THE ORGANIZATION AND FINANCE OF INVENTION IN CLEVELAND, 1890-1920

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The Second Industrial Revolution is conventionally associated with the development of in-house R&D laboratories at major firms such as General Electric, AT&T and Du Pont. Scholars have generally assumed that the growing complexity of technology during this period, coupled with the difficult information problems associated with contracting for new technology in the market, spelled the doom of the independent inventor and gave firms who invested in their own R&D facilities a competitive advantage.[1] Although it now seems that the contracting problems associated with the market exchange of technological knowledge have been greatly exaggerated,[2] there is no doubt that the rising complexity of technology, and the resulting greater requirements in terms of both human and physical capital for effective invention, made it more difficult for technologically creative people to pursue careers as independent inventors by the early twentieth century.

What has not been recognized is that the movement of inventors into firms took two very different forms and that there was a pronounced regional pattern to the incidence of these alternatives. The movement of creative people into positions of employment in in-house R&D labs was primarily an East Coast phenomenon. By contrast, in the Midwest it was much more typical for inventors to become principals in new enterprises formed to exploit their technological discoveries. Although there have been many studies of the growth of R&D labs during this period,[3] little is known about the contemporaneous surge in what might be called high-tech start-ups. The purpose of this paper is to begin to redress this imbalance by studying the changing way in which inventive activity was organized and financed in the city of Cleveland, Ohio.

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[1] Mowery, Teece, Hughes, etc.
[2] Lamoreaux and Sokoloff, Stern, etc.
[3] Mowery, Hounshell and Smith, Reich, Wise, etc.

Like many Midwestern cities, Cleveland experienced rapid industrial development in the late nineteenth and early twentieth centuries. [details about the growth of population and industry] It also experienced a surge in patenting rates during this period. In 1900, residents of the Cleveland metropolitan area obtained 392 patents. That translated to a rate of about 65 per 100,000 population, 2.3 times the national average, slightly below the rate for Chicago (76) but slightly above that for Boston (58) and New York (63).[4] Much of this activity was in industries associated with the Second Industrial Revolution, including steel, chemicals, electricity, and automobiles. [details]

In this paper, we first document the long-run trends that occurred in patenting behavior, demonstrating the increased tendency of the most important inventors to become associated with firms and also the different ways in which this trend manifested itself across regions. We then show that Cleveland inventors were representative of the general Midwestern pattern in that they tended to become principals in high-tech startups rather than employees of large in-house R&D labs. In the remainder of the paper we attempt to understand the way in which Cleveland inventors mobilized finance to support these new ventures. We begin by exploring the informal channels that inventors first exploited to raise funds—family connections, of course, but also the networks of knowledgeable business people that formed in industries like hardware telegraphy. We then turn our attention to more formal financial institutions. Although initially banks and similar intermediaries played only an indirect role in financing the exploitation of new technological discoveries, over time they became more integrally involved in underwriting the

[4] David C. Hammack, Michael S. Fogarty, and Gasper S. Garofalo, "Explaining Cleveland as an Industrial Region: An Open System of Innovation, 1840-1930," paper presented at the Annual Meeting of the Business History Conference, Lowell, Mass., June, 2003; Fogarty, Garofalo, and Hammack, "Cleveland from Startup to the Present: Innovation and Entrepreneurship in the 19th and Early 20th Centuries," Report of the Center for Regional Economic Issues, Weatherhead School of Management, Case Western Reserve University, 200??.

securities of new firms. They also played a major role in organizing the Cleveland Stock Exchange, where the stocks and bonds of many of these enterprises came to be actively traded.

The National Context for Inventive Activity in Cleveland

Early industrialization in the United States was associated with a very broad spectrum of the population making contributions to technological change, but a marked long-term trend toward invention being carried out by individuals who were relatively specialized at that activity was evident by the latter half of the 19th century. As indicated in Table 1, the proportion of patents awarded to individuals who obtained only one patent over their careers dropped from over 57 percent during the 1820s and '30s to less then 20 percent by the 1890s. At the same time, the proportion of inventors who received ten or more patents over their careers increased from below 5 percent to more than 35 percent. A number of developments helped account for this dramatic shift. First, as technology became more complex over time, it became more and more important for individuals effective at invention to be well acquainted with a technical understanding of the frontiers of knowledge, and this required investments in specific human capital. This necessarily narrowed the range of people who were active at invention, and encouraged those with the appropriate human capital to specialize in that activity. Second, as economic growth proceeded and industrial composition changed, there was a general increase in the relative size of industries (reflected in both output and patents) characterized by more capital-intensive and complex technologies, such as railroads, chemicals, telecommunications, and electricity, where the returns in inventive potential to investing in specialized knowledge (and in inventive activity) were probably highest, and a corresponding decline in the relative size of industries where technical knowledge was not such a prerequisite to invention.

Yet another important reason for the increasing prominence of specialized inventors was the evolution of a market for patented technologies that made it easier for creative individuals to realize the returns to their discoveries by selling or licensing off the rights to the product (new technologies) they had a comparative advantage at producing. Increases in the extent of the market for new technological knowledge encouraged specialization in the production of new technological knowledge. Not surprisingly, given that those who were most capable or successful at invention would be the most inclined toward, and best able to, attract the resources necessary for continuing along that career path, the movement toward greater specialization by inventors was especially pronounced among the most important inventors. Those patentees whose inventions were significant enough to warrant them recognition in the *Dictionary of American Biography* had on average much higher totals of career patents and rates of assignment than did patentees in general, and far higher levels of formal schooling than did the general population.[5]

From the middle until late in the 19th century, many of the most productive patentees extracted much, if not all, of the returns from their inventions by selling off patent rights to other individuals or firms.[6] Not only did the resulting division of labor enable them to spin off the distracting and time-consuming work of commercialization to others, giving them the freedom to

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[5] See Naomi R. Lamoreaux and Kenneth L. Sokoloff, "The Decline of the Independent Inventor: A Schumpeterian Story?" unpublished paper, 2002; and "Market Trade in Patents and the Rise of a Class of Specialized Inventors in the Nineteenth-Century United States," *American Economic Review*, Papers and Proceedings, 91 (May 2001), pp. 39-44. Their patents were also more concentrated in capital- and human capital-intensive sectors such as telecommunications, transportation, and heavy industry.

[6] The analysis in this section of the paper is based on a longitudinal data set constructed for three cohorts of patentees whose last names began with the letter "B." Our starting point was three random cross-sectional samples (totaling about 6,600 patents) drawn from the *Annual Reports of the Commissioner of Patents* for the years 1870-71, 1890-91, and 1910-11. We select from the three cross-sectional samples all (561) inventors whose last names began with the letter "B" and then collected information from the *Patent Gazettes* and the *Annual Reports of the Commissioner of Patents* for all (6057) patents obtained by these patentees for the twenty-five years before and after they appeared in one of our samples. For each patent, this information included a brief description of the invention, the name and location of the patentee(s), and the names and locations of any assignees who were granted rights to an invention before the date the patent was issued. We also linked the data on patents to other information, such as characteristics of the counties in which the patentee resided or the kinds of firms to which the patentee assigned patent rights.

concentrate on generating new technological ideas, but it also made it easier for the inventor to realize returns from geographically-segmented product markets. Another advantage to eschewing long-term attachments with a single firm was that inventors with many different ideas could do better as independents if firms differed in their ability to exploit the commercial potential of particular inventions. One way of demonstrating this pattern is to explore how many different assignees extremely productive inventors dealt with over their careers. Based on a sample of randomly-drawn patentees from 1870-71, 1890-91, and 1910-11, which we traced back and forward 25 years (for a total of 50) from the year we found them, the most productive inventors from the late-19th and early 20th centuries did not generally maintain stable long-term attachments with the assignees they transferred their patent rights to. As indicated in Table 2 [Contractual Mobility and Career Productivity of Patentees] 168 patentees (or 30.8 percent of the sample) received ten or more patents over their careers (accounting for 80.6 percent of the total 5794 patents the 545 were awarded), and 51 of these 168 (or just over thirty percent of the inventors with ten or more career patents) sold their patent rights to four or more different assignees over their careers. These 51 patentees (9.4 percent of the total number of patentees) received 2034 patents (more than 35 percent of the total patents received by the 545, or nearly 44 percent of all of the patents granted to 10+ patentees). If we look at the 75 patentees who received 20 or more patents over their careers, we find that nearly half of the patents they received went to the 33 inventors who dealt with four or more different assignees in the assignments they made at issue.[7]

[7] This way of describing the patterns in the data on assignments at issue may seem to slightly overstate the strength of the relationship we want to highlight because the possibility of having more assignees increases with the number of patents, but the qualitative result is robust to other approaches. On the other hand, the table records only those assignments made on or before the date of issue of the patent. If we had information on assignments or licensing agreements made after the date the patent was issued, the numbers of different assignees the inventors deal with (our measure of contractual mobility) would be even higher. For evidence that the bulk of these assignments were indeed arms-length transactions, see Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Inventors, Firms, and the Market for Technology in the Late Nineteenth and Early Twentieth Centuries," in *Learning By Doing in Firms, Markets, and*

There is considerable evidence, however, that the number of different assignees a patentee dealt with over his career had begun to decline by the early twentieth century. For example, as indicated in Table 3, there is a marked decrease from the second to third cohorts (c2 to c3, or 1890-91 to 1910-11) in the proportion of patentees that contracted with 4 or more different assignees over the course of their careers – a decrease which is all the more dramatic if the patentees are weighted by the number of their career patents.[8] Although small cell sizes lead the regional figures to bounce around, obscuring the trend somewhat, the shift over time is pronounced for the country overall.[9] By the early twentieth century, the most productive inventors were more likely to form, or did so at an earlier stage of their careers, some kind of long-term attachments with a single enterprise.

Why the associations between productive inventors and the firms to which they assigned began to strengthen during this period is an important question. A number of factors may have played a role. For one, as regional output markets gave way to an emerging national market, the advantages to an inventor of dealing with different firms were likely much reduced. Another crucial change, however, was the growing complexity of technology, which was associated with increases in the amount of capital, both financial and human, that were required for effective inventive activity. With growing needs for capital to support their work, inventors may have found it increasingly difficult to remain productive at invention as well as highly independent. In

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Nations, eds. Lamoreaux, Daniel M. G. Raff, and Peter Temin (Chicago: University of Chicago Press, 1999), pp. 19-57.

[8] For a subset of the patentees from this sample that were able to trace in city directories, we obtained some information on the their occupations, job titles, and places of work. Our analysis of these data suggested that there was an increase over time in the prevalence of inventors assigning their patents to firms that they were principals in. See Lamoreaux and Sokoloff, "Inventors, Firms, and the Market…."

[9] It is interesting to note that the proportion of patentees that had no assignees jumped from the second to the third cohort, and to speculate about its source. This pattern seems to reflect an increased dispersion among patentees in their career totals. A larger fraction of them has very few career patents, and a larger fraction has many more patents (say over 20). This development may have come from the growing pressure on inventors to attract support for their efforts. Those who generated inventions that were sought by the market, as indicated in assignment, were able to sustain their inventive activity. Those whose inventions were not demanded by the market, however, were not able to keep inventing.

this sort of environment, it would not be unreasonable for productive inventors to either go to work for firms that were well capitalized (and willing to support their inventive activity) as employees, or -- if able -- organize a firm around their intellectual property (in hand or to come) and financial capital provided by others.

We have sought to investigate this change in the behavior of inventors by classifying the types of assignees they assigned their patent rights to, and examining how the patterns of assignment changed over time, especially among the most productive patentees. In Table 4 we characterize assignments according to the following typology: (0) the inventor did not assign the patent at issue; (1) the inventor made a partial assignment to an individual (often a partner); (2) a full assignment to an individual; (3) an assignment to a company with the same name as the patentee (indicating that the inventor likely was a principal in the firm); (4) an assignment to a company for which financial information was reported in the *Commercial and Financial Chronicle* or in *Poor's* or *Moody's Manual of Industrial Securities* (indicating that the company was important enough to tap the national capital markets) or, alternatively, that was listed in an early-1920s National Research Council directory of companies with research laboratories; (5) an assignment to a not-already classified company that was located in the same city as the patentee; (6) an assignment to a not-already classified U.S. company (thus a company located in another city from that of the patentee); and (7) an assignment to a company located in another country.

Perhaps the most immediately striking feature of the estimates presented in Table 4 is the enormous contrast in behavior, one that grew more extreme over the cohorts, between the specialized or productive patentees (those with 10 or more patents over their career) and the inventors for whom patenting was relatively infrequent. By the 1910-11 cohort (c3), the specialized inventors were assigning nearly two-thirds of their patents away at issue, while

inventors with 5 or fewer career patents were assigning only about a fifth. But there was also a remarkable difference in the identities of those to whom the two groups of inventors chose to assign their patents. When they made assignments, the specialized inventors overwhelmingly assigned their patents to companies, whereas the other group relied on individuals (often assigning only share of the patent). Virtually all of the patents assigned to companies classified as (3) or (4) (companies with the same name as the inventor or firms that were highly-capitalized or had early R & D labs) were from these specialized inventors.

The rather distinctive pattern of specialized or productive inventors assigning to the large well-capitalized firms became much stronger over time (as indicated by cohorts), as did their assignment to companies that bore the inventor's family name. Indeed, by the 1910-11 cohort (c3), 37.8 percent of the patents assigned by the most productive patentees went to such family-related firms (or 23.5 percent of all their patents, out of the 62.4 percent of the patents that were assigned at issue), as opposed to 22.6 percent to the large companies. More directly, there is substantial evidence that the more productive inventors were becoming increasingly likely to either be associated as principals with enterprises organized to exploit their inventions or were employed by large companies that supported their inventive activity.

The rather distinctive pattern among specialized patentees of assigning to companies, especially those that were very large or shared a name with the inventor, as well as the greater salience of that pattern over time, are consistent with our idea that creative individuals came under increasing pressure to gain access to capital if they were to enjoy productive careers in inventive activity. In Table 5 we present the results of another test of the implications of the theory. Here we look at how the assignment behavior of specialized inventors (those with 10 or more patents over their career) evolved over their careers (using the earliest patent as the

beginning of each inventor's career). The logic is that before would-be specialized inventors were able to either mobilize capital to organize firms based on the plan of realizing the returns to their intellectual property, or to gain a position in a large firm that was willing to support their inventive activity, they had to demonstrate that they had the 'right stuff' to generate valuable technological knowledge. If so, their patterns of assignment late in their careers would look very different from those at an early stage; specifically, they would have higher assignment rates and would be much more likely to assign to large firms and family-name firms. At the early stage of their careers, however, before they had obtained the backing of individuals or firms who thought their technological creativity might be worth investing in, their patterns of assignment should – in our theory – look much like those of inventors who had short careers as patentees (low assignment rates and a tendency to assign shares of patents to individuals rather than full assignments to companies). Moreover, this career trajectory in assignment behavior should be more pronounced in the later cohorts, as technology and inventive activity became more capital intensive.

The patterns of assignment behavior exhibited by specialized patentees over their careers, and over the various cohorts, presented in Table 5 are quite consistent with the predictions derived from our theory. The patents they received more than 15 years after their career in invention began were much more likely to be assigned, and assigned to large companies or companies with the same name. Again, as implied by our theory, the distinctive career trajectory is much stronger in the later cohorts.[10]

[10] The results we report in Table 5 were derived from our 'B' sample of patentees randomly drawn form the patent rolls in 1870-71, 1890-91, and 1910-11. We have also performed a similar analysis on data we have collected for a sample of 'great inventors' listed in the *Dictionary of American Biography*. The qualitative findings about the distinctive career trajectory in assignment behavior held among this group of very important inventors as well.

Another striking feature in the patterns of assignment patterns is a marked contrast across regions. As Table 6 shows, inventors in the Midwest (E. North Central states) were disproportionately likely to assign their patents at issue to companies that bore their name: 56.7 percent of their assignments went to such firms and only 7.4 percent to large integrated (in the sense that invention and commercial exploitation was carried out within the same firm) enterprises. Trends in the Middle Atlantic were just the opposite, with 36.2 percent of assignments going to large firms and only 4.4 to companies with the inventor's name. New England was an intermediate case, with 35.4 percent of assignments going to large enterprises and an equivalent number to entrepreneurial firms (those that shared the name of the inventor). Although regional differences in industrial composition might in principle account for these disparities, the same qualitative pattern holds even when we control for the sectoral classification of the patents.[11]

In order to better understand both the source of the trend toward stronger or earlier long-term attachments between patentees and assignees, as well as the regional difference in the types of firms inventors develop attachments with, we collected samples of patent data for two groups of inventors that were resident in the vicinity of Cleveland at the beginning of the 20th century. In each case, we sought to identify patentees that were more likely to be among the most productive or specialized inventors of their cohort. The first group is composed primarily of those inventors who received patents in 1900, were also awarded a patent in 1898 or 1902, and received at least three patents in those three years. Several additional inventors were added to

[11] As our theory would predict, inventors whose patents were classified as being in sectors that would normally be considered as having more technical or capital-intensive technologies, such as electricity/telecommunications or heavy industry, were much more likely to assign their patents at issue and to make assignments to large firms or firms that shared their name, than those whose patents were in sectors such as light manufacturing or agriculture/food processing. The different patterns across sectors do not account for the regional differences however. For example, inventors who received patents classified as electricity/telecommunications or as heavy industry were much more likely to assign them to large companies (as opposed to firms with the same name) if they resided in the Middle Atlantic than if they resided in the East North Central states.

this group, however, on the basis of the *Dictionary of American Biography* identifying them as 'great inventors' who had been resident in Cleveland. We then collected information on all of the patents awarded to these 36 individuals over the years from 1892 to 1912 inclusive (except for 1895, 1901, and 1904), and found patents for 35 of these individuals (who collectively were awarded 22.4% of the patents granted to Cleveland inventors in 1900). The second group consists of the inventors who received a patent in 1912, and received three or more patents in 1910, 1911, and 1912. This group included 107 inventors (who collectively received 43.9% of the patents awarded to Cleveland inventors in 1912). Working with a sample of inventors from a single locale has many advantages, associated with the increased feasibility of obtaining and employing other relevant information about the individuals. To enrich our analysis of these patent data, we sought (and were generally able) to establish the occupation of our patentees by consulting city directories for Cleveland, and identify whether they were principals in the firms they assigned their patents to. This allows us to probe more deeply into the nature of the attachments between inventors and the assignee firms than relying the use of family name to establish a link.

As is evident in Table 7, we observe in both these groups of Cleveland inventors roughly the same pattern of assignments as we observed for the E. North Central states in our national sample. The proportions of the patents assigned at issue, and the proportions assigned to companies in which the patentee is a principal (or in which the inventor and the company share a name) are relatively similar to the figures in the 1890-91 and 1910-11 cohorts reported in Table 6. For example, the third cohort (1910-11) of E. North Central inventors from the national sample, assigned at issue 55.4% of their patents, as compared to the 55.2% assigned by the 1910-12 Cleveland inventors. Assignments to large integrated companies were more common, and

assignment to related companies (as indicated by family name or status as a principal) less so, among the Cleveland inventors than East North Central inventors overall, but this may be due to Cleveland being such a major industrial city.

What is also very much consistent with our finding about the pattern of assignment in the E. North Central states is that many of these active or especially productive inventors in Cleveland were assigning their patents to firms that they had direct interests in. They do not seem to have been mere employees, but rather true principals. Perhaps the most compelling evidence that the inventors were not passive in the development of these long-term attachments comes from the detailed firm and personal histories – some of which will be recounted below. The patent data also provide some insight, especially for the numerically inclined. In Table 8, for example, it is evident from the careers of our first group of active Cleveland inventors (those we have followed for twenty years, from 1892 to 1912) that the assignment patterns of the very productive inventors who were principals in the firms they assigned to were very different from the patterns of assignment among those who were not. Although they made nearly 75 percent of their assignments to the companies they were principals of, it is striking that they had a much lower assignment rate (39.0 percent) than did the patentees who were also very productive at invention but assigned to firms they were not principals of (74.7%). Indeed, their exceptionally low assignment rate suggests that they were able to retain a remarkable degree of autonomy, or property rights to their inventions, in their relationship with the company they were a principal of – or more precisely, the other owners (or providers of capital) of the firm. The natural question, therefore, is how these productive inventors were able to mobilize the capital for their firms?

Finance through Personal Connections

Although there were already a number of banks and other financial intermediaries in Cleveland when the city's industrial sector began its period of rapid growth in the late nineteenth century, as is invariably the case local inventors seeking funds to support their activities had to rely initially on personal connections, most importantly their own relatives. A number of families in the region had accumulated substantial wealth in trade, resource extraction, or related activities by the last quarter of the nineteenth century. Although parents typically insisted that their sons prove themselves before gaining access to family wealth, they were ultimately important sources of capital for entrepreneurial ventures. Many of the sons who attained adulthood during this period started their careers by pursuing technical training, sometimes through apprenticeships but more commonly by attending one of the growing number of engineering schools across the country. Some turned out to be highly talented inventors, especially in the new technologies to which they were exposed in their studies.

A good example is Alexander E. Brown, son of Fayette Brown, a prominent Cleveland merchant banker, iron dealer, and manufacturer.[12] Born in 1852, Alexander attended Brooklyn Polytechnical Institute in the early 1870s and then took a job from 1873-74 as chief engineer with the Massillon (Ohio) Bridge Company. While in the company's employ, he invented a method of using scrap iron and steel to build bridge columns. Returning to Cleveland, he attempted to pursue a career as an inventor, in part by working with the arc-lighting pioneer Charles F. Brush, but found himself so strapped for funds that even the notice that the Patent Office had approved his application for a hoisting-machine patent brought him little joy. As he

[12] The following account is based on "Brown, Alexander Ephraim" and "Brown, Fayette," *Online Encyclopedia of Cleveland History* (http:/ech.cwru.edu/); "Brown, Fayette," *Dictionary of American Biography* (hereafter *DAB*); and William Ganson Rose, *Cleveland: The Making of a City* (Cleveland: World Publishing Co., 1950), pp. 437-8.

complained to his older brother Harvey H. Brown in 1880, "I have spent so much time and money on this case, in what was necessary, but which . . . is only a loss or expense to me." He begged Harvey, an iron ore dealer, to help him defray the cost of obtaining the patent and also of acquiring the Canadian rights, promising him in exchange a quarter interest in the patent. As he explained, "I have my Electric Lamp patents to get yet, and they will cost like 'sin' for I will have to get English and other patents for them."[13] Shortly thereafter, his father, who was himself an accomplished inventor, recognized the potential of the hoisting-machine patent to revolutionize the handling of cargo on the Great Lakes, and stepped in to organize the Brown Hoisting & Conveying Machine Company with a capital of $100,000. Fayette Brown took charge as president of the company; Harvey also played a managerial role and assumed the presidency upon his father's death in 1910. Alexander became vice president and general manager, a position that allowed him to continue his creative work and secure over the course of his career hundreds of additional patents, most of them related to hoisting machinery.

Sons who had entrepreneurial aspirations but were not inventors also had to prove themselves to obtain family backing. Often this process involved scouting out and then teaming up with impecunious inventors who needed both capital and business expertise. Jacob Dolson Cox, founder of the Cleveland Twist Drill Company, followed this strategy.[14] His father, also named Jacob Dolson Cox, was a Civil War general, Governor of Ohio, Grant's Secretary of the Interior, and a railroad president. His mother was the daughter of the great revivalist preacher

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[13] Letter from Alexander E. Brown to Harvey H. Brown, 30 July 1880, Container 1, Folder 1, Harvey Huntington Brown Paper, 1848-1923, Mss. 3342, Western Reserve Historical Society Manuscript Collections.

[14] The following account comes from Jacob Dolson Cox, Sr., *Building an American Industry: The Story of The Cleveland Twist Drill Company and Its Founder* (Cleveland: Cleveland Twist Drill Co., 1951). The narrative was originally written in 1905. Cox was known as Sr., even though his father had the same name. His own son was Jacob D. Cox, Jr. See also "Recollections . . . How Acme-Cleveland Began in 1876" and "Speech, December, 1975—Draft #2," Container 1, Folder 1, and Minutes of Stockholders' Meeting, 7 Feb. 1905, Records of the Cleveland Twist Drill Company, Container 2, Folder 21, Acme-Cleveland Corporation Records, 1869-1982, Mss. No. 4507, Western Reserve Historical Society Manuscript Collections.

and longtime president of Oberlin College, Charles Grandison Finney. Despite the ostensible advantages of his parentage, Cox was forced to set out at the age of seventeen to learn the iron business the hard way, becoming a skilled machinist and iron worker through stints of hard labor at the Cleveland Iron Company and the Cuyahoga Steam Furnace Company. Temporarily unemployed in 1875, he furthered his education by reading technical books and practicing mechanical drawing. While in Buffalo, New York, on a failed attempt to secure a supervisory job in an iron mill, he met C. C. Newton, an inventor of metal cutting tools whose shop was in nearby Dunkirk. Cox thought that the cutting-tool business was technologically promising, and Newton was badly in need of money. The two agreed to a partnership and almost immediately moved the firm to Cleveland. Cox's father would not give him the necessary funds, but was willing to lend him the initial capital investment of $2000 (at 7 percent interest) and also to provide help in the form of orders for tools. Virtually all of the company's early business was with the Wabash Railroad, which Cox's father headed, and it was only the railroad's timely payment of its bills that allowed the young firm to buy badly needed capital equipment.[15]

Family connections were also important at other times in the firm's early history. Cox discovered that his partner was unreliable, had little mechanical talent, and in fact had copied other inventors' machines. The firm only succeeded because Cox proved under duress to be himself a capable and creative inventor. When Cox decided to buy Newton out in 1879, he borrowed the $9,000 he needed from his wife's father, Judge S. B. Prentiss. As Cox built up the

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[15] According to Cox, the firm had no credit rating, so 'Blaisdell & Company had forwarded the lathes and sent the bill through the express company, C. O. D. I . . .was debating with the teamster in the rear of the shop, trying to get him to deliver the lathes to us without the money, as we had not sufficient funds in the bank to meet the bill, when the postman came in at the front end of the building . . . . [M]uch to my surprise and relieve [I] found a check from the Wabash Railroad for their bill in full. This gave us the means to pay for the two lathes. It was an exceedingly close shave for the new firm." *Building an American Industry*, pp. 93-4.

Cox seems to have been equally adamant that his own sons had to earn positions of responsibility in the Twist Drill Company and not obtain them as a birthright. See letters from J. D. Cox to his sons dated 7 Dec. 1902 and 28 Jan. 1903, Container 1, Folder 3, Acme-Cleveland Corporation Records.

business, inventing new types of twist drills and also the machines that produced them, Prentiss, and to a lesser extent Cox's father, provided additional funding that the company needed to weather some tough years during the mid-1880s and emerge as the nation's leading producer of twist drills. In order to focus on his inventive work, Cox found that he needed an associate to handle sales and other administrative aspects of the business. Impressed by his wife's cousin, Francis F. Prentiss, Cox offered to sell him a share of the business in 1880. Prentiss agreed, and the two began a long, mutually beneficial partnership, finally incorporating their business in 1905.[16]

[Other examples here?]

As Cleveland's economy developed, successful businesses became themselves important sources of finance for related enterprises, many of them organized to exploit more effectively technology developed in their own shops. Indeed, some early firms, such as the White Sewing Machine Company, gave rise to an extensive series of such ventures. The company's founder, Thomas H. White, had moved his small sewing-machine company to Cleveland in the late 1860s, and, in combination with Howard W. White (his half-brother) and Rollin C. White (no relation), had formed the White Manufacturing Company in 1866 (the firm was reorganized by the same men ten years later as the White Sewing Machine Company). Under the leadership of the enterprise's main inventors, George W. Baker and D'Arcy Porter (who apparently did not have ownership interests), the firm had developed its own line of precision machine tools. In

[16] Francis Prentiss had a similar, though even more unhappy, start in business, joining in partnership with a man who had patented a brass padlock of the type used by railroads to prevent switches from being moved by unauthorized persons. Prentiss learned the hard way that a patent was no guarantee of value when the Pennsylvania Railroad deemed the locks unsatisfactory, and the firm failed. Prentiss subsequently (with the help of his father) bought a two-fifths interest in Cox's firm. Cox, *Building an American Industry*, pp. 107-8; "A Memorandum of the Association of Mr. F. F. Prentiss with the Cleveland Twist Drill Company," Container 2, Folder 19, Acme-Cleveland Corporation Records.

1890, the Whites spun off a separate corporation, the Cleveland Machine Screw Company, headed by Rollin C. White, to manufacture the devices.[17]

Like many other enterprises using machine-tool technology, the White Sewing Machine Company made a number of products over the years besides sewing machines. These included kerosene street lamps, roller skates, phonographs, and bicycles.[18] Thomas's son, Rollin H. White, was a gifted inventor who had double majored in both mechanical and electrical engineering at Cornell. When Rollin developed in 1899 a new kind of flash boiler for steam vehicles, the sewing machine company added the production of automobiles to its already diversified product line. Rollin ran the factory, Windsor kept the books, and a younger brother, Walter C., opened a sales office in London. The vehicles proved so successful that the Whites spun off production into a separate automobile concern, the White Company, in 1906. Capitalized at [??], Windsor T. White was made president and Rollin H. and Walter C. first and second vice president respectively. It is clear from extant correspondence that Rollin H. supervised production and had responsibility for ongoing technical development.[19]

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[17] "Register"; and White Motor Company, "Important Milestones in White Motor History: Chronological Highlights of Present and Predecessor Organizations (1859-1949)," Container 4, Folder 39, Thomas H. White Family Papers Collected by Betty King, Ms. 4725, Western Reserve Historical Society Manuscript Collections; Rosemary Solovey Hritsko, "The White Motor Story," unpub. Ph.D. diss., University of Akron, 1988, pp. 9-11; Rose, *Cleveland*, p. 336; "White, Rollin Charles," and "White, Thomas H.," *Online Encyclopedia of Cleveland History*.

[18] Rose, *Cleveland*, p. 336.

[19] See, for example, letters 25 Nov. 1911, 14 Dec. 1911, 19 Jan. 1912, 7 Mar., 1912, and 21 Mar. 1912 from Rollin H. White to his father Thomas H. White, Contain 1, Folder 3, Rollin H. White and Walter C. White Papers, Ms. 4734, Western Reserve Historical Society Manuscript Collections. According to Hritsko, Thomas H. White hand bought a steam car from Locomobile in 1899 and gave Rollin H. responsibility for maintaining it. Frustrated by the unreliability of the car's engine, Rollin developed an improved boiler and offered to sell his invention to Locomobile. When the Locomobile refused to buy it, the Whites decided to develop their own car. "White Motor Story," pp. 13-19. See also White Motor Company, "Important Milestones in White Motor History"; "Twenty Years of Knowing How: Tracing the Development of The White Company and its Product Through Two Decades of Transportation Achievement," *The Albatross*, 9 (1921), pp. 4-5, in Container 4, Folder 39, Thomas H. White Family Papers; Richard Wager, *Golden Wheels: The Story of the Automobiles Made in Cleveland and Northeastern Ohio, 1892-1932* (2nd edn. (corrected): John T. Zubal, Inc., 1986), pp. 53-60; Rose, *Cleveland*, p. 620; "White, Rollin Henry," *Online Encyclopedia of Cleveland History*.

In 1909 the White Company bowed to trends in popular demand and began producing gasoline vehicles, the main components of which were designed by other companies, phasing out the production of steam cars in 1911. Rollin now had comparatively little outlet for his creativity and was forced to spend more of his time simply managing production. Stimulated by a visit to a Hawaiian plantation owned by another brother, Clarence, he turned his energies toward designing agricultural equipment, inventing the first crawler-type tractor. He was not able to interest the White Company in shifting any of its resources to the production of tractors. Nor, as the Company increasingly concentrated on the production of high-priced cars and trucks, was he able to interest his officer brothers in pioneering the development of a smaller, cheaper car for the mass market. Tensions began to rise, and after his father died in 1914, Rollin left the company. With Clarence's help, he founded the Cleveland Motor Plow Company in 1916. (The company changed its name to the Cleveland Tractor Company—Cletrac—in 1917). Rollin was president of the new company, but he still took major responsibility for technological design. With Cletrac a big success, he founded another car company, the Rollin Motor Company, in 1923, but that venture lasted only a few years though it produced cars that embodied notable advances.[20]

In the latter years of the nineteenth century, the Cleveland Machine Screw Company had also diversified its output beyond machine tools. Like his brother Rollin H., Windsor White had engineering training (he had attended Worcester Polytechnic Institute), and the two brothers developed a type of "safety bicycle" while working in the company's employ. Windsor became treasurer of the Screw Company and head of its bicycle department. When the Whites acquired

[20] Letters from Henry Merkel to Betty King, 4 Jan. 1991 and 14 Jan. 1991; Report 3, Alice Lunn to Betty King, 29 Dec. 1990; Report 10, Alice Lunn to Betty King, 11 March 1991; and photocopy, "28 Years of Constant Improvement Behind Cletracs" Container 4, Folder 34, Thomas White Family Papers; Hritsko, "White Motor Story," pp. 45, 49-50; Wager, *Golden Wheels*, pp. 63-66, 186-8; Rose, *Cleveland*, p. 730.

a local bicycle stamping concern, the A. L. Moore Company, Rollin H. became its factory manager. Cleveland Machine Screw sold off the bicycle part of its business to the American Bicycle consolidation in 1898.[21] At around the same time, the great inventor Elmer Sperry designed an electric car and arranged for the Cleveland Machine Screw Company to produce it in 1898, assigning the company his patents in exchange for shares of its stock and agreeing to assume the position of electrical engineer. This business, along with Sperry's patents, were also sold to the American Bicycle Company in 1900.[22]

Walter C. Baker, son of George W. Baker who had been one of key early inventors at White Sewing Machine, graduated from the Case School of Applied Science in 1891. That same year he married the daughter of Rollin C. White, and, after a stint as a civil engineer, went to work for the Cleveland Machine Screw Company. In 1893 he established his reputation at the Chicago Exposition by helping to build the "Electrobat," a light electric vehicle equipped with bicycle-type wheels. Baker invented a revolutionary anti-friction ball bearing that could be used for bicycles, carriages, and automobiles, and with the assistance of his father-in-law and several other men, organized the American Ball Bearing Company in 1895, the same year he received his patent. Baker became president of the new company. In 1897 he built an electric automobile with F. Philip Dorn, secretary of the Ball Bearing Company. The two men worked on the car in the same Brush Electric Company factory where their friend Elmer Sperry was also building his car. While Cleveland Machine Screw geared up to produce Sperry's vehicle, its president, Rollin C. White, and Rollin's son, Fred R. White, helped Baker and Dorn organize the Baker Motor Vehicle Company in 1898. Baker held the post of vice president and mechanical engineer of that

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[21] Report 3, Alice Lunn to Betty King, 29 Dec. 1990, Container 4, Folder 34, Thomas White Family Papers; Hritsko, "White Motor Story," pp. 13 -14.

[22] Thomas Parke Hughes, *Elmer Sperry: Inventor and Engineer* (Baltimore: Johns Hopkins Press, 1971), p. 88; Hritsko, "White Motor Story," pp. 12 -13; Wager, *Golden Wheels*, pp. 221-23.

company until 1906, when he gave up that position in order to concentrate his energies more fully on the Ball Bearing Company. Baker was also a director of the Peerless Motor Car Company and helped engineer that company's cars. He was an extraordinarily talented inventor who counted Thomas Edison among his friends (Edison bought his first electric car). He also worked with Lee DeForest on the development of amplifiers for radio.[23]

The White Sewing Machine Company and its founder, T. H. White, were a source of funds for less high-tech enterprises as well. A good example is Theodor Kundtz's furniture company, which specialized in building cabinets for White's sewing machines. Kundtz had migrated to the United States in 1873 from Austria-Hungary and settled in Cleveland. Twenty years old and without financial resources, he took a job with a small woodworking firm that made tables for sewing machines. When the owner went bankrupt, he and three other employees pooled their savings and bought the business at a fire-sale price. Kundtz gradually earned enough to buy out his partners, but his big break came when he became the main supplier of cabinets for the nearby White Sewing Machine Company. At that time, sewing-machine furniture consisted of little more than tables on which the machines were bolted. Kundtz's innovation was to design cabinets which converted into attractive pieces of furniture, and he obtained over thirty patents on mechanisms that made it possible to swing the machines out of sight when not in use. White bought much of Kundtz's output and also frequently lent him the money he needed to build his business. As the business grew, Kundtz expanded into new products from school desks to church pews to and bicycle wheels, many of which were based on

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[23] Jeffrey Robert Yost, "Components of the Past and Vehicles of Change: Parts Manufacturers and Supplier Relations in the U.S. Automobile Industry," unpub. Ph.D. diss., Case Western Reserve University, 1998, pp. 85-6; Wager, *Golden Wheels*, pp. 204-18; "Baker, Walter C." and "White, Rollin Charles," *Online Encyclopedia of Cleveland History*; "The Baker Motor Vehicle Company," *Men of Ohio* (www.cwru.edu...4/UL/DigiLib/CleveHist/MenOfOhio/); Hritsko, "White Motor Story," pp. 11-13; Rose, *Cleveland*, 564, 589; *A History of Cleveland, Ohio: Biographical* (Chicago: S. J. Clarke, 1910), Vol. 2, pp. 332-3.

his own inventions. Later he also built automobile bodies for the Whites. By 1910, Kundtz headed a vertically integrated enterprise that employed 2500 workers in five plants and was the largest consumer of hardwood in the state of Ohio. The White Sewing Machine Company bought out Kundtz's company after World War I. [24]

Networks of Information and Finance

As last example suggests, downstream (or upstream) businesses could be important sources of finance for new businesses. Indeed, these kinds of businesses could play particularly significant roles in more technologically advanced industries because their executives had both the expertise and the motive to search out promising new prospects. For example, Alexander E. Brown and other entrepreneurs associated with the Brown Hoisting Machine Company provided most of the capital for the Elwell-Parker Electric Company of America in 1893. Brown had been looking for an electric motor capable of driving his ore-handling machinery, discovered the Elwell-Parker Company in Britain, and arranged for the formation of a company to produce the motor in Cleveland. The new firm was hit badly by the Panic of 1893 and the ensuing depression, but orders from Brown kept the company going (Brown even provided the company with production space) while it developed the new types of motors and generators that allowed it to expand its customer base and move into a new factory of its own.[25]

Another similar example was the Cleveland Cap Screw Company, the acorn from which TRW ultimately grew. Cleveland Cap Screw was organized in 1900 by David J. Kurtz, a

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[24] Christopher J. Eiben, *Tori in Amerika: The Story of Theodor Kundtz* (Cleveland: Ewald E. Kundtz, Jr., 1994), pp. 13-14, 20-3, 25-6, 48-9. According to Rosemary Hritsko, T. H. White gave Kundtz's wife a sewing machine in appreciation for doing the family's laundry. Kundtz built a cabinet for the machine that White liked so much that he gave Kundtz a contract. See "White Motor Story," p. 29. See also "Kundtz, Theodor," *Online Encyclopedia of Cleveland History*; Rose, *Cleveland*, pp. 529, 693.

[25] Rose, *Cleveland*, p. 546.

prominent local businessman, to exploit a new electric welding technology owned by the Thomson Electric Welding Company of Lynn, Massachusetts. Kurtz's background was in hardware, as was that of another early investor, Samuel M. Mathews, and the two men thought that the welding process would enable them to reduce dramatically the cost of manufacturing cap screws in standard sizes. Kurtz and Mathews, along with Frederick Bright, a Philadelphian whose brother Verner owned a small machine shop in Cleveland, licensed the technology (and purchased the necessary machinery) from Thomson, and then transferred these rights, along with a factory site they acquired, to the newly formed company in exchange for stock. Although the organizers were able to market about $80,000 in additional stock over the next couple of years to investors in Cleveland and Philadelphia, profits did not materialize and debts mounted. The firm was able to make the screws successfully using the welding process, but not at a price low enough to attract many customers. Part of the problem was that Kurtz and the other officers did not have the requisite technological know-how. The enterprise only turned around when automaker Alexander Winton, who had previously invested in some of the company's stock, bought control of the company. He forced Kurtz and his associates out and negotiated a new licensing agreement with Thomson. At the same time, he expanded the company's product line to include gasoline engine valves for his automobiles. Later Winton spun off the Steel Products Company, as the firm was renamed, under the capable leadership of Charles E. Thompson. Thompson, who had previously worked in Massachusetts for Elihu Thomson, the inventor of the process, built the company into a major supplier of automotive parts.[26]

Hardware dealers like Kurtz and Mathews were particularly well placed to obtain information about new products and production processes, as well as to attract investors for new

[26] Davis Dyer, *TRW: Pioneering Technology and Innovation since 1900* (Boston: Harvard Business School Press, 1998), pp. 17-27; *History of Cleveland*, Vol. 2, pp. 925-26.

ventures, because their shops were gathering places for people who bought and made the vast variety of products they sold. Indeed, from early on they tended to be involved in a number of related businesses in addition to their mercantile activities. For example, when Jacob Cox made his trip to Buffalo, New York in 1876, he was seeking employment at the Niagara Bridge Company, which was owned by a man named Pratt who was also a hardware wholesaler. It was at Pratt's store that Cox met his first partner, machinist C. C. Newton. One of Cox's stated reasons for immediately moving the business to Cleveland was that he was "well acquainted with the principal hardware dealers in Cleveland, George Worthington & Company, and Wm. Bingham & Company, and also with some of the bankers." Although he does not seem to have been helped by any of these connections, Bingham and Worthington were in fact major investors in Cleveland industry.[27] Worthington had founded the Cleveland Iron Company in 1849, and he and Bigham together organized the Cleveland Iron and Nail Works in 1863. Bingham was president of the Cleveland Iron Company, and his son, who was trained in geology, mining, and chemistry later organized one of Cox's major competitors, the Standard Tool Company, as well as the Parrish & Bingham Company, a producer of bicycle parts.[28]

A more important node of technological innovation was the telegraph industry. Western Union, the industry leader by the end of the Civil War, provided financial support for numerous inventions related to telegraphy, including early work by Thomas Edison. (Several of Western Union's top executives also backed Edison's research in incandescent lighting at Menlo Park.)[29] One of Western Union's early manufacturing operations had been located in Cleveland. When

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[27] Cox, *Building an American Industry*, pp. 83, 87-8, 112.

[28] "Bingham, Charles W.," "Bingham, William," and "Worthington, George," *Online Encylopedia of Cleveland History*; Rose, *Cleveland*, p. 217; Fogarty, Garofalo, and Hammack, "Cleveland from Startup to the Present," pp. .

[29] Jocelyn Pierson Taylor, *Mr. Edison's Lawyer: Launching the Electric Light* (New York: Topp-Litho, 1978), pp. 32-34; Paul Israel, *From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention* (Baltimore: Johns Hopkins University Press, 96-99.

the company decided to concentrate its production in Illinois in early 1867, the plant's superintendent, George Shawk, bought the tools and equipment for $1,500 and went into business himself, though he maintained close relations with his former employer. A couple of years later another Western Union employee, Enos Barton, joined the firm as a partner, his mother mortgaging the family farm to provide him with the $1,500 he needed for the investment. One of the inventors who hung out at Shawk's shop was Elisha Gray, who would later obtain a telephone patent that rivaled that of Alexander Graham Bell. Gray had studied physics at Oberlin College, where his technical creativity brought him to the attention of Jeptha Wade, president of Western Union and a member of the advisory board of the Oberlin school of telegraphy. When Gray obtained his first patent for a telegraph relay in 1867, Western Union provided financial support for him to continue working on this and related devices in Cleveland where Shawk's machinists could build his prototypes. Gray and Barton became close friends and subsequently partners when Gray bought Shawk out. Gray raised the money for the venture with financial assistance from another Western Union executive, Anson Stager, who gave him the funds he needed in exchange for an interest in a printer telegraph that Gray had invented.[30]

Although Western Union soon induced Gray and Barton to move to Chicago (a couple of years later, the partnership merged with the company's manufacturing department to form Western Electric), other telegraph-related businesses stayed in Cleveland and became important sources of support for new technologies related to electricity. The Cleveland Telegraph Supply Company, for example, played a major role in financing both the invention and commercialization of Charles F. Brush's arc lighting system. Brush had studied chemistry at the

[30] Stephen B. Adams and Orville R. Butler, *Manufacturing the Future: A History of Western Electric* (New York: Cambridge University Press, 1999), pp. 15-29; Hal D. Cooper and Thomas M. Schmitz, *A History of Inventions, Patents and Patent Lawyers in the Western Reserve* (Cleveland: Cleveland Intellectual Property Law Association, 1993), p. 12.

University of Michigan. After graduating in 1869, he moved to Cleveland, working for several years as an independent consultant and then joining with Charles E. Bingham [no relation to the hardware wholesaler??] in an iron-dealing partnership. He also studied electricity on the side and, by 1875, had devised and built his first dynamo. George W. Stockley, who was vice president and a major stockholder of the Telegraph Supply Company, put Brush on the company's payroll and gave him the run of its machine shop while he developed his lighting system. In 1876, the company agreed to manufacturer and sell Brush's system, but Telegraph Supply was only capitalized at $200,000 and it soon became clear that a bigger enterprise was needed. Stockley organized the Brush Electric Company in 1880, becoming its president; Brush licensed his patents to the company in exchange for a royalty of 20 percent. The new company was capitalized at $3 million, and Stockley worked hard to attract investors, in part by staging a successful public demonstration in Cleveland's Public Square in 1879.[31] One of the potential investors whom Stockley approached was Jacob Cox, who was at that time too strapped for funds for his own business to be able buy any stock. Cox later regretted his inability to participate: "The original holders made immense sums of money, but as I had no funds to invest, I missed this rare opportunity."[32] Another was Washington Lawrence. A manufacturer of sewing machines and then bolts, Lawrence had bought stock in the Cleveland Telegraph and Supply Company and then became one of the major investors in the Brush Electric Company, serving for a time as general manager until he sold out his interest and invested in real estate.[33]

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[31] Harold C. Passer, *The Electrical Manufacturers, 1875-1900* (Cambridge: Harvard University Press, 1953), pp. 14-21; W. Bernard Carlson, *Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870-1900* (New York: Cambridge University Press, 1991), pp. 81-82, 186; "Brush, Charles Francis," "The Brush Electric Co.," and "Electrical and Electronics Industries," *Online Encyclopedia of Cleveland History*; "The Cleveland Elec tric Illumination Company," *Men of Ohio*; Rose, *Cleveland*, pp. 413, 440; Cooper and Schmitz, *History of Inventions*, p. 10.

[32] Cox, *Building an American Industry*, pp. 90-1.

[33] "Lawrence, Washington H.," *Online Encyclopedia of Cleveland History*; "Washington H. Lawrence," *A History of Cleveland, Ohio: Biographical* (Chicago: S. J. Clarke, 1910), Vol. 3, pp. 14-18.

Lawrence did not stay out of the business for long. The year 1886 saw him organize the National Carbon Company. In 1881, W. H. Boulton, a foreman at Brush Electric, had formed a partnership with Willis [??there are at least three different middle initials in the sources] Masters [??was he the son of Irvine U. Masters, a prominent Cleveland businessman and politician] to organize the Boulton Carbon Company which supplied carbons for arc lights to his former employer and other firms. Lawrence invested in the company, reorganized it as the National Carbon Company, and brought in wealthy investors such as Myron T. Herrick, a local lawyer who had organized a hardware company and built the Society for Savings into a major financial institution, and Webb C. Hayes, son of the ex-president. He then used this firm as a vehicle to acquire competing enterprises and expand into batteries and other components of electrical systems.[34]

One of customers of National Carbon was Elmer A. Sperry, who had invented his own arc lighting system. Lawrence got to know him, and impressed with Sperry's inventive genius, organized what became known as the Sperry syndicate in 1890. The group included Herrick, Hayes, and others associated with the promotion of the National Carbon Company. Sperry was then working in Chicago, but the group brought him to Cleveland to develop a prototype for an electric streetcar, promising that, if the prototype proved workable, the syndicate would either form a company to build the streetcars or sell or license the patents to a company that would. This was really early stage financing. Although Sperry already had some patents in this area, he had not yet developed a working model. Through their Cleveland contacts, however, members of the syndicate had good reason to believe the idea was practicable. Earlier in 1884, working in the shops of the Brush Electric Company, Walter H. Knight and Edward Bentley had developed

[34] "Technology and Industrial Research," "National Carbon Company," and "Lawrence, Washington H.," *Online Encyclopedia of Cleveland History*; Rose, *Cleveland*, p. 476; "Washington H. Lawrence" and "Hon. Myron T. Herrick," *A History of Cleveland, Ohio*, Vol. 3, pp. 14-18, 315-22.

an underground power supply cable (powered by a Brush generator) to run the first electric streetcar line operated by the East Cleveland Railway Company. Sperry developed his streetcar over next couple of years and, in 1892, the syndicate arranged to exploit the invention in a joint venture with the Thomson-Houston Electric Company (which a few months later became General Electric). The resulting Sperry Electric Railway Company contracted to pay Sperry a lucrative salary as consultant in addition to a share in the profits the company would earn from the sale of his streetcars.[35]

A couple of years later when Sperry got interested in the idea of an electric automobile, he turned to the syndicate again. It was with their backing that he set up shop in part of Brush works and developed his electric vehicle, which was then licensed to the Cleveland Machine Screw Co, one of the White family of enterprises.[36]

The Role of Banks and Other Financial Intermediaries

Cleveland's well-developed commercial banking sector's initial role in facilitating the flow of investment funds into Cleveland's innovative firms was very similar to that played by other commercial networks, such as hardware stores and the telegraph. Bankers were aware of who in the city had investment funds and might be interested in investing in new enterprises. They included on their boards of directors a variety of well-placed businessmen, including patent lawyers, who could keep them informed about new technological developments. Thus the most important role for Cleveland's banks in the late nineteenth century development of Cleveland's

[35] Hughes, *Elmer Sperry*, pp. 70-73; "Electrical and Electronics Industries" and *Online Encyclopedia of Cleveland History*; Cooper and Schmitz, *History of Inventions*, pp. 11, 57; Rose, *Cleveland*, p. 465.

[36] Hughes, *Elmer Sperry*, pp. 80-88.

innovative manufacturing firms was probably not as a financial intermediary per se, but as a match-maker, bringing together investors and inventors to create new enterprises.

In 1870, Cleveland's banking sector consisted of five national banks, most of which dated to the 1840s, and one very substantial savings institution, the Society for Savings, which had been founded in 1849 (Table 9). In 1868, Ohio adopted a law permitting the creation of building and loan or savings and loan associations. Over the next decade almost twenty such institutions were formed, though some of them closed during the crises of the 1870s. Between 1876 and 1890, five new national banks were opened; there was one merger. By 1892 Cleveland had ten national banks. Between 1895 and 1903, eight new national banks were formed, but all eight ended up consolidating into other banks before 1906. After the clean-up from the 1907 crisis in 1910, there were only seven national banks, most of which could trace their origins to the original National Banking charters of 1864 and 1865 if not to the Ohio State banking system that preceded it. Between 1890 and 1910, there were almost 50 savings banks, savings and loans, and building and loans formed in Cleveland. Most of these were quite short-lived. Some were consolidated into other financial institutions and some were closed. In 1910, there were twelve savings institutions still in operation, including the Society for Savings, by far the oldest and largest. In 1883, state law allowed the creation of trust companies and at least one was formed in Cleveland immediately thereafter. A dozen such institutions were created over the next 25 years; they were on average much more successful, at least as measured by the duration of the institution. There were 11 active in 1910. As we discuss further below, these trust companies were much more likely to be significant sources of finance than the smaller, but more numerous home building-oriented savings institutions that were created during these same decades.

Once formed, some innovative firms clearly did turn to formal financial institutions for capital to aid in the establishment and growth of their companies. These funds came in several ways. First, banks and trust companies could provide loans directly to firms (sometimes in the form of discounted notes). Second, banks and trust companies could underwrite bonds issued by the firms. Third, banks and trust companies provided funds indirectly when they provided loans to individuals in which they accepted firm bonds or equities as collateral for loans. Some firms turned to public equity markets to provide greater liquidity to their stockholders. While some Cleveland enterprises were able to access national capital markets, and some tried to interest the London market, it was much more common for firms to offer their equity to local investors, initially through informal or individual-broker mediated exchange and, after its formation in 1900, on the local Cleveland Stock Exchange.

Banks and trust companies were more likely to be sources of new capital for firms, but this source of capital is more difficult to track. That banks were an important vehicle for the provision of capital to Cleveland firms is suggested by an article in the *Cleveland Plain Dealer* of 1895 which reported that Cleveland's national banks were 'now indebted to the large eastern houses to the extent of probably $1,500,000 or $2,000,000. This is money borrowed to meet the requirements of local customers."[37] The data that we have available does not begin to allow us to quantify the aggregate amount of capital that went from the banking sector into manufacturing. But we can say something much more modest, namely that there were a range of banking institutions – savings banks, national banks, and trust companies – which did provide capital to manufacturing firms, including some that did not (yet) have access to public equity markets.

[37] April 15, 1895, p. 11.

For evidence on the role of Cleveland banks in providing finance to Cleveland firms, we rely on the records of the Cleveland Trust Company and its constituent companies which are housed in the Western Reserve Historical Society Archives. The Cleveland Trust Company was formed in 1894, six years after passage of Ohio's trust company law. Cleveland Trust was the sixth trust company formed in Cleveland since the passage of the trust law in 1883. Over the next fifteen years it acquired 17 other banks and trust companies, including the Fairmount Savings Bank which had an independent existence from 1901 to 1904. It eventually became the largest financial institution in the Midwest, before entering a long period of decline coinciding with Cleveland's economic decline and related political turmoil, including an anti-trust suit brought against it by the United States Department of Justice during the 1950s because of its substantial interlocking directorates with all of Cleveland's machine tool manufacturers. It essentially went out of existence in 1992. Larry Neal has argued that trust companies were the most important financial innovators during this period, and that their role "was to invest in corporate issues and to help underwrite them."[38] His evidence draws mainly on the activities of New York trust companies and the national firms which they financed, but the evidence discussed below suggests that regional trust companies played a similar role.

During 1903 and 1904, the weekly meetings of the Fairmount Saving Bank's discount and loan committee listed all the loans approved and the collateral accepted for them. Between July 1903 and November 1904, the Finance Committee of the bank approved 108 new loans. Five loans were declined, 40 renewed, and 17 notes were discounted. The value of the loans made ranged from $15 to $15,000. Over 80% of the new loans went to individuals (or occasionally couples). About 5% went to churches, local governments, or other non-profits. Only about 13% went directly to firms. This is consistent with the primary purpose of savings

[38] "Trust Companies and Financial Innovation, 1897-1914" *Business History Review* 45:1 (1971), p. 40.

banks in the U.S., which has been to provide loans for home mortgages. In fact, about 40% of the new loans list real estate as collateral. Many are explicitly building loans for new homes.

If we focus on those loans made to firms or on those loans for which personal estate is given as security, we do find that even the local savings bank played a role in providing finance to Cleveland's burgeoning manufacturing sector. The loans made directly to firms are actuall y the less interesting ones for the purposes of this paper. There are really only eight different commercial borrowers during this period, and most are small retail establishments – a lumber company, a carpet cleaner, an ice cream store. The most interesting of these was a loan made to a retail boot and shoe establishment; the loan to them was made specifically to finance the merger of two shoe stores and their subsequent expansion. The store was incorporated in the process and shares of the new corporation were used as collateral for the loan.[39] There were also two relatively large loans to the Lamprecht Brothers, in addition to 5 loans to George Lamprecht personally. Lamprecht Brothers was a large Cleveland brokerage and banking house. The securities offered for these loans varies, so it is not possible to determine from these records whether the Lamprecht loans were for a particular purpose; more likely they were just part of his ordinary business operations.

An examination of the loans to individuals in which the collateral offered is a security for a local manufacturing firm proves much more fruitful, suggesting, not surprisingly, that the role of savings banks in the provision of capital to manufacturing firms was indirect. Of the 148

[39] "Miller Bros proprietors of several shoe stores in the city applied for a loan of $10,000 on the following terms: The Miller Bros. Stores show net assets of about $32,000. To further increase their business a corporation has been formed taking over the assets of R. H. Fetterman on Euclid Av. with a capital stock of $50,000. The Miller Bros. propose to secure the above loan with $25,000 stock in the new corporation and they are to give their account to the bank. This application comes recommended by Mr. S. L. Pierce. Mr. Moore moved that the application of Miller Bros. for a loan of $10000 secured by $25000 of the capital stock of the Miller-Fetterman Shoe Co approved on condition that their account be continued with us as long as the loan stands. Aye: Messrs. Goff, Moore, Bates. Nay: None" Journal of the Finance Committee of the Fairmount Savings Bank (1903), , Ameritrust Corporation Collection, Western Reserve Historical Society.

loans and renewals approved during this period, just over 25% were backed by some sort of financial security, 20% by a private security. Of the loans backed by a private security, 20% were local railway securities.[40] Over a third relied on securities from local financial institutions. And half used the securities of local manufacturing firms for their collateral.[41] Fourteen different companies appear in this sample. These include loans to two individuals, accepting as collateral equity shares in the Adams-Bagnall Electric Company.[42] Adams-Bagnall Electric acquired patents from several highly productive inventors between 1910 and 1912. Another offered stock in the George Westinghouse Company as collateral. Westinghouse was already a large national firm, but its appearance in this sample may reflect Westinghouse's local presence, both as a manufacturer and supplier of industrial securities, following its purchase of Walker Manufacturing in 1898. Other securities offered came from other significant innovative manufacturing firms in Cleveland in the period and reflect the range of Cleveland manufacturing. For example, on October 18, 1904, the Fairmount Savings Bank approved a loan of $600 to P. J. Morgan, accepting as collateral 2000 shares of the Osborne-Morgan Company "guaranteed in case of default by G. C. Butts." Morgan was a principal in Osborne-Morgan, a consulting engineering firm. His partner in this firm, Henry C. Osborne "designed, produced, and financed a duplicating machine based on the rotary drum principle which was patented 10 March 1903" and became the basis of American Multigraph.[43] And on May 3, 1904, George E. Collings borrowed $5000 using as securities 100 shares in Collings Taylor Woolen Manufacturing firm. There is no

[40] There was only one non-local railroad security in the whole sample, bonds of the Pittsburg Terminal Railway and Coal Company.

[41] This adds to more than 100% because some loans offered more than one type of security as collateral.

[42] The two loans totaled $3,500. One of the borrowers was J. G. Goff. I have not been able to determine if there is any relationship between him and Frederick H. Goff, a prominent Cleveland banker and president of the Cleveland Trust Company.

[43] American Multigraph was actually founded in 1902 by Osborne (sometimes spelled Osborn) and Henry C. Gammeter. *Encyclopedia of Cleveland History* "Henry C. Gammeter" and "AM International Inc" http://ech.cwru.edu/ech-cgi/article.pl?id=AII

record of any particular innovation associated with Collings Taylor, but George Collings was also a large investor and director of the Dow Chemical Company. Charles W. Bramley, the founder of Cleveland Trinidad Paving Company, offered 400 shares in this firm as partial backing for a loan of $5000. This firm, founded in 1890, laid the first asphalt street in Cleveland in the mid-1890s. Initially it used natural asphalt from Trinidad, but it soon re-located itself to a plant adjacent to Standard Oil's Cleveland facility so that it could use a new petroleum-based asphalt.[44] In another example, in 1903 Fairmount lent J. B. Fay, a prominent Cleveland patent and commercial lawyer, $1200, taking as collateral his shares in Jandus Electric, another firm that appears as a frequent acquirer of patents.

Other securities included firms in the iron and steel, brick, rubber, brewing, and electrochemical industries (not to mention the Euclid Avenue Garden Theater). We can conclude from this small sample that the primary purpose of savings banks was to provide mortgage loans and discount notes, but that they were also willing to provide loans that indirectly financed some of Cleveland's most innovative firms and entrepreneurs.

In these same years, the Cleveland Trust Company underwrote bonds for a range of innovative local manufacturing firms. Records have survived describing 122 bond issues that Cleveland Trust underwrote between 1903 and 1908.[45] These issues total over $72 million. They are made to firms in every sector: land and property development; railroad and shipping; electric power; telephone; mining; services and non-profits. Twenty-eight of these issues, amounting to $17.8 million, went to manufacturing firms (Table 10). They are almost all Cleveland firms. Notable exceptions are Midwestern breweries. Undoubtedly these 'out-of-

[44] "Cleveland Trinidad Paving Co" *Encyclopedia of Cleveland History* http://ech.cwru.edu/ech-cgi/article.pl?id=CTPC viewed March 19, 2003.

[45] This includes almost all the bonds underwritten during this period, and perhaps all of them. The records change during the 1907 crisis so it is not possible to be sure, but it is unlikely there were many new bond issues during the crisis period.

state" breweries had acquired Cleveland breweries in the many mergers that occurred in the industry during this period. They also underwrite bonds for the Akron, Ohio-based Goodyear Tire Company and the Midland, Michigan-based Dow Chemical Company. Both of these firms were relatively young (less than ten years old) firms working on the technological frontier; they also both had substantial connections to Cleveland including Cleveland investors in their firms.

The bond issues underwritten by Cleveland Trust's range in value from $8 million for the Independent Breweries of St. Louis to $8,000 for the Painesville Veneer Company and $15,000 for the Cleveland-Walker Laboratory Company. Several of the manufacturing firms whose bonds Cleveland Trust was underwriting appear as frequent acquirers of Cleveland patents. For example, in September 1903, Cleveland Trust underwrote a quarter of a million dollar bond issue for the Long Arm System Company. Between 1903 and 1905, it underwrote three issues for the Wellman-Seaver-Morgan firm, for a total of $2.3 million.[46] These bond issues also went to firms such as the Addresso Printograph Company and the Commercial Adding Machine Company as well as the steel and tool manufacturing firms that we would expect to see.

Loan records for Cleveland Trust are not available for the first decade of the century, but we were able to take a sample of six months of loans or discounts during 1919. We only sampled those over $100,000, so we have excluded loans to small firms. These are all short term loans of between 30 days and six months, though most were renewable. We find that Cleveland Trust made several substantial loans to firms that were active innovators and acquirers of patents. For example, National Acme had $650,000 in outstanding loans from Cleveland Trust in 1919. White Sewing Machine had over a million dollars in loans in the same year. Since the White

[46] We do not have a record of the Cleveland Trust Company's loans during this period, but we do know that S. T. Wellman, a director of the Cleveland Trust Company and a principal in the Wellman-Seaver-Morgan company, had loans from the Cleveland Trust Company in 1907 (when the Trust Company's president announced a new "no loans to directors" policy).

family also sat prominently on the board of another prominent Cleveland trust company, the Guardian Savings and Trust, we can probably safely assume that this was not their sole source of bank financing. Cleveland Trust had half million dollar loans outstanding to both Firestone and Goodyear Tire Companies. The Theodor Kundtz Company also had a half-million in outstanding loans, not counting the loans that Mr. Kundtz co-signed for non-profit institutions (such as the Norwood Methodist Episcopal Church and the Mt. Zion Building Fund). By 1919, these firms and families were no longer newcomers to Cleveland manufacturing or to Cleveland banks, and they seem to have been able to tap into significant sources of funds for working capital.

Because of the greater capital requirements of second industrial revolution firms, the financial resources that the existing banking institutions (and informal capital markets) provided were likely insufficient for the needs of innovative and growing firms. Cleveland's financial institutions had originally been designed to provide finance for the canal and lake trade, and the transition to the provision of finance may also have taken time.[47] Thus we see rapid growth in Cleveland's financial sector in the second half of the nineteenth century and into the first decade of the twentieth century. The number of national banks doubled. Trust companies, such as Cleveland Trust, Guardian Trust, and State Banking and Trust were founded and in most cases became secure and trusted financial institutions. Savings institutions were founded in waves and while some disappeared quickly in waves of consolidations and failures, others developed a niche in the Cleveland financial sector.

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[47] For example, Cleveland first (two) bank, the Commercial Bank of Lake Erie was founded in 1816, failed in 1820, was re-founded in 1832 but floundered after having to suspend specie payment during the crisis of 1837. The *Encyclopedia of Cleveland History* describes the operation of the Commercial Bank, "Reorganization [in 1832] coincided with a tremendous growth in Cleveland's canal trade in the 1830s, and the bank extended credit to Cleveland's merchants and financed shipments of Ohio farm surpluses". The bank reorganized again in 1845 under the new state banking law and then in 1865 under the National Banking Act as the Commercial National Bank.

Perhaps because these financial institutions could play a role, either directly or indirectly, in providing access to necessary capital, many entrepreneurs became themselves engaged in the development of new financial institutions – especially trust companies – and banks and trust companies became more directly involved in intermediating investment funds to Cleveland manufacturing firms.

The participation of leading manufacturers and merchants in Cleveland's banks was not a late development. The founders of the Commercial Bank of Lake Erie, Cleveland's first bank (and one that was still prominent in the period studied here) included not just the 'father" of the Ohio Canal and the author of the precursor legislation for the National Banking Acts, Alfred Kelley. It also included a tannery owner, a dry goods store owner, and the organizer of the Cleveland & Newburgh Railway, the Cleveland, Columbus & Cincinnati Railroad Company, the Cleveland Iron Mining Company and the Cleveland Rolling Mill Company. Similarly, the founders of Cleveland's national banks in the 1860s included George Worthington and Edward Bingham, its two leading hardware men, and Jeptha Wade,. Wade was a pioneer in the telegraph industry and president of Western Union, director of a half dozen railroads, and a founder of the Cleveland Rolling Mill Company. But he was also president of the National Bank of Commerce and a founder of Cleveland's first savings and loan, Citizens Savings & Loan Association. But there is a new group of men who join the boards and found Cleveland's banks during the 1890s and early 1900s. For example, E. R. Edson and Theodor Kundtz, two of the most prolific inventors in Cleveland during this period were also members of the founding board of directors of the Detroit Street Savings and Loan.[48] Jesse B. Fay, a prominent patent attorney, is a founder

[48] Detroit Street Savings & Loan Minutes 1895-1901, Ameritrust Collection, Western Reserve Historical Socitey Collection. The Detroit Street Savings and Loan merged with the Forest Street Savings Bank in 1901, and Forest subsequently merged with Cleveland Trust.

of the Fairmount Savings Bank. C. A. Grasselli, a leading chemical manufacturer, was one of the founders and president of Cleveland's first trust company, the Broadway Savings and Trust Company, (founded in 1884) and its second trust company, Woodland Avenue Savings and Trust Company (founded in 1886).

This of course increased the numbers of interlocks between the boards of financial institutions and those of firms exploiting inventions, improving the ability of banking institutions to perform a match-making role. In 1903 there were 120 men who sat on the board of at least one Cleveland bank and at least one non-bank firm listed on the Cleveland Stock Exchange. These included such prominent local manufacturers as principles or directors of the Brown Hoisting, Grasselli Chemical, Wellman-Seaver-Morgan, White, Edson, National Carbon, National Malleable, and American Linseed firms.

While this alone is not evidence that these banks provided capital to these firms, it was big news when, following the financial crisis at the end of 1907, the president of Cleveland Trust Company announced that it would no longer provide loans directly to trust company directors. (Loans to directors' firms continued without criticism.) The reports produced by Cleveland Trust in response to this change in policy indicated that most directors did have such loans outstanding.

The Role of the Secondary Market

Most early enterprises closely held. Since capital was raised from family and friends, there was a presumption that it would not be sold off to strangers who might interfere with the operation of the firm. But even where that was the case, shares in firms would be sold off over time. In fact, having a market for the shares in one's firm made them much more useful as

collateral for loans and permitted national banks, which were restricted from holding non-traded shares, to invest in them.

There were also cases, especially for established inventors or for projects which required a very large capital investment, for equities to be marketed to the general public in the very earliest stages of firm formation. This was the case, for example, with Brush Electric. There were also probably many intermediary cases, in which, in order to raise sufficient capital equity was sold through a broader network of businessmen. In these cases, information networks, whether organized by bankers or hardware dealers or patent lawyers, could provide crucial in allowing start-up firms to tap into broader sources of capital.

However equity was offered initially, the corporate form allowed for the possibility of anonymous trading, and such trading arose in Cleveland from the early 1880s. Secondary equity markets allow initial investors to dispose of their investment (and use it as collateral for borrowing), thus increasing liquidity and lowering the cost of capital to these firms. But it would have been unusual for these publicly organized, anonymous markets to provide new capital to new manufacturing firms in the way that they did for the railroads of the 1870s and 1880s or for the dot.com startups of the 1990s

There was substantial growth of the secondary market during the late nineteenth and early twentieth centuries. Between 1880 and 1900, Cleveland brokers established an active trade in local equities and bonds. By 1893, there were a dozen or so brokers in Cleveland. In 1880, these firms brokered everything from wheat to railroad bonds, but by the time the Cleveland Stock Exchange was established in 1900 there were thirty active (broker) members who purchased seats on the exchange, as well as 70 "inactive" members, mostly commercial bankers who were supporting the formation of the exchange but who did not actively trade shares on it.

Not surprisingly, the local market before the formation of the exchange was dominated by railroad securities. There were also quite a few banks and mining companies that were regularly traded. As early as 1886, however, there were a few non-bank, non-railroad, non-mining "miscellaneous" firms whose securities were regularly quoted and advertised by local dealers. These included firms such as the Cleveland Driving Park Co., which apparently owned and operated race tracks in the Cleveland area,[49] the Cleveland Electric Light Company,[50] the Brush Electric Light and Power Company,[51] the Brush Electric Company, the Union Steel Screw Company, the Cleveland Rolling Mill Company, and Walker Manufacturing Company. While no one would claim that a twenty-plus year old race track company was an innovative firm, the electric companies (including Walker, a producer of power-transmitting machinery and cable railway networks) certainly should not be thought of as stodgy old utilities.[52] Rather, they were manufacturing electrical equipment and bringing cutting edge power transmission technology to Cleveland, and Cleveland's general public was happy to invest in them. The Cleveland Rolling Mill Company, founded in 1863, was certainly not a start-up firm when its stock was traded in the 1880s, but it had been one of the first U.S. companies to use the Bessemer process.[53] Likewise, the Union Steel Screw Company, formed in 1872 by a group of Cleveland investors,

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[49] According to the *Encyclopedia of Cleveland History*, "Once the site of horse, auto, bicycle, and foot races, the Glenville track was built in 1870 by the Cleveland Driving Park Co. as part of the Northern Ohio Fair, whose major grounds were located across the street." "Glenville Race Track" http://ech.cwru.edu/ech-cgi/article.pl?id=GRT viewed March 18, 2003.

[50] "The Cleveland Electric Light Co., established on 21 June 1884, bought a power-generating station on Johnson St. between Bank (W. 6th) and Water (W. 9th) streets and used the power to supply its Edison incandescent lights in several downtown stores." *Encyclopedia of Cleveland History* "Cleveland Electric Illuminating Co." http://ech.cwru.edu/ech-cgi/article.pl?id=CEIC viewed March 18, 2003.

[51] Brush Electric Light and Power and Cleveland Electric Light merged in 1892 to form the Cleveland Electric Illuminating Company. *Encyclopedia of Cleveland History* "Cleveland Electric Illuminating Co." http://ech.cwru.edu/ech-cgi/article.pl?id=CEIC viewed March 18, 2003.

[52] Walker Manufacturing Company was founded in 1883 by John Walker, a Cleveland machinist. As a result of a patent infringement suit successfully brought by Westinghouse Electric, Walker sold out to Westinghouse in 1898 for about $1 million. *Encyclopedia of Cleveland History* "Westinghouse Electric Company" http://ech.cwru.edu/ech-cgi/article.pl?id=WEC1 viewed March 18, 2003.

[53] *Encyclopedia of Cleveland History* "U.S. Steel Corporation" http://ech.cwru.edu/ech-cgi/article.pl?id=USC1 viewed March 18, 2003.

was not a young firm. But its president Fayette Brown was an inventor and supported inventive activities with many of his investments, including those in his children, discussed above. (He was also a well established banker and founder of the Cleveland Clearinghouse.) Thus in 1880s and 1890s, there were a few well-established, but presumably innovative manufacturing firms that could tap directly into the savings of Cleveland individuals through public equity markets. The holdings of local private securities were surely much broader than what is described here, but most of these securities were not actively traded, so their liquidity was significantly less. There were over 400 ads by brokerage firms in 1895 alone, and many of these advertised individual securities which they were prepared to buy or sell, but without regularly quoted prices, liquidity is still quite limited. But the extent to which Clevelanders were willing to make such investments is suggested by an article in the *Cleveland Plain Dealer* in 1895 which claimed that Clevelanders held about $100 million (face value) in securities of local firms.[54]

By 1900 the group of local manufacturing firms actively traded had expanded. It now included at least three firms that were the result of national mergers in which Cleveland firms were key players: American Chicle, American Linseed, and National Carbon. There was also at least one brewery and one new electric company, the Forest City Electric Company. Many breweries appear on the Cleveland exchange over this period, as mergers and the scale economies in new beer-production technology encouraged firms to turn to public equity markets to raise capital. American Linseed and National Carbon also appear in our sample of firms to which Cleveland inventors assigned patents during this period. As in the earlier period, we do not see young firms actively traded on the Cleveland Exchange. Instead, we see innovative manufacturing firms that have established themselves, and in some cases consolidated their industry through merger, tapping into this market.

[54] October 19, 1895.

The Cleveland Stock Exchange was founded in 1900 by a group of Cleveland brokers "who had [previously] made ... trade in Cleveland securities ... an incident of their regular transactions, upon the New York Stock Exchange and the Chicago Board of Trade."[55] There had been an active (i.e. publically reported) market in the securities of local firms since the early 1880s. Several Cleveland brokerage firms specialized in buying and selling local securities.[56] The exchange was formed at the instigation of the local chamber of commerce and with the active support of local banks (many of which became associated with the exchange as "inactive members").

Opening in March, the exchange quickly announced itself a success. Sales averaged about 1500 shares a week for the first six months, reaching an aggregate value of securities traded of $150 thousand over the period.[57] The pace of trading picked up over the next six months, as sales volume ranged from 2500 to 5000 securities a week. Recalcitrant local brokers joined the exchange, convinced by the success of its first six months. The number of active members (brokers who were allowed to trade on the exchange) increased from twenty in October 1900 to the maximum allowed of thirty in January 1901. By February, a seat on the exchange sold for $650. The original cost of a seat had only been one hundred dollars.[58]

With the establishment of the Cleveland Stock Exchange in 1900, the number of local firms whose equity is actively traded increased. Much of this increase is driven by the listing of new telephone companies (twenty of them by 1903) and electric companies and electric railway

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[55].Prior, "Cleveland."

[56].*Cleveland Plain Dealer*, January 31, 1886, p. 1, June 1886, and August 22, 1886.

Sep 12, 1886

57.Cleveland Plain Dealer, September 23, 1900.
58.Cleveland Plain Dealer, February 1, 1901, p. 9.

companies. But there are also ten strictly manufacturing firms. In addition to those mentioned above, there are Sherwin Williams, Quaker Oats, American Ship Building, two cement firms, and the National Refining Company.[59] By 1914, there are 37 manufacturing firms listed on the exchange. (The telephone companies have all but disappeared; after the consolidations of the previous decade, only two remain.) These included six breweries, three paper companies, four chemical companies, an oil refiner, four rubber companies, two auto companies, four heavy machinery manufacturers, and four iron and steel firms. Their appearance on the Cleveland Stock Exchange does not indicate that the Exchange was now listing young firms, though many of these had formed after 1900. Rather, as new industries developed and the leading firms in those industries matured, those firms got access to public equity markets. By 1930, there are well over 100 manufacturing firms listed on the Exchange.

Cleveland investors and the Cleveland Stock Exchange were willing to take limited risks on innovative firms; as those firms became more established (and the risk went down), they were more likely to be traded actively on anonymous exchanges. We can see this by a comparison of the firms acquiring patents in the early 1900s with the firms listed on the Cleveland Stock Exchange. In 1900, 330 patents were issued to Cleveland residents. Of these, 137 were assigned at issue. Seventeen firms and three individuals received the bulk of these assignments (80 out of the 134 assigned patents). Of the seventeen "high acquiring" firms in 1900, two had equities that were actively traded on public exchanges by 1900, four by 1912, and six by 1930.[60] Of course,

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[59] National Refining Company's president was a Mr. J. I. Lamprecht. J. H. Lamprecht 2nd also served on the board. The Lamprecht family owned the largest brokerage house in Cleveland in the late 19th and early 20th centuries, and they served on the boards of multiple banks. They were also the largest single endorser of notes in the Fairmount Savings Bank sample described above.

[60] The National Carbon Company and American Linseed were both traded actively traded in local markets prior to the formation of the Cleveland Stock Exchange in 1900. They were both listed on the Cleveland Stock Exchange by 1903. Wellman-Seaver-Morgan and Bishop & Babcock were traded on the Cleveland Stock Exchange by 1912. By 1930, National Malleable (Cleveland Stock Exchange) and Westinghouse Electric (New York Stock Exchange) were also traded.

several of these firms no longer existed by 1930. Their non-appearance on the Cleveland Stock Exchange in 1930 may be because they were no longer in existence (either because of failure or merger).

If we look at the "high-acquirers" in 1912, we find a similar story. Of the 282 patent assignments at issue in 1912, 155 were acquired by 23 firms and 4 individuals. Of these 23 firms, six were traded on the Cleveland Stock Exchange at the time (1912), with six more joining the exchange between 1912 and 1930.[61]

Between 1892 and 1912 there were 39 firms that received assignments from Cleveland's 36 most prolific or important inventors.[62] Of these, only two (Walker Manufacturing Company, a Cleveland firm acquired in 1899 by Westinghouse, and General Electric) were actively traded in Cleveland's local equity markets before 1900. By 1912, another four of these firms (Brown Hoisting, Bishop & Babcock, Wellman-Seaver-Morgan, and White Company) have equity that is actively traded in local markets. By 1930, two more of these firms (National Malleable and Electric Controller) have joined the group of traded firms.

Thus we can see that the role of anonymous, public securities markets in providing capital to innovative firms early in their life is limited. But over time, as firms mature, their access to these markets improves, giving greater liquidity to their initial investors.

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[61] American Multigraph, National Carbon, Brown Hoist Machinery, Peerless Motor Company, Wellman-Seaver-Morgan, and White Company were listed on the Cleveland Stock Exchange in 1912. Electric Controller and Manufacturing, National Acme Manufacturing, National Malleable Castings, National Tool, Ohio Varnish, and Van Dorn & Dutton were listed by 1930.

[62] It should be pointed out that this is not the same as the 39 most innovative Cleveland firms. First, this list includes several firms whose headquarters was outside Cleveland (Chicago Railway Equipment Company, General Electric, Hooker Chemical, and Westinghouse). It also excludes several innovative Cleveland companies who innovations, including their patent acquisitions, did not come from one of these 36 inventors.

Conclusion

In this paper we have argued that the increasing capital intensity of technology and inventive activity over the late-19th and early-20th centuries was an important reason why the most productive inventors came to be more and more likely to develop long-term attachments with the firms they assigned their patents to. Although other solutions to the problem were possible, and indeed had been more common earlier in the 19th century when capital requirements for inventive activity were relatively modest, the dominant pattern by the early decades of the 20th century was for such creative and talented individuals to obtain the financial support they needed to explore their ideas by either going to work as an employee for an established enterprise inclined to invest in inventive activity, or to organize a firm that was able to mobilize funds to pursue a business plan based on the exploitation of the inventor's ability to contribute to new technological knowledge.

The latter approach to the finance of invention and innovation appears to have been much more prevalent in the Middle West than it was in the Middle Atlantic, and we have sought to improve our understanding of the sources and consequences of this regional difference through a detailed study of these developments in early 20th-century Cleveland. Among the crucial issues are whether and why Cleveland (or Midwestern) financial institutions may have been more conducive to the financing of entrepreneurial ventures focused on the generation of new technologies than were those in regions that had industrialized during a much earlier period. Was the local orientation of those institutions well suited to the identification and monitoring of venture capital projects? Or alternatively, was the pattern due to the fact that Cleveland had a relatively limited base of firms in the emerging industries of the Second Industrial Revolution,

and thus provided an environment rich with new opportunities and yet few established firms with a major presence in those fields to hire young inventors?

Although the research is ongoing, our results to date provide some support for each sort of explanation. On the one hand, the less formal financial institutions, which were of course more important prominent in regions far from financial centers like New York, were probably better suited for the financing of new companies oriented toward the development of new technologies. It is striking how virtually all of the early financing of start-ups in Cleveland came through informal channels, and that only when firms were much more mature did banks and securities markets enter the picture in a significant way. Moreover, there were clearly some advantages to creative young inventors being able to organize and serve as principals in the firms they invented for. They enjoyed more autonomy as well as freedom to develop their ideas (and a higher share of the returns from), and in fields based on new technologies it may have sometimes worked out well for them to have great influence in setting the direction of firms.

On the other hand, as intriguing as it may be to contemplate the possibility that the entrepreneurs in Cleveland did not merely settle for informal sources of finance because of an undeveloped sector, it is likely that the professional managers often brought in to run the firms also had positive contributions to make, even when they came into conflict with one of the firm founders. Indeed, it is notable how quickly many of the successful firms organized around creative inventors came to effectively controlled by others who were brought in later. That the regional differences in both the management structures of the firms as well as in the methods of financing seem to have narrowed considerably over time (converging toward the Middle Atlantic patterns) would seem to support the notion that Cleveland and the Middle West were on the same development path as the Northeast, but with a lag of a generation or so. Whether the evidence

ultimately sustains this view, or establishes the importance of another factor, however, our understanding of the processes of technological change will be much enhanced by learning what is was that made Cleveland such an attractive location for the formation of new innovative firms during the Second Industrial Revolution.

TABLE 1

DISTRIBUTION OF PATENTS BY PATENTEE COMMITMENT TO PATENTING, 1790-1911

	Number of "Career" Patents by Patentee					
	1 Patent	2 Patents	3 Patents	4-5 Patents	6-9 Patents	10+ Patents
	%	%	%	%	%	%
1790-1811	51.0	19.0	12.0	7.6	7.0	3.5
1812-1829	57.5	17.4	7.1	7.6	5.5	4.9
1830-1842	57.4	16.5	8.1	8.0	5.6	4.4
1870-1871	21.1	12.5	9.9	15.8	11.8	28.9
1890-1891	19.5	10.3	10.3	10.3	13.8	35.9
1910-1911	33.2	14.3	8.2	9.8	9.4	25.0

Notes and Sources: The figures from 1790 to 1842 are drawn from Kenneth L. Sokoloff and B. Zorina Khan, "The Democratization of Invention During Early Industrialization: Evidence from the United States, 1790-1846," *Journal of Economic History*, 50 (June 1990), pp. 363-78. The figures for the latter years were computed from the longitudinal "B" data set constructed.

TABLE 2

CONTRACTUAL MOBILITY AND CAREER PRODUCTIVITY OF PATENTEES:

DISTRIBUTIONS OF PATENTS AND PATENTEES

		Career Patent Total for Patentee				
		1-2 Pats (%)	3-5 Pats (%)	6-9 Pats (%)	10+ Pats (%)	n
		Panel A: Distributions of Patents				
No Assignees	row%	23.8	25.3	15.2	35.8	875
	col%	76.8	52.1	30.9	6.7	15.1%
1 Assignee	row%	6.1	15.0	9.2	69.8	1042
	col%	23.3	36.8	22.3	15.6	18.0%
2-3 Different Assignees	row%	-	2.4	8.1	89.6	1781
	col%	-	9.9	33.5	34.2	15.8%
4+ Different Assignees	row%	-	0.2	2.7	97.0	2096
	col%	-	1.2	13.3	43.6	36.2%
n		271	424	430	4669	5794
		4.7%	7.3%	7.4%	80.6%	

		Career Patent Total for Patentee				
		1-2 Pats	3-5 Pats	6-9 Pats	10+ Pats	
		(%)	(%)	(%)	(%)	n
		Panel B: Distributions of Patentees				
No Assignees	row%	59.9	22.5	7.5	10.1	267
	col%	78.8	53.6	32.3	16.1	49.9%
1 Assignee	row%	32.3	30.1	10.5	27.1	133
	col%	21.2	35.7	22.6	21.4	24.4%
2-3 Different Assignees	row%	-	12.8	24.4	62.8	86
	col%	-	9.8	33.9	32.1	15.8%
4+ Different Assignees	row%	-	1.7	11.9	86.4	59
	col%	-	0.9	11.3	30.4	10.8%
n		203	112	62	168	545
		37.3%	20.6%	11.4%	20.6%	

Notes and Sources: These estimates were computed from the patentees in the 'B' sample that were residing in the U.S.. The sample consists of all patents ever awarded to a randomly drawn group of 561 patentees (whose surnames began with the letter 'B') from the total population of patentees in 1870-71 (cohort 1), 1890-91 (cohort 2), and 1910-11 (cohort 3). Panel A presents the distribution of patents for U.S. residents and Panel B presents the distribution for one patent per patentee, where the patent is selected randomly from the patentee's record. We estimated the total number of career patents for each patentee in the sample by searching the annual reports 25 years before their cohort and 25 years afterward. We were quite conservative in estimating the number of different assignees, and thus we believe our figures underestimate the extent of contractual mobility.

TABLE 3

CHANGES OVER COHORTS IN CONTRACTUAL MOBILITY:

DISTRIBUTIONS OF PATENTEES WITHIN REGION

		Region of Patentee				
		N. Eng.	Mid Atl.	E. N.Cent	Oth U.S.	
		col. (%)	col. (%)	col. (%)	col. (%)	n
No Assignees	c1	51.2	64.8	60.5	57.1	87
	c2	25.7	42.4	36.7	41.7	69
	c3	34.8	48.4	55.0	60.4	111
1 Assignee	c1	39.0	18.5	26.3	14.3	38
	c2	28.6	12.1	38.3	33.3	49
	c3	17.4	29.0	13.8	27.1	46
2-3 Different Assignees	c1	2.4	9.3	5.3	21.4	11
	c2	25.7	25.8	16.7	12.5	39
	c3	34.8	12.9	18.8	10.4	36
4+ Different Assignees	c1	7.3	7.4	7.9	7.1	11
	c2	20.0	19.7	8.3	12.5	28
	c3	13.0	9.7	12.5	2.1	20
n	c1	41	54	38	14	147
	c2	35	66	60	24	185
	c3	23	62	80	48	213

Notes and Sources: These estimates were computed from the patentees in the 'B' sample that were residing in the U.S.. The sample consists of all patents ever awarded to a randomly drawn group of 561 patentees (whose surnames began with the letter 'B') from the total population of patentees in 1870-71 (cohort 1), 1890-91 (cohort 2), and 1910-11 (cohort 3). Panel A presents the distribution of patents for U.S. residents and Panel B presents the distribution for one patent per patentee, where the patent is selected randomly from the patentee's record. We estimated the total number of career patents for each patentee in the sample by searching the annual reports 25 years before their cohort and 25 years afterward. We were quite conservative in estimating the number of different assignees, and thus we believe our figures underestimate the extent of contractual mobility.

TABLE 4

DISTRIBUTION OF PATENTS BY ASSIGNEE TYPE AND CAREER PATENTS:

BY COHORTS, 1870-71, 1890-91, AND 1910-11

		Categories of Patentees By Career Patents			
		1-2 Pats	3-5 Pats	6-9 Pats	10+ Pats
		col. (%)	col. (%)	col. (%)	col. (%)
Not Assigned	c1	82.4	88.6	87.7	75.3
	c2	72.9	70.5	60.6	45.6
	c3	85.0	78.1	57.5	37.6
Individual – Share	c1	10.3	3.6	4.1	5.5
	c2	10.0	11.6	12.8	3.9
	c3	7.5	6.5	5.8	2.6
Individual – Full	c1	2.9	5.0	2.5	8.8
	c2	2.9	8.5	6.4	9.6
	c3	1.5	3.2	1.7	3.0
Family-Name Co.	c1	-	-	-	1.7
	c2	-	1.6	3.7	6.1
	c3	-	-	5.8	23.5
Large Integrated Co. (R & D labs)	c1	-	-	0.8	1.2
	c2	1.4	-	0.5	9.9
	c3	-	1.9	-	14.1
Other Local Co.	c1	1.5	0.7	2.5	4.5
	c2	10.0	3.9	5.3	15.9
	c3	1.5	3.9	15.8	8.0
Other Companies	c1	2.9	2.1	2.5	2.9
	c2	4.3	3.9	10.6	9.0
	c3	3.9	6.5	13.3	6.7
n		68	140	122	749
		70	129	188	2060
		133	155	120	1860

Notes and Sources: These estimates were computed over the records of patenting by the patentees from the "B" sample with 10 or more career patents that were residing in the U.S.. The "B" sample consists of all patents awarded over a fifty -year period to a randomly drawn group of 561 patentees (whose surnames began with the letter 'B') from the total population of patentees in 1870-71 (cohort 1), 1890-91 (cohort 2), and 1910-11 (cohort 3). We assembled the list of patents by searching annual reports for 25 years before and 25 years after the cohort the patentee was drawn from. The figures for assignments to foreign companies are not reported in the table, but counted when computing the percentages.

TABLE 5

THE ASSIGNMENT OF PATENTS AT ISSUE:
BY COHORT AND STAGE OF CAREER
OVER PATENTEES WITH 10 OR MORE CAREER PATENTS

		Stage of Career		
		<=5 years since 1st pat	>5 and <=15 yrs since 1st pat	>15years since 1st pat
		col. %	**col. %**	**col. %**
Not Assigned	c1	81.9	75.3	68.9
	c2	62.0	52.7	36.6
	c3	45.6	50.3	29.7
Individual – Share	c1	6.2	6.7	3.6
	c2	4.0	5.4	3.0
	c3	6.9	4.0	0.8
Individual – Full	c1	4.1	11.4	10.8
	c2	12.1	11.1	8.0
	c3	7.2	3.1	1.8
Family-Name Co.	c1	0.4	0.0	4.8
	c2	2.2	4.2	8.4
	c3	1.3	17.1	32.6
Large Integrated Co. (R & D labs)	c1	0.0	0.0	0.0
	c2	7.1	6.3	12.9
	c3	12.1	7.3	17.8
Other Local Co.	c1	6.6	3.1	7.6
	c2	8.4	15.1	18.6
	c3	17.1	11.7	3.8
Other Companies	c1	0.8	3.5	4.4
	c2	4.3	5.4	12.6
	c3	9.8	6.5	5.9
n		243	255	251
		323	651	1086
		305	479	1076

Notes and Sources: These estimates were computed over the records of patenting by the patentees from the "B" sample with 10 or more career patents that were residing in the U.S.. The "B" sample consists of all patents awarded over a fifty -year period to a randomly drawn group of 561 patentees (whose surnames began with the letter 'B') from the total population of patentees in 1870-71 (cohort 1), 1890-91 (cohort 2), and 1910-11 (cohort 3). We assembled the list of patents by searching annual reports for 25 years before and 25 years after the cohort the patentee was drawn from. The figures for assignments to foreign companies are not reported in the table, but were counted when computing the percentages.

TABLE 6

ASSIGNEE TYPE BY COHORT AND REGION

		New England	Mid. Atlantic	E. No. Central
		col. (%)	col. (%)	col. (%)
Not Assigned	c1	76.1	75.6	83.0
	c2	24.7	58.1	51.3
	c3	35.0	38.1	44.6
Individual – Share	c1	3.7	5.5	8.3
	c2	3.8	5.3	4.8
	c3	3.7	2.0	3.1
Individual – Full	c1	10.6	8.3	2.3
	c2	7.8	4.5	18.3
	c3	5.2	3.2	2.1
Family-Name Co.	c1	0.6	2.3	0.5
	c2	3.4	5.0	6.8
	c3	23.0	2.7	31.4
Large Integrated Co.	c1	-	-	-
	c2	15.5	9.4	3.8
	c3	23.0	22.1	4.1
Other Local Co.	c1	7.5	3.9	1.0
	c2	30.8	9.5	10.6
	c3	3.7	8.2	8.4
Other Companies	c1	1.6	4.4	-
	c2	14.1	8.2	4.4
	c3	6.5	23.8	6.4
n		322	434	218
		555	947	707
		383	601	1050

Notes and Sources: These estimates were computed over the records of patenting by the patentees from the "B" sample with 10 or more career p atents that were residing in the U.S.. The "B" sample consists of all patents awarded over a fifty -year period to a randomly drawn group of 561 patentees (whose surnames began with the letter 'B') from the total population of patentees in 1870-71 (cohort 1), 1890-91 (cohort 2), and 1910-11 (cohort 3). We assembled the list of patents by searching annual reports for 25 years before and 25 years after the cohort the patentee was drawn from. The figures for assignments to foreign companies are included in the category for "other companies".

TABLE 7

THE ASSIGNMENT OF PATENTS AT ISSUE:

TWO GROUPS OF ACTIVE INVENTORS FROM CLEVELAND: 1892-1912 and 1910-192

	No Assignment	Individuals	Company Where Patentee Principal	National Company	Local Company	Other Company	TOTAL
35 patentees from 1898-1902, and followed 1892-1912	395 47.1%	30 3.6%	148 17.6%	95 11.3%	77 9.2%	90 10.7%	839
107 patentees from 1910-12, and followed 1910-12	271 44.8%	27.5 4.5%	118.5 19.6%	121 20.0%	58 9.6%	10 1.7%	606

Notes and Sources: The groups of active inventors were selected using similar procedures, but their records of patenting employed for constructing these estimates extend over different lengths of time. The first group consists primarily of inventors who received a patent in 1900, and had a total of at least three patents in 1898, 1900, and 1902. There are a few other inventors included in this group on the basis of their being listed as inventors in the Dictionary of American Biography and resident in Cleveland at some poin in their patenting career. The patent record for this group includes all of the patents they were awarded between 1892 and 1912 inclusive, except for the years 1895, 1901, and 1904. The second group consists of patentees who received a patent in 1912, and at least three patents during 1910, 1911, and 1912.

TABLE 8

THE ASSIGNMENT OF PATENTS AT ISSUE:

BY ACTIVE INVENTORS FROM CLEVELAND, 1892-1912

Total patents	No Assignment	Individuals	Company Where Patentee Principal	National Company	Local Company	Other Company	TOTAL
1-5 patents 6 inventors 1 is principal	9 60.0%	2 13.3%	--	--	4 26.7%	--	15 1.8%
6-15 patents 9 inventors 5 principals	41 49.4%	6 7.2%	21 25.3%	--	14 16.9%	1 1.2%	83 9.9%
>15 patents and all principals (n=13)	269 61.0%	14 3.2%	116 26.3%	9 2.0%	25 5.7%	4 0.9%	441 52.6%
>15 patents and not a principal (n=7)	76 25.3%	8 2.7%	11 3.7%	86 28.7%	34 11.3%	85 28.3%	300 35.8%
	395 47.1%	30 3.6%	148 17.6%	95 11.3%	77 9.2%	90 10.7%	839

Notes and Sources: See the note to Table 7. The small number of assignments made by patentees classified as non-principals to firms in which the patentee was a principal involve cases where that status was rather brief.

Table 9

Banks, Savings & Loans, and Trust Companies

Year	Number of Chartered Banks, Savings & Loans, and Trust Companies	Total Deposits
1816	1	
1821	0	
1832	1	
1834	2	
1837	2	
1845	4	
1849	5	
1853	7	
1854	6	
1863	6	
1869	7	
1890	31	$ 54.8 million
1900	50	144.7 million
1910	31	254.0 million
1920	38	820.5 million
1930	17	1,075.5 million
1934	8	524.3 million

Table 10

Cleveland Trust Company
Bond Underwriting 1903-1908

Date	Company	Amount of Bond Issue ($000)
	Wellman-Seaver-Morgan Company	
May-03		800
May-03	Frisbie Company	50
September-03	Long Arm System	250
October-03	Wellman-Seaver-Morgan Company	400
October-03	Dow Chemical Company	300
April-04	Detroit Iron & Steel	400
May-04	Addresso Printograph Co	15
May-04	Falls Rivet & Machinery Co	500
June-04	General Cartage & Storage Co.	200
July-04	Interstate Foundry Co	100
July-04	Continental Sugar Co	250
July-04	Goodyear Tire and Rubber	300
July-04	Federal Package Co	35
January-05	American Rwy Signal Co	25
February-05	Ohio Baking Co	350
March-05	Stark-Tuscarawas Breweries	1500
April-05	United Special Machine Co	20
June-05	Alliance Brewing Co	60
August-05	Ashland Steel Rang & Mfg Co	50
October-05	Wellman-Seaver-Morgan Company	1100
November-05	Kansas City Breweries Co	3500
December-05	Commercial Adding Machine Co	30
March-06	Independent Ice Co	270
	Cleveland Walker-Gordon Laboratory Co	
April-06		15
April-06	Federal-Harris Mfg Co	125
September-06	Horton Mfg. Co	25
September-06	Painesville Veneer Co	8
July-07	Independent Breweries of St. Louis	8000
		18,678