WOULD PATENT IN EACH YEAR

Variable name	Definition	Mean	Standard Deviation	Minimum	Maximum
Patenting	= 1 if an inventor applied for a successful patent	0.024	0.152	0	1
Age	= Year minus year of birth	38.753	9.766	20	74
Majors					
Chemical		0.167	0.373	0	1
Civil		0.137	0.344	0	1
Electrical		0.191	0.393	0	1
Mechanical		0.317	0.465	0	1
Metallurgical		0.118	0.322	0	1
Mining		0.022	0.148	0	1
Physics		0.045	0.206	0	1
Not Listed	Major not listed in the commencement book	0.004	0.062	0	1
From Cuyahoga Prior Bachelors					
Year (of patent application)		1945.0	9.549	1921	1960

Notes and Sources: See Table 12. Birth and death information come from Ancestry.com. We consider each graduate to be “at risk” for patenting from his year of graduation until his death or 1970, whichever came first (or if death year was missing, the year he turned 75 or 1970, whichever came first). Where birth year was missing, it was imputed as the average year of birth for the class the person belongs to. Out of 2480 graduates, 130 persons were missing date of birth and 502 were missing date of death.

TABLE 15. ESTIMATES OF THE PROBABILITY OF PATENTING IN EACH YEAR CASE GRADUATES,
1920s GRADUATES ONLY

	(1)	(2)	(3)	(4)	(5)
Age	0.188** (0.0312)	0.191** (0.0314)	0.191** (0.0315)	0.190** (0.0316)	0.216** (0.0329)
Age squared	-0.00240** (0.000364)	-0.00243** (0.000366)	-0.00243** (0.000367)	-0.00242** (0.000368)	-0.00266** (0.000378)
Chemical Engineering		1.688** (0.358)	1.688** (0.358)	1.685** (0.357)	1.684** (0.357)
Electrical Engineering		0.750* (0.370)	0.750* (0.370)	0.776* (0.369)	0.775* (0.369)
Mechanical Engineering		1.364** (0.324)	1.364** (0.322)	1.389** (0.321)	1.386** (0.322)
Metallurgical Engineering		0.833* (0.388)	0.833* (0.387)	0.857* (0.385)	0.853* (0.385)
Mining Engineering		-0.774 (0.584)	-0.774 (0.585)	-0.724 (0.586)	-0.727 (0.585)
Physics		2.867** (0.413)	2.867** (0.415)	2.870** (0.417)	2.873** (0.416)
From Cuyahoga County			0.00000891 (0.202)	0.0313 (0.209)	0.0337 (0.209)
Prior Bachelor's degree				0.582+ (0.342)	0.577+ (0.342)
Year patent application, 1929-33					0.365** (0.128)
Constant	-7.253** (0.647)	-8.518** (0.691)	-8.518** (0.736)	-8.575** (0.740)	-9.274** (0.775)
Observations	49794	49751	49751	49751	49751

+ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$

Notes and sources: See Table 12. The omitted major is Civil Engineering. The regressions are estimated over the years 1920-1970, so an individual is “at risk” for patenting from the year that he graduates until he dies or until 1970, whichever comes first. Standard errors are in parentheses. Errors are clustered by individuals.

TABLE 16. ESTIMATES OF THE PROBABILITY OF PATENTING IN EACH YEAR,
CASE GRADUATES, 1920-1939

	(1)	(2)	(3)	(4)	(5)
Age	0.225** (0.0227)	0.222** (0.0228)	0.222** (0.0228)	0.223** (0.0228)	0.201** (0.0233)
Age squared	-0.00276** (0.000274)	-0.00272** (0.000276)	-0.00272** (0.000276)	-0.00274** (0.000276)	-0.00250** (0.000278)
Chemical Engineering		1.792** (0.248)	1.793** (0.247)	1.799** (0.246)	1.799** (0.246)
Electrical Engineering		1.444** (0.249)	1.444** (0.249)	1.470** (0.249)	1.469** (0.249)
Mechanical Engineering		1.494** (0.235)	1.494** (0.235)	1.522** (0.235)	1.522** (0.235)
Metallurgical Engineering		1.057** (0.270)	1.056** (0.269)	1.088** (0.269)	1.084** (0.269)
Mining Engineering		0.491 (0.572)	0.495 (0.573)	0.548 (0.573)	0.537 (0.575)
Physics		2.530** (0.287)	2.533** (0.287)	2.563** (0.287)	2.564** (0.286)
From Cuyahoga County			0.0297 (0.124)	0.0547 (0.126)	0.0537 (0.126)
Prior Bachelor's degree				0.845** (0.285)	0.840** (0.285)
Year of graduation, 1931-37					-1.014** (0.281)
Constant	-8.043** (0.460)	-9.472** (0.496)	-9.494** (0.510)	-9.579** (0.513)	-9.049** (0.529)
Observations	98333	98290	98290	98290	98290

+ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$

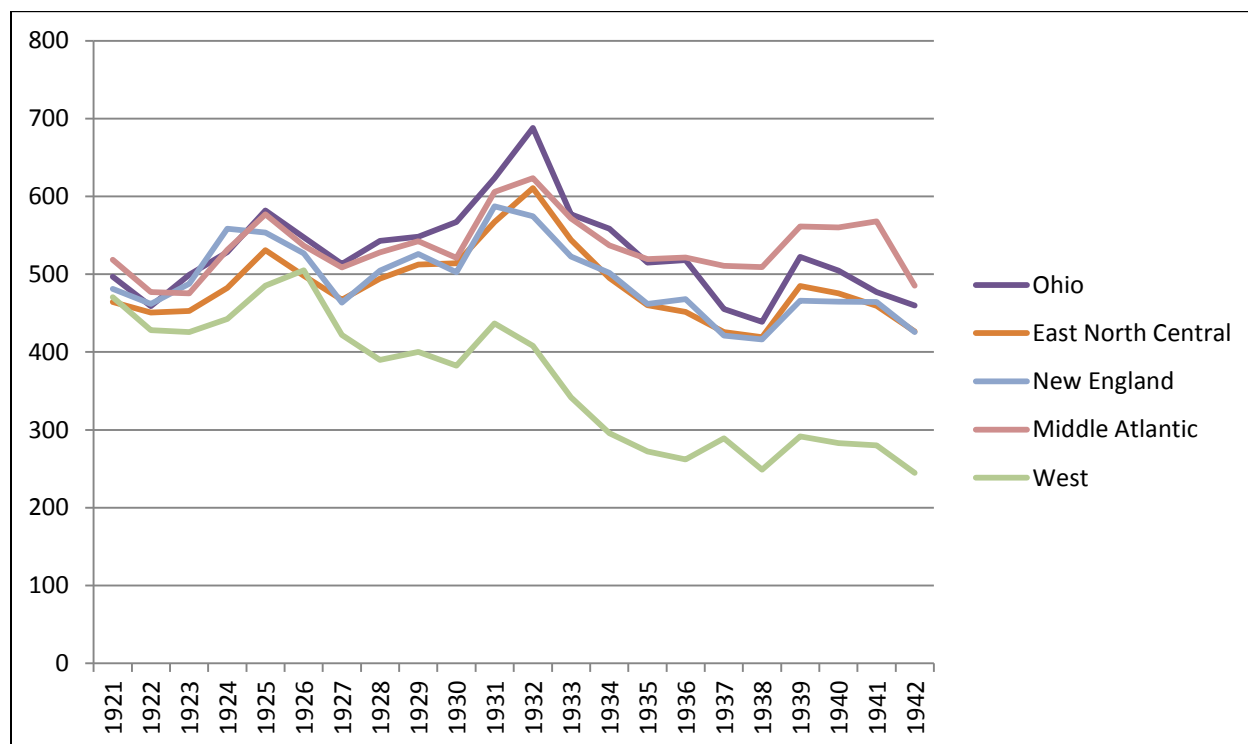
Notes and sources: See Table 12. The omitted major is Civil Engineering. The regressions are estimated over the years 1920-1970, so an individual is “at risk” for patenting from the year that he graduates until he dies or until 1960, whichever comes first. Standard errors are in parentheses. Errors are clustered by individuals.

TABLE 17. CASE GRADUATES' CHARACTERISTICS, 1920-39

	Average Age	From Cuyahoga	Had a Previous Bachelor's Degree
1920	23.2	77.2%	0.0%
1921	22.9	66.0%	0.0%
1922	22.7	71.2%	0.0%
1923	23.2	74.2%	0.8%
1924	22.9	61.0%	1.0%
1925	22.6	69.9%	1.0%
1926	22.5	78.4%	1.7%
1927	23.1	74.5%	1.0%
1928	22.7	70.0%	1.7%
1929	22.7	69.0%	2.0%
1930	22.6	71.1%	0.9%
1931	22.6	77.0%	1.4%
1932	22.5	81.2%	0.0%
1933	22.7	79.1%	0.0%
1934	22.6	82.2%	0.0%
1935	22.4	81.7%	0.0%
1936	22.2	85.5%	0.0%
1937	22.3	78.0%	0.0%
1938	22.3	78.0%	0.0%
1939	22.4	77.8%	0.6%
Total	22.7	75.2%	0.6%

Sources: See Tables 12 and 14.

FIGURE 1. PATENTING RATES PER CAPITA BY REGION, 1921 TO 1942



Notes and Sources: Patent rates are numbers of patents per million residents of the region. Patent counts come from the U.S. Commissioner of Patents, *Annual Reports*, 1921-25 and 1946. Population figures are from Carter et al. (2006), Vol. 1, 28-29.

FIGURE 2. BANK DEPOSITS IN CUYAHOGA COUNTY AND THE LARGEST TWENTY-FIVE MANUFACTURING COUNTIES, 1920 – 1936

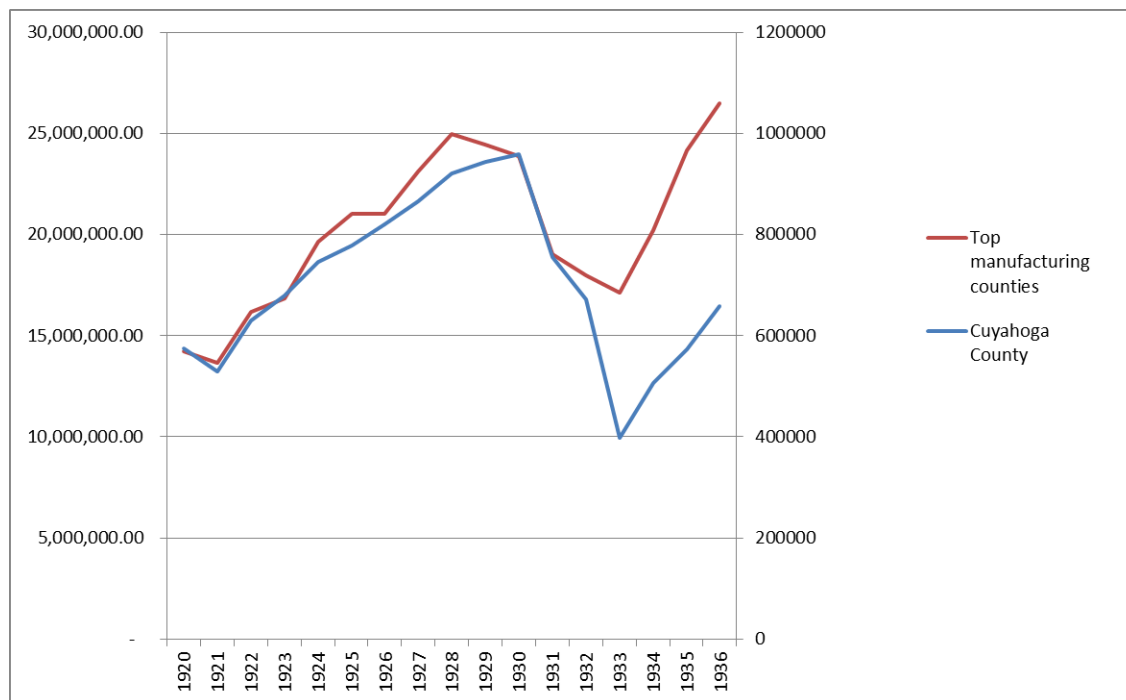


FIGURE 3. NUMBER OF BANKS IN CUYAHOGA COUNTY AND THE LARGEST TWENTY-FIVE MANUFACTURING COUNTIES, 1920 – 1936

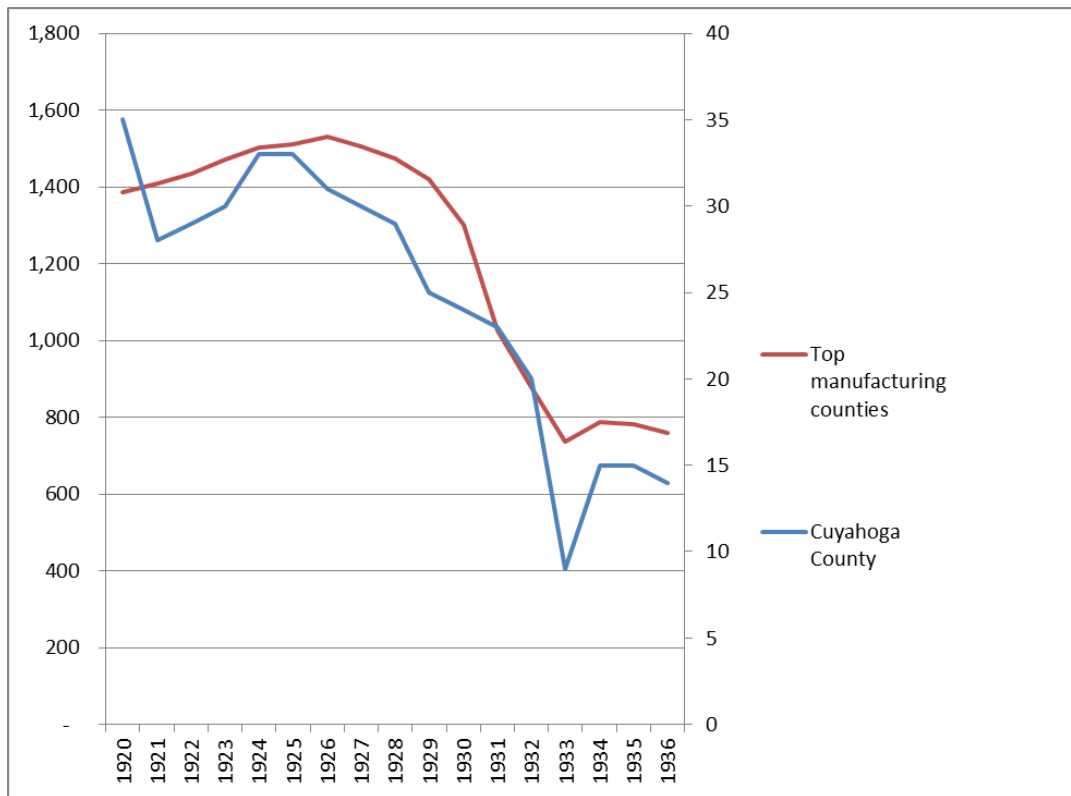
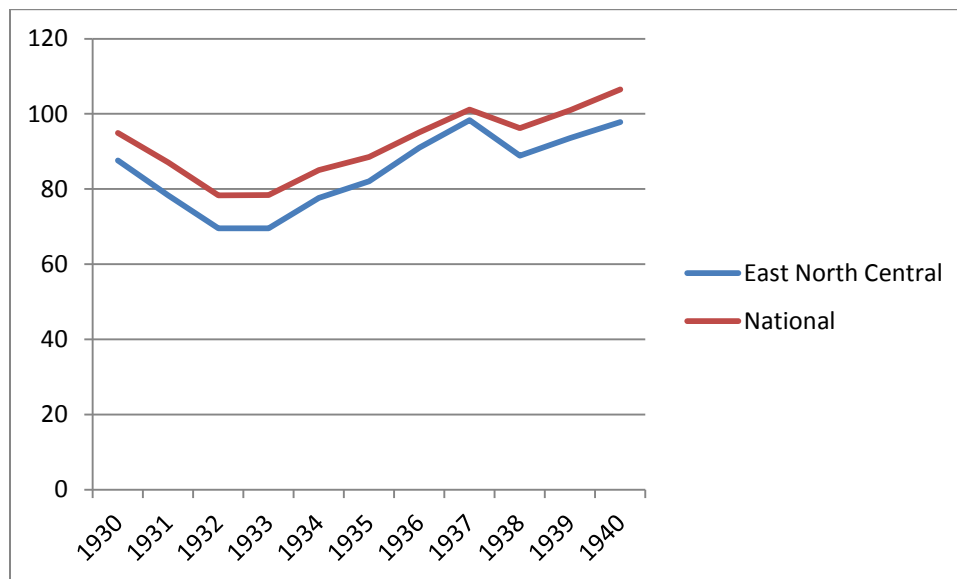
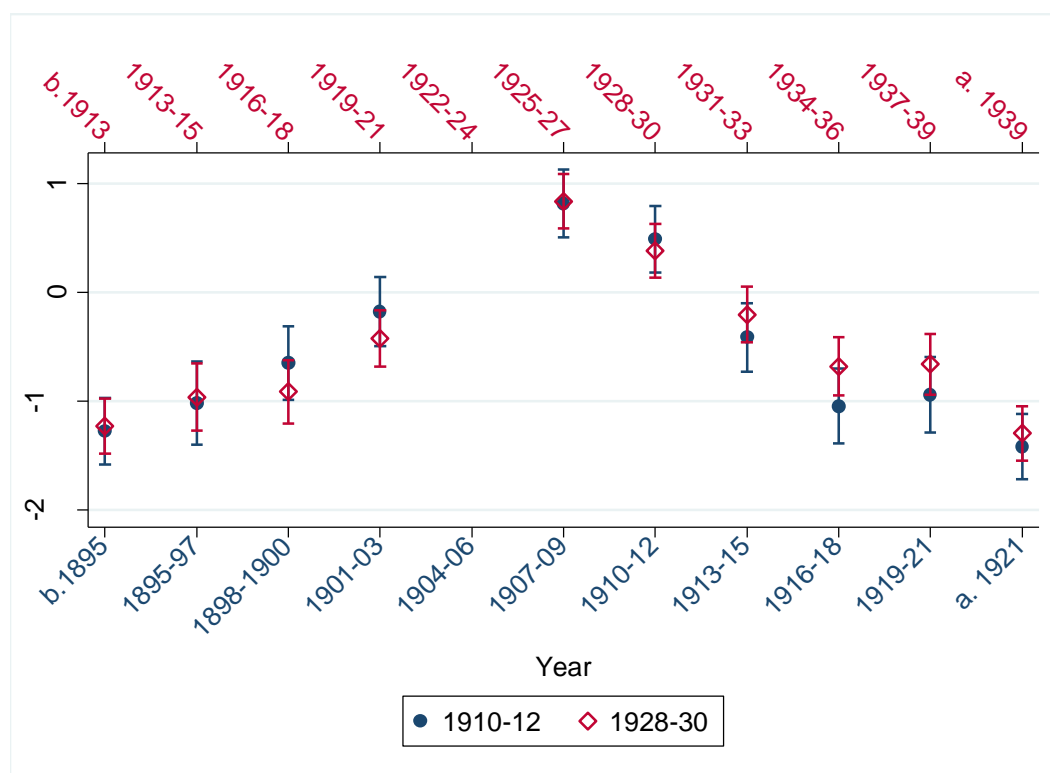


FIGURE 4. REGIONAL EMPLOYMENT INDICES: TOTAL MANUFACTURING (AUGUST 1929 = 100)



Source: Wallis (1989), Table 2, p. 53.

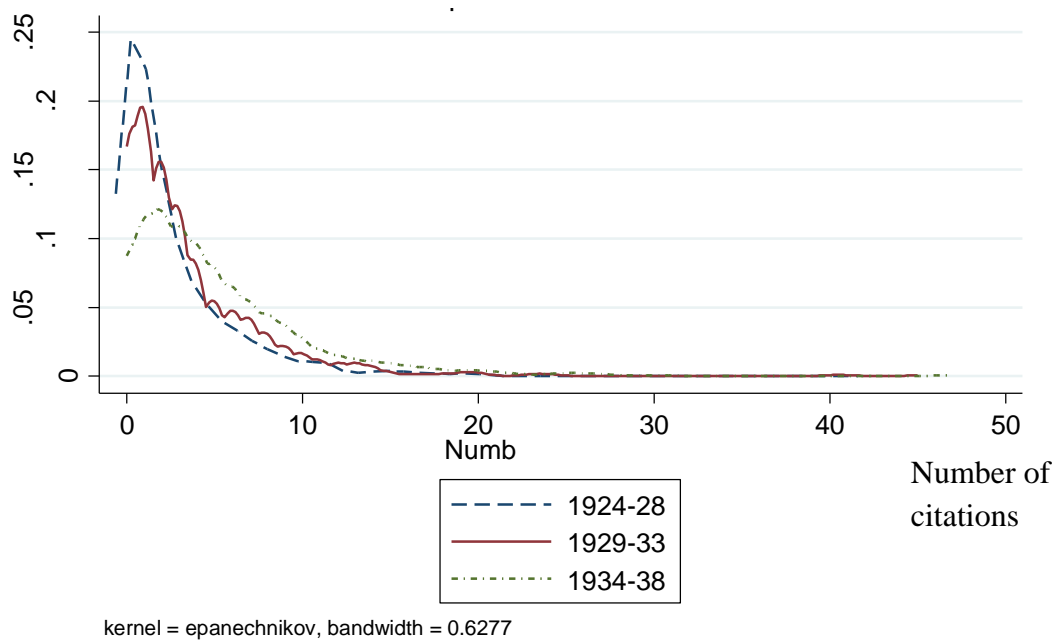
FIGURE 5. POINT ESTIMATES AND CONFIDENCE INTERVALS FOR THE YEAR DUMMY MARGINAL EFFECTS, 1910-12 AND 1928-30 FREQUENT INVENTORS



Sources: See Appendix Tables 10A and 10B.

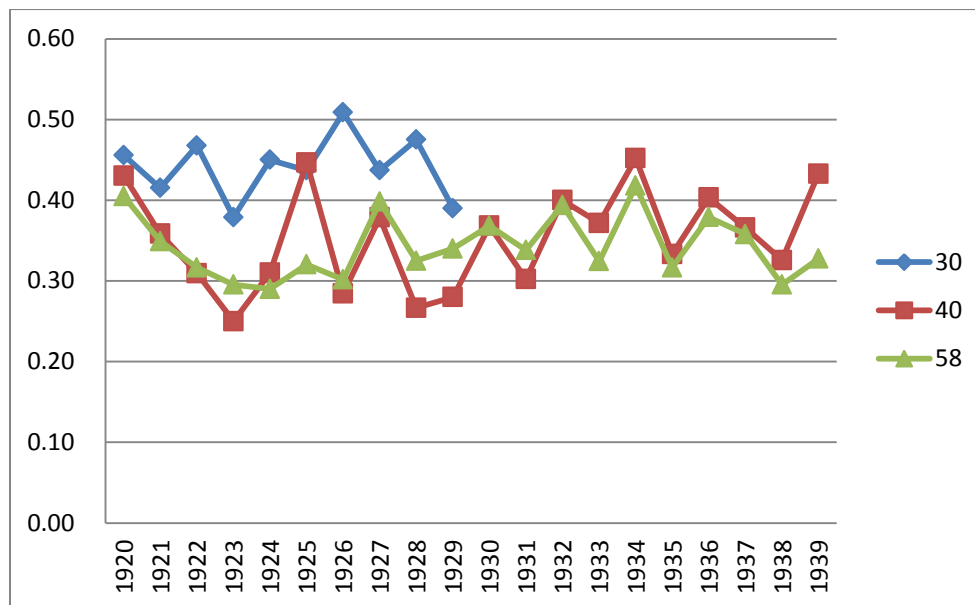
Notes: The blue indicate confidence intervals for the 1910-12 point estimates (represented by blue circles), and the red lines confidence intervals for the 1928-30 estimates (red diamonds).

FIGURE 6. DISTRIBUTION OF CITATIONS BY YEAR OF PATENT APPLICATION
 PATENTS ISSUED TO 1928-30 FREQUENT INVENTORS



Sources: For patents, see Table 10B. Citation counts for 1949 and afterwards were kindly supplied by Tom Nicholas.

FIGURE 7.
PROPORTION OF CASE GRADUATES LIVING IN CUYAHOGA COUNTY,
BY GRADUATION YEAR



Sources: Case Commencement Programs, 1920-39; the manuscript 1930 and 1940 population censuses available at Ancestry.com; and the 1958 Case Alumni Directory.

APPENDIX TABLE 10A. LOGIT ESTIMATES OF THE PROBABILITY OF PATENTING IN EACH YEAR BY THE 1910-12 FREQUENT INVENTORS
(MARGINAL EFFECTS EVALUATED AT THE MEANS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Includes Patents Granted in 1910-12					Excludes Patents Granted in 1910-12				
Age	0.0496** (0.00380)	0.0468** (0.00384)	0.0362** (0.00453)	0.0497** (0.00380)	0.0361** (0.00457)	0.0401** (0.00344)	0.0397** (0.00349)	0.0323** (0.00412)	0.0401** (0.00345)	0.0322** (0.00415)
Age squared	-0.000540** (0.0000401)	-0.000506** (0.0000406)	-0.000373** (0.0000461)	-0.000541** (0.0000401)	-0.000374** (0.0000465)	-0.000435** (0.0000363)	-0.000430** (0.0000369)	-0.000331** (0.0000412)	-0.000435** (0.0000365)	-0.000332** (0.0000415)
Years before 1895			-0.138** (0.0186)		-0.139** (0.0180)			-0.114** (0.0180)		-0.115** (0.0174)
Year 1895-97			-0.104** (0.0164)		-0.104** (0.0159)			-0.0850** (0.0159)		-0.0852** (0.0155)
Year 1898-00			-0.0740** (0.0177)		-0.0745** (0.0177)			-0.0563** (0.0169)		-0.0567** (0.0168)
Year 1901-03			0.141** (0.0316)		0.143** (0.0320)			-0.0514** (0.0163)		-0.0510** (0.0162)
Year 1907-09		0.303** (0.0335)	-0.0228 (0.0181)		-0.0233 (0.0180)		0.0340 (0.0217)	-0.0104 (0.0175)		-0.0108 (0.0174)
Year 1910-12			0.0767* (0.0356)		0.0787* (0.0362)			-0.0376+ (0.0196)		-0.0369+ (0.0197)
Year 1913-15			-0.0522* (0.0208)		-0.0511* (0.0210)			-0.0367+ (0.0196)		-0.0357+ (0.0197)
Year 1916-18			-0.107** (0.0167)		-0.106** (0.0168)			-0.0895** (0.0154)		-0.0883** (0.0155)
Year 1919-21			-0.100** (0.0190)		-0.0988** (0.0190)			-0.0844** (0.0175)		-0.0828** (0.0175)
Years after 1921			-0.176** (0.0321)		-0.172** (0.0312)			-0.159** (0.0288)		-0.155** (0.0280)
Principals				0.0611* (0.0244)	0.0609* (0.0260)				0.0561* (0.0235)	0.0535* (0.0236)
Independents/ Patent Attorneys				0.0722* (0.0340)	0.0763* (0.0362)				0.0677* (0.0324)	0.0658* (0.0317)
Observations	6554	6554	6554	6554	6554	6554	6554	6554	6554	6554

+ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$

Notes and sources: See Tables 5A and 9A. The omitted occupational categories are employees and unknowns/deceased, and the omitted years are 1904-06. Standard errors are in parentheses. Errors are clustered by individuals.

APPENDIX TABLE 10B. LOGIT ESTIMATES OF THE PROBABILITY OF PATENTING IN EACH YEAR BY THE 1928-30 FREQUENT INVENTORS,
MARGINAL EFFECTS AT THE MEANS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Includes Patents Granted in 1928-30					Excludes Patents Granted in 1928-30				
Age	0.0534** (0.00288)	0.0506** (0.00293)	0.0391** (0.00385)	0.0533** (0.00288)	0.0383** (0.00391)	0.0442** (0.00268)	0.0439** (0.00272)	0.0338** (0.00357)	0.0440** (0.00268)	0.0329** (0.00365)
Age squared	-0.000580** (0.0000300)	-0.000547** (0.0000309)	-0.000408** (0.0000395)	-0.000579** (0.0000301)	-0.000404** (0.0000400)	-0.000474** (0.0000280)	-0.000472** (0.0000286)	-0.000355** (0.0000361)	-0.000473** (0.0000281)	-0.000350** (0.0000367)
Years before 1913			0.133** (0.0268)		0.136** (0.0270)			-0.0180 (0.0159)		-0.0167 (0.0159)
Year 1913-15			-0.116** (0.0194)		-0.122** (0.0193)			-0.0849** (0.0200)		-0.0914** (0.0198)
Year 1916-18			-0.0871** (0.0118)		-0.0895** (0.0115)			-0.0501** (0.0148)		-0.0533** (0.0141)
Year 1919-21			-0.0847** (0.0121)		-0.0862** (0.0119)			-0.0464** (0.0143)		-0.0486** (0.0139)
Year 1925-27		0.272** (0.0293)	-0.0455** (0.0122)		-0.0467** (0.0122)		0.0170 (0.0161)	-0.00952 (0.0137)		-0.0110 (0.0135)
Year 1928-30			0.0509* (0.0238)		0.0547* (0.0240)			0.0510* (0.0217)		0.0549* (0.0218)
Year 1931-33			-0.0280 (0.0171)		-0.0239 (0.0171)			0.0262 (0.0206)		0.0314 (0.0207)
Year 1934-36			-0.0732** (0.0147)		-0.0692** (0.0149)			-0.0288+ (0.0174)		-0.0236 (0.0179)
Year 1937-39			-0.0725** (0.0155)		-0.0674** (0.0159)			-0.0278 (0.0190)		-0.0212 (0.0197)
Years after 1939			-0.153** (0.0236)		-0.143** (0.0227)			-0.0979** (0.0225)		-0.0872** (0.0218)
Principals				0.0377* (0.0189)	0.0398+ (0.0203)				0.0350+ (0.0184)	0.0377* (0.0187)
Independents/ Patent Attorneys				-0.00234 (0.0322)	-0.00246 (0.0342)				-0.00985 (0.0321)	-0.00950 (0.0332)
Observations	10239	10239	10239	10239	10239	10239	10239	10239	10239	10239

+ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$

Notes and sources: See Tables 5B and 9B. The omitted occupational categories are employees and unknowns/deceased, and the omitted years are 1922-24. Standard errors are in parentheses. Errors are clustered by individuals.