The Reorganization of Inventive Activity in the United States in the Early Twentieth Century

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Abstract: The standard view of U.S. technological history is that the locus of invention shifted during the early twentieth century to large firms whose in-house research laboratories were superior sites for advancing the complex technologies of the second industrial revolution. In recent years, this view has been subject to increasing criticism. At the same time, new research on equity markets during the early twentieth century suggests that smaller, more entrepreneurial enterprises were finding it easier to gain financial backing for technological discovery. We use data on the assignment (sale or transfer) of patents to explore the extent to which, and how, inventive activity was reorganized during this period. We find that two alternative modes of technological discovery developed in parallel during the early twentieth century. The first, concentrated in the Middle Atlantic region, centered on large firms which seem to have owed their prominence less to R&D labs than to their superior access to the region's rapidly growing equity markets. The other, located mainly in the East North Central region, consisted of smaller, more entrepreneurial enterprises that drew primarily on local sources of funds. Both modes seem to have made roughly equivalent contributions to technological change during this period.

The Reorganization of Inventive Activity in the United States in the Early Twentieth Century

According to the standard view of U.S. technological history, inventive activity was reorganized in early twentieth century. Individuals had dominated the process of technological discovery in the late nineteenth century, an era that the great historian Thomas Hughes dubbed the golden age of the independent inventor (Hughes 1989). As the economy shifted from the mechanical technologies of the first industrial revolution to the science-based technologies of the second, however, the capital requirements (both human and physical) for successful invention soared. Large firms were better able to muster the resources needed for technological discovery, and the in-house research laboratories they built after the turn of the century enabled them, in Joseph Schumpeter's words (1942), so completely to routinize innovation that advances were realized "as a matter of course." Although individual inventors never completely disappeared, they came to play a secondary role in technological change, as did the small entrepreneurial enterprises with which they were often associated.

There is, however, another literature on the early twentieth century that has very different implications for our understanding of trends in the location of innovative activity. This literature focuses on capital markets and portrays the early twentieth century as a period when more and more Americans were investing their savings in equities and, as a result, a broader range of companies was able to raise capital from the general public (see, for example, O'Sullivan 2007). The implication is that improved access to finance made it possible for small- and medium-sized enterprises (SMEs) to continue to make important contributions to technological discovery, even as the capital requirements for effective invention rose.

Until recently the technological history of the twentieth century has been written as if this second literature did not exist—as if the only story was the shift toward large-firm R&D. The tide is now turning, and there are a growing number of studies questioning both the advantages of large firms' in-house research laboratories and whether the labs were ever really the dominant source of new technological discoveries. Thus far, however, the evidence offered in support of this revisionist view has been mainly anecdotal. The purpose of this paper is to bring systematic evidence to bear on these questions, using data on the assignment (that is, sale or transfer) of patents.

In the next section of the paper we review the literature on the rise of large-firm R&D, as well as recent studies that have led to a reassessment of the value of in-house research labs. We then survey the literature on equity markets and discuss its implications for understanding the reorganization of technological change during the early twentieth century. After a brief section describing our data sources, we move on to an investigation of whether the patterns in the assignment data are consistent with the view that large firms were increasingly dominating the process of technological discovery. We find that large firms with industrial research labs accounted for a rising share of patents during this period but that so did small entrepreneurial enterprises. Indeed, these two alternative modes of organizing technological discovery seem to have developed in parallel in different regions of the country. Large firms accounted for the lion's share of the inventions in the Middle Atlantic, though our evidence raises doubts about whether their prominence (at least during this period) owed much to their R&D labs. By contrast, in the East North Central region smaller, more entrepreneurial enterprises predominated. To the extent that these latter firms benefited from the growth of financial markets, the relevant institutions seem to have been regional exchanges that drew primarily on local sources of capital. In our conclusion we suggest that large firms would later come to dominate technological discovery, but that the change was more a function of the Great Depression and government policy during the Second World War than of the inherent superiority of in-house R&D.

The Literature on Industrial Research Labs and Securities Markets

Until the last decade or two, most economists and business historians would have agreed with Schumpeter (1942) that large firms had become the drivers of innovation in the U.S. economy.[1] The avidity with which large firms built industrial research laboratories from the 1920s into the 1960s (see Mowery and Rosenberg 1989) certainly indicates that their executives thought the labs were a superior way of organizing technological discovery. Moreover, there seemed to be good theoretical reasons to believe they were right. In the first place, scholars argued, the electro-chemical technologies of the second industrial revolution were much more complex than the mechanical technologies of the first. As a consequence, not only did successful invention require much greater investments in both physical and human capital, it required the kind of coordinated teamwork at which industrial research labs excelled. Second, inventors are better able to solve production problems or create new products that consumers want to buy if they have access to knowledge gained in manufacturing and marketing. Because this kind of knowledge is largely firm-specific, it is not easily acquired by outsiders, but, scholars have argued, it can readily be transmitted to researchers in a firm's own R&D facilities. Third, in-house R&D can solve the information problems that impede the commercialization of new technologies by making it difficult for independent inventors to find buyers for their inventions.

[1] Examples from widely disparate parts of the literature include Jewkes, Sawers and Stillerman 1958; Chandler 1977; Hughes 1989; Lazonick 1991; Teece 1993; Cohen and Klepper 1996.

Before buyers will invest in a technology, they need to be able to estimate its value—to assess, for example, the extent to which a new process will lower production costs, or whether a novel product is likely to appeal to consumers. But sellers of inventions have to worry that buyers will steal their ideas, so they may not be willing to reveal enough information about their discoveries to effectuate a sale. These problems can be avoided by moving the process of technological discovery in-house.[2]

Of course, there were always dissenters who argued that the value of in-house R&D for large firms was less a matter of efficiency than of market dominance through the control of important technologies (see, for example, Reich 1977, 1980, and 1985). There was also a large literature that questioned the relationship between firm size and innovation and suggested that most big businesses were considerably larger than the threshold at which size mattered (see, for example, Scherer 1965 and Cohen, Levin, and Mowery 1987). However, it was not until the 1990s, when large firms began to cut back their R&D expenditures and even shut down their labs, that scholars began seriously to question the idea that in-house R&D was a superior way of organizing technological discovery (Rosenbloom and Spencer 1996). As some then pointed out, there were important information and contracting problems associated with the movement of R&D in-house that were different from those that afflicted the market exchange of technological ideas but potentially just as troublesome. In order to learn about and gain control of new technologies developed in their facilities, for example, firms had to invest in monitoring their employees' activities and to create incentives that aligned employees' interests with those of the firms. It soon became apparent, however, that it was not easy to design a reward structure that induced employees to work hard at generating new technological ideas without discouraging

[2] For examples of scholars who have made these arguments, see Nelson 1959, Arrow 1962, Teece 1986 and 1988, Mowery 1988 and 1995, Hughes 1989, and Zeckhauser 1996.

cooperation and the sharing of information within the firm (Lamoreaux and Sokoloff 1999). The problems of managing research employees were greatly magnified, moreover, when firms started hiring academically trained scientists who wanted to raise their status in the academic community by publishing discoveries their employers would prefer to keep proprietary and who were more interested in working on scientifically interesting problems than in improving their firm's bottom line (Leslie 1980, Wise 1985; Smith and Hounshell 1984, Hounshell and Smith 1988). In addition, the informational advantages of locating R&D inside the firm turned out not to be as great as expected because research labs were often sited at a remove from the company's other facilities. It required considerable and continuous managerial effort to keep communication flowing across the different units of the firm (Hounshell and Smith 1988, Usselman 2007; Lipartito 2009).

At the same time as scholars were highlighting the problems faced by industrial research laboratories, they were also showing that the difficulties associated with transacting for technology in the marketplace were not as great as hitherto believed. Although patent rights are never perfectly enforced, they provide enough protection to inventors to enable them to engage in market exchange. Moreover, there are a number of ways to solve the information problems that still may impede trade. Firms seeking to purchase outside technologies can invest in facilities for assessing them and can develop a reputation for safeguarding inventors' interests; intermediaries can emerge who possess the trust of parties on both sides of the market; and talented inventors can establish track records that give buyers confidence in the worth of their discoveries (Gans and Sterns 2003; Lamoreaux and Sokoloff 2007). Naomi Lamoreaux and Kenneth Sokoloff (1996, 2001, and 2003) demonstrated that a vibrant trade in patented inventions developed during the second half of the nineteenth century, intermediated by patent agents and lawyers, that enabled talented independent inventors to specialize in technological discovery. Steven Usselman (2002) and Stephen Adams and Orville Butler (1999) provided examples of firms that built reputations that encouraged inventors to bring them their ideas. Ashish Arora, Andrea Fosfui, and Alfonso Gambardella (2001) documented the revival of trade in patented technology in high tech industries in the late twentieth century. Moreover, scholars have uncovered considerable evidence that large firms continued to purchase inventions from outsiders even after they created industrial research laboratories. Indeed, David Mowery (1995) has argued that the original function of most in-house R&D facilities was to keep abreast of (and vet for purchase) externally generated technology (see also Lamoreaux and Sokoloff 1995 and 2007). Large firms became more inward-looking over time, he hypothesizes, because that was a way to reduce their risk of prosecution under the anti-trust laws. Tom Nicholas (2009) has used geo-coded data on the location of inventors and research labs to show that a significant fraction of the most valuable patents acquired by large firms during the 1920s were most likely *not* generated in the firms' research laboratories. Eric Hintz (2007) has provided case-study evidence showing that, even in the heyday of the industrial research lab in the 1950s, large firms transacted for important technologies with outside inventors who insisted on maintaining their independence.

If the 1920s was the decade when large firms first began to build industrial research laboratories in significant numbers, it was also the decade when the securities markets began to channel funds to firms on the technological cutting edge. During the nineteenth century, trading on the markets was pretty much limited to the securities of banks, railroads (bonds, not equities), other transportation companies, and utilities (Navin and Sears 1955; Cull, et al. 2006). The number of industrials whose securities were listed on the New York Stock Exchange could be counted on one's fingers, and the number whose unlisted securities traded in New York was also very low (Baskin and Miranti 1997). Industrials had a greater presence on regional exchanges such as Boston's, but even there their shares traded only infrequently (Martin 1898). The general view among scholars is that problems of asymmetric information limited the public's appetite for equities. Markets were unregulated, firms reported little information about their affairs, and insiders manipulated both the flow of information and corporate decisions to their advantage (De Long 1991, Baskin and Miranti 1997, White 2003). Even the savvy could get taken, as Commodore Vanderbilt found when officers of the Erie Railroad responded to his attempt to buy control by cranking up the printing press and turning out more and more Erie stock (Adams 1869).

By the turn of the century, however, private parties with an interest in expanding the reach of the securities markets were taking steps to increase the confidence of investors. The New York Stock Exchange, for example, instituted a rule change in 1896 requiring firms listed on the exchange to publish audited balance sheets. A few firms had already begun to provide this kind of information on their own, but the new rule helped to make the exchange an imprimatur of quality, increasing trading, the value of listed shares, and not coincidentally, the price of a seat on the exchange (Neal and Davis 2007). At the same time, investment bankers such as J. P. Morgan exploited the reputations for probity they had built up over the years to expand the market for specific securities. Morgan had worked out a technique for building investors' confidence when he reorganized bankrupt railroads during the 1890s, putting his own people on the boards of directors to reassure stockholders that the business would be run in their interests (Carosso 1987). The railroads' return to profitability enhanced his reputation, and Morgan used the same method to promote the securities of the giant consolidations he orchestrated at the turn of the century. Studies by J. Bradford De Long (1991) and Miguel Simon (1998) suggest that stockholders responded by flocking to buy the securities of "Morganized" firms and also typically profited handsomely from their purchases.

This record of profitability whetted investors' appetites for securities, but it was not until the 1920s that the market really expanded. Investment bankers had developed new techniques during World War I to sell Liberty Bonds. When, with the return of "normalcy" in the 1920s, it became apparent that there was money to be made in securities, aggressive new investment banking houses applied these techniques to the sale of equities. Eager to enter this business, commercial banks circumvented laws that prevented them from dealing in stocks by setting up affiliates to sell securities to their customers. At the same time, enterprising financiers brought large numbers of small investors into the market for the first time by creating new investment vehicles that gave them access to diversified portfolios. The most important of these new vehicles, the investment trust, served much the same purpose as mutual funds do today (Carosso 1970; White 1984 and 1990; De Long 1991; O'Sullivan 2007). Investment was also fueled during this period by competition between the NYSE and the New York Curb Exchange, which (like the NASDAQ more recently) specialized in issues of newer firms in technologically dynamic industries, by the growth of regional exchanges such as Cleveland's, which promoted the securities of local enterprises, and by the development of a national network of dealers that sold securities "over the counter" (O'Sullivan 2007; Lamoreaux, Levenstein, and Sokoloff 2006 and 2007; Federer 2008).

As investors lapped up what the bankers initially had to offer, firms began to issue more and more new securities. Mary O'Sullivan (2007) has shown that the number and size of new corporate stock issues soared in the early twentieth century, reaching levels during the late 1920s that in real terms were not reached again until the 1980s. Even if one leaves out the bubble years of 1928 and 1929, issues were higher as a proportion of GDP during the 1910s and 1920s than in any other period of American history except the recent dot-com boom. Moreover, the great bulk of the issues during the Great Bull Market consisted of common stock, with investors for the first time seeking to profit primarily from a run-up in share prices.

It might be expected that the primary beneficiaries of this growth in the securities markets would be large, well-established firms, for the simple reason that investors could readily gather information about them (Calomiris 1995). Certainly, as Tom Nicholas (2003, 2007, and 2009) has shown, during the 1920s investors particularly favored the equities of large firms with R&D facilities and substantial portfolios of patents in cutting-edge technologies (see also White 1990). But there is also evidence that this appetite for technology stocks spilled over to smaller firms. The most obvious is the enormous expansion in the number of firms about which the financial press reported information. Whereas only a handful of industrials were even mentioned in the pages of the *Commercial and Financial Chronicle* in the 1890s, during the late 1920s Moody's devoted more than three thousand pages of its annual securities manual to financial information on an even greater number of individual industrial enterprises. O'Sullivan (2007) has shown that investors were particularly supportive of firms in "high-tech" industries such as radios and aviation. The advent of commercial broadcasting stimulated a craze for radio stocks during the early 1920s that led to so many IPOs that wags estimated the number of new shares to be about equal to the number of radios sold. Similarly, after Lindberg's transatlantic flight captured the public's attention, soaring interest in aviation stocks elicited about 125 additional offerings of securities, many of them from new entrants to the industry. O'Sullivan calculated that the medium age of the issuers was only 0.4 years! Most of the new securities promoted during the

1920s were not listed on the NYSE, but were instead traded on regional exchanges, on the curb market, over the counter, or through more informal channels.

The implication of the literature on the growth of equity markets is that SMEs on the technological cutting edge were increasingly able to tap into broader capital markets to finance their inventive activities. This implication, however, is difficult to square with the standard argument that industrial research laboratories had already begun to displace entrepreneurial enterprises as a locus of technological discovery by the late 1920s. Support for both views is largely anecdotal, however. In the rest of the paper we bring systematic evidence to bear on this puzzle. Our aim is to determine whether there was a reorganization of technological discovery during the early twentieth century in favor of large firms or whether SMEs (and perhaps also independent inventors) continued to play an important role in the generation and exploitation of new technologies.

Data Sources

We approach this problem through the analysis of patent data.[3] The starting point for our analysis is four random cross-sectional samples of patents that we drew from the *Annual Reports of the Commissioner of Patents* for the years 1870-71, 1890-91, 1910-11, and 1928-29. For each

[3] We recognize that some scholars would object that large firms often eschewed patenting in favor of secrecy, taking advantage of the new legal protections for trade secrets that emerged in the early twentieth century (Fisk 2001), but we see no reason to assume a priori that large firms were more likely to favor secrecy than small firms. Indeed, economists working on late twentieth-century data have sometimes found the opposite. Using survey data, they have shown, for example, that small enterprises worry that they will be not be able to protect their intellectual property against infringement by large firms—that they will be for all practical purposes defenseless against giants with the resources to hire the best legal talent (Lerner 1995; Cohen, Nelson, and Walsh 2002; Arora and Cohen 2007). Some scholars might also object that large firms devoted a significant proportion of their R&D resources to systematizing and elaborating new technologies in ways that often were not patentable (see Usselman 2002 on the railroads, for example). That may well have been the case, but our primary aim in this paper is to understand whether large firms with R&D facilities were the dominant source of new technological discoveries by the late 1920s.

patent in the samples we recorded a brief description of the invention, the name and location of the patentee(s), and the names and locations of any assignees who obtained rights to the invention before the patent was actually issued. We then linked the patents to other information we collected on the assignees to whom the patentees transferred their patent rights. For example, we looked up each company that received a patent in the directories of industrial research laboratories compiled by the National Research Council (NRC). We also collected information about companies receiving patents from financial publications: the *Commercial and Financial Chronicle* for the 1870-71 and 1890-91 cross-sections; *Poor's Manual of Industrials* for 1910-11; and *Moody's Manual* for 1928-29. Finally, we looked up both individual and company assignees wherever possible in city directories.

The information in these financial publications and city directories enabled us to classify a large number of the companies who obtained patents by size, measured in terms of the firms' total assets (or in a few cases, total capitalization). We were also able to determine for a large number of firms whether the inventor was an officer, director, or proprietor of the company to which he (or in rare cases she) assigned the patent. Our basic method is to use this information to look for changes over time in the relationship between patentees and their assignees and in the types of companies obtaining assignments. Were inventors increasingly less likely over time to be principals in the firms obtaining their patents? Were they more likely to be employees? Was there a shift over time in the types of firms obtaining assignments toward very large firms or toward firms with in-house research laboratories? Following a method pioneered by Nicholas (2003), we use the NBER database of citations by patents granted from 1975-2002 to weight patents by quality so we can assess whether patents assigned to large firms were generally more valuable than those going to other kinds of enterprises. In future work, we will also use the number of claims granted in a patent as a measure of its importance.[4]

Evidence on Large-Firm R&D

If there was a reorganization of inventive activity in the early twentieth century in favor of large firms with their own R&D facilities, one would expect to find, first of all, that inventors were assigning an increasing proportion of their patents to companies by the time of issue, and second, that large firms with research labs would account for a growing proportion of patent assignments. Certainly, the evidence bears the first expectation out. As Table 1 shows, the fraction of patents assigned at issue increased quite steeply over time, rising from about 16 percent in the 1870-71 cross section to 56 percent in 1928-29, with about 87 percent of assignments at issue in the latter period going to companies. The proportion of patents that went to large companies also increased dramatically. For the 1928-29 cross section, the proportion going to companies that Moody's reported as having assets of at least $10 million was 19 percent, and fully 15 percent went to companies in that category that were listed by the NRC as having industrial research labs.[5]

These last figures represented a significant increase over those for 1910-11, when few large firms had their own research laboratories and the proportion of patents that went to firms

[4] We are also currently updating our longitudinal sample in which we collect all the career patents of a subset of patentees from each cross-section to include the 1928-29 sample. We will add an analysis of this dataset to the next version of this paper.

[5] It is important to bear in mind that assignments to companies can come from outside inventors as well as from employees, so our figures overestimate the proportion of patents generated by the firms concerned. We only include in our analysis utility patents granted to residents of the United States. Adding patents awarded to foreigners would not change the analysis because there were so few of them. Even in 1930, there were only about 40. Intriguingly, somewhat more of them were acquired by firms not reported in Moody's than by large firms. We also exclude from the analysis the small number of patents that were assigned to foreign companies and the small number of patents that were reissued.

with more than $10 million in assets was only 3 percent.[6] The question, however, is whether the 1928-29 numbers are large enough to make the case that such enterprises were coming to dominate the process of technological discovery. Over the same period, the proportion of patents assigned to companies for which no financial information was reported also rose—from 14 to 25 percent—so, it would seem that small firms were more than holding their own as generators of patentable technology. Of course it is possible that the small firms' patents were in different industries from those assigned to large firms with industrial research labs—that they were less "high tech," for example. It is also possible that they were less important.

Taking the question of importance first, we find no evidence that the patents acquired by large firms with industrial research laboratories were more significant on average than those acquired by smaller firms. Admittedly, it is difficult to measure the importance of patents in the early twentieth century, when no renewal system was in place and it was not yet common practice for inventors to cite prior art in their applications for patents. Following Nicholas (2003), we use information on whether or not a patent in our sample was cited much later on (by a patent granted between 1975 and 2002) as a measure of its importance. Intriguingly, the citation results do not favor large firms with industrial research laboratories. Only 24 percent of the patents assigned at issue in 1928-29 to this type of firm were cited by a patent granted between 1975 and 2002, whereas the proportion for firms for which no financial information was reported was 31 percent (see Table 2, panel A).[7] Perhaps even more surprising, the proportion was even higher for patents not assigned at issue. Indeed, 48 percent of the cited patents in this cross section were not assigned at issue (see Table 3, panel A), suggesting that the inventors may

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

[7] None of our results change when we use the number of later citations as a measure of importance rather than simply whether or not the patent was ever cited.

have decided to retain control of many of their most valuable discoveries in order better to profit from their exploitation. This finding fits with work by Lamoreaux, Levenstein, and Sokoloff (2006 and 2007), which showed that inventors associated with entrepreneurial start-ups in the Cleveland region often had considerable bargaining power vis-à-vis their financial backers and maintained that power by licensing rather than assigning their patent rights to their companies. The result for large firms also fits with evidence that firms like the American Telephone and Telegraph Company (AT&T) patented virtually all the inventions (whether important or not) devised by their employees for morale reasons and because even minor patents could be useful for blocking rivals' incursions in their markets (Lamoreaux and Sokoloff 1999; Reich 1977, 1980, and 1985).

Regression analysis of the 1928-29 sample confirms these results. So as better to compare the performance of different types of enterprises, we restrict the analysis to patents assigned at issue to companies. The dependent variable is a dummy that takes a value of one if the patent was cited by a patent awarded in 1975-2002. Independent variables are dummies for the firms' size in terms of total assets (the omitted category is firms for which no financial information was reported in Moody's), whether the NRC listed the firm as having an industrial research lab, whether the inventor was an officer, director, or proprietor of the firm (which we take to be an indicator of the firm's entrepreneurial character), the region in which the assignee was located, and whether the patent was in a high-tech industry of the time (which we define to be electrical machinery and products, chemicals, petroleum, plastics and rubber, automobiles, primary metals, mining machinery, and transportation equipment). As the first three columns of Table 4 show, none of these variables is statistically significant. Patents assigned to firms with more than $10 million in assets were no more likely to be cited at the end of the century than those that went to firms not included in Moody's. Firms with R&D labs were no more likely to acquire patents that would be cited later than those without. Nor were firms in which the inventor was a principal. Perhaps more surprisingly, patents in the high-tech industries of the time were no more likely to be cited than other patents. Indeed, the point estimates suggest that high-tech patents were actually somewhat less likely to be cited later on than were patents in other industries.

This last result in particular raises the question of whether citations from such a later period are an unbiased measure of importance at the time of the original patent. It is at least possible that technology was changing more rapidly in high-tech industries than in low-tech ones, making more inventions in these sectors obsolete and thus less likely to be relevant to patents granted in the late twentieth century. For example, Lee de Forest's patents for amplifiers were unquestionably important at the time, but because they use vacuum-tube technology they do not show up in the patents cited after 1974.[8] On the other hand, one could argue that patents in old industries circa 1930 were even more likely to be irrelevant in the late twentieth century and hence still less likely to be cited. Before the next draft of this paper, we plan to explore an alternative measures of importance that has been suggested in the literature—the number of claims allowed in each patent grant (Lanjouw and Schankerman 2004).

As for the question of whether the patents acquired by large firms with industrial research laboratories were more likely to be in high-tech industries than those acquired by firms operating below the financial radar screen, the answer is yes. For the years 1928-29, fully 76 percent of the patents acquired by the former were in high-tech industries, as opposed to 53 for firms not found in Moody's (Table 2, panel B). As the regressions in Table 4 show, moreover, whether

[8] We searched in Google patents for de Forest's patents that included the word "vacuum." Unlike de Forest's other patents, none of these were cited in the late twentieth century.

the firm had a research lab was more strongly associated with the type of technology than was the firm's size. In the first specification (column 4), the only variable that was significantly related to the type of technology was the dummy for research lab. (Evaluated at the mean, patents from firms with industrial research labs were 16 percent more likely to be in high-tech industries than other patents.) The interactions added to the specification (column 5) indicate that large firms with industrial research labs were more likely to acquire patents in high-tech industries than other firms with R&D facilities, though the relationship was not statistically significant. Controlling for region does not change the qualitative results, though the estimates in column 6 indicate that high-tech patents were more likely to be assigned to firms in the Middle Atlantic region, a point to which we will return later.

Before one leaps to the conclusion that large firms' industrial research laboratories were dominating inventive activity in the high tech sectors of the economy by the end of the 1920s, it is important to note that firms not included in Moody's still accounted for a substantial proportion of high-tech patents—27 percent, compared to 23 percent for large firms with research labs and 27 percent for all large firms (Table 3, panel B). Moreover, it is not at all clear how many of the patents acquired by large firms with R&D facilities actually originated in their labs. As Table 2 (panel B) shows, large firms were disproportionately high tech as early as 1910-11, before many of them had R&D labs. For the 1928-29 cross section, moreover, more than a quarter of the assignments to large firms with research labs came from patentees located in a different state from the company. This latter finding is consistent with that of Nicholas (2009).[9] It is also consistent with the argument (Mowery 1995, Lamoreaux and Sokoloff 1999)

[9] Nicholas found that a quarter of the inventions assigned during the 1920s to 69 large firms operating 94 industrial research labs came from inventors who resided beyond commuting distance of the labs. In the case of the General Electric Company (GE), Nicholas was able to check his list of inventors against employment records and found that about a fifth of the patents GE acquired came from outside inventors. Nicholas also found that the patents his 69

that the reason that many firms established R&D labs in the first place was to improve their ability to assess inventions offered for sale by outside inventors. To give one example, at the end of the First World War Standard Oil of New Jersey founded its first research department on the principle that "new ideas and inventions … would arise in the main from external sources, and that [its] primary job … would be to uncover these ideas, test them out, and carry them forward to some practical end"—not, as has been generally assumed, to foster "primary research" (Gibb and Knowlton 1956).

Finally, our data enable us to test one of the arguments that scholars have offered for the superiority of research laboratories—that they facilitated the teamwork required for effective innovation in the complex, science-based technologies of the second industrial revolution. If we take the presence of multiple inventors on a patent to be an indication of teamwork, we find that large firms, even those with industrial research laboratories, had only slightly more of it. 14 percent of the patents acquired by large firms with R&D facilities were granted to more than one inventor, as opposed to 11 percent of firms not included in Moody's (Table 2, panel C). That difference, however, is not statistically significant, as the regressions in Table 4 (columns 7 to 9) show. Indeed, in two of the specifications, the point estimates of the effect of R&D labs on whether a patent was collaborative were actually negative, though not statistically significant in either case.

To recap the results thus far, assignments to large firms with R&D facilities accounted for an increased proportion of patents by the late 1920s, but the share acquired by these firms was by no means overwhelming. Assignments to small firms without access to national capital markets still accounted for a significant (and growing) share of patents. Moreover, although the

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firms obtained from distant inventors were substantially more important on average (more likely to be cited by late twentieth century patents) than those acquired from inventors who lived within commuting distance of the labs.

lion's share of the patents acquired by large firms with research laboratories were in high-tech industries, small firms maintained a presence in those sectors that was fully equal to that of their big-business competitors. We find no evidence that the patents acquired by large firms with research labs were more important (as measured by later citations) than those acquired by firms in other categories, though this result might change when we experiment with alternative measures of importance. Nor does our evidence support the idea that R&D facilities improved the efficiency of invention by economizing on information or facilitating teamwork. Many of the patents acquired by big businesses came from inventors who were unlikely to be employees because they were located in a different state than the company, and there was no association between large-firm R&D and collaborative invention. Moreover, large firms were disproportionately acquiring high-tech patents already in 1910-11, when only a few of them had research labs. Indeed, the direction of the relationship between large firms' investments in industrial research labs and the generation of high-tech inventions is not at all clear. Rather than enabling large firms to dominate the process of technological discovery, research labs may instead have helped their managers make better decisions about which of the complicated technologies being proffered by small firms and outside inventors they should buy.

Evidence on Equity Markets

One important marker of the expanded access that SMEs had to capital markets was the enormous number of pages (more than 3,000 by the late 1920s) that Moody's devoted to reporting information about their securities offerings and balance sheets. If the easier access that entrepreneurial firms had to equity markets was providing them new resources for technological discovery, one might expect to find that the smaller category of firms reported in Moody's was accounting for an increasing share of patents. Although the share did increase over time, in 1928-29 it was still quite small: about 6 percent of patents, up from 3 percent in 1910-11 (Table 1). Unlike the case of large firms, where most of the assignments went to enterprises with R&D labs, most of the assignments to these “small cap” firms went to enterprises that did not show up in the NRC lists as having industrial research facilities. These firms also look very different from the larger firms in Moody’s in that a much greater share of the patents they acquired came from inventors who were also officers or directors of the enterprise (Table 2, panel D). In 1928-29, inventor principals generated 27 percent of the patents that went to small firms included in Moody’s, as opposed to only 5 percent of those going to large firms.[10] In other words, the small firms look much more entrepreneurial. Indeed, in terms of the proportion of patents that came from inventor-principals, the small firms reported in Moody’s look a lot more like those that were below the financial radar screen.[11] The proportions of their patents classified as high-tech were also very similar—51 percent and 53 percent, compared to 71 percent for large firms (Table 4, panel B).

The expansion of equity markets in the early twentieth century thus seems to have allowed some entrepreneurial firms to raise capital more broadly, but the quantitative weight of these firms in terms of the proportion of total patents they acquired was still rather modest compared to firms not included in Moody’s. The latter’s share of patents was not only considerably larger but was also increasing quite rapidly during the 1910s and 1920s (Table 1). It is, of course, possible that the promise of being able to go to capital markets down the road encouraged local financiers to invest in firms formed to exploit new technological discoveries

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[10] The comparisons in this paragraph of all “small cap” and all “large cap” firms can be calculated using the counts in Table 1 as weights to add up the subcategories in Table 2.

[11] For the firms not included in Moody’s, our figures on the proportion of inventors who were principals in the firms receiving their assignments are probably underestimates. We obtained this information by looking up the firms in city directories and thus were not able to check assignments to firms located in areas not covered by this source.

and thus accounts at least in part for the growth of this category of firms. It is also possible that this promise explains some of the sharp rise in the assignment rate between 1910-11 and 1928-29, because local investors may have put more pressure on inventors to assign their patents to the company in order to make it easier to attract external finance. Lamoreaux and Levenstein (2008) found such a change in entrepreneurial enterprises in Cleveland in the 1920s.

Although we do not have the ability to test these possibilities directly, we can get a better idea of the role that capital markets played in the organization of technological discovery by examining regional breakdowns of the data. One might expect that firms located in the vicinity of the nation's main capital markets in New York would have had more ready access to that source of funding because, all other things being equal, financiers would have superior information about nearby firms than about those farther away. Certainly, large firms located in the Middle Atlantic acquired a disproportionate share of the patents assigned to this class of firms in 1928-29. If entrepreneurial firms were similarly benefiting from access to Wall Street, one might expect assignment to such firms to have displayed much the same geographic pattern. As Table 5 shows, however, they did not. To the contrary, in 1928-29 the Middle Atlantic's share of patents that were assigned to small firms included in Moody's was less than half its share of patents assigned to the larger category of firms (23 percent compared to 52 percent). Indeed, as Table 6 shows, patents assigned to firms in the smaller size category were about twice as likely to go to enterprises in the East North Central region as they were to those in the Middle Atlantic (45 percent compared to 23 percent).

The reports in Moody's include information about the exchanges on which the companies' securities traded. Very few of the "small cap" firms were listed on the New York Stock Exchange. The securities of a few more traded on secondary markets in New York such as the Curb or the Producer Exchange. The majority, however, traded on regional exchanges such as Chicago, Detroit, Cincinnati, and Cleveland.[12] It seems that entrepreneurial firms found it easier to "go public" in markets in those outlying cities. Moreover, not only were assignments to firms with reported capital of less than $10 million more likely to occur in the East North Central than in the Middle Atlantic, but so were all assignments to firms in which the patentee was a principal. Approximately 44 percent of the assignments involving inventor-principals went to enterprises in the East North Central as opposed to 24 percent to the Middle Atlantic.[13] If we assume that the promise of being able to go public down the road was important for encouraging local investment in new ventures, the regional pattern suggests that large firms' dominance of the nation's main capital markets in New York may have crowded out smaller, entrepreneurial enterprises.

The proportion of patents in the East North Central region that were high-tech was about the same as in the Middle Atlantic, as was the proportion of patents deemed important by our citation measure (Table 5). By contrast, patenting in New England was much more likely to be associated with the older technologies of the first industrial revolution. The evidence thus suggests that two alternative ways of organizing high-tech inventions coexisted during the 1920s, each concentrated in a different region. On the one hand, assignments of patents to large firms disproportionately occurred in the Middle Atlantic, probably because access to the nation's most important capital markets was easier for businesses that located there. Large firms with R&D labs garnered the biggest share of the assignments in this region, though as we have seen, the direction of causation is not at all clear. On the other hand, assignments to entrepreneurial

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[12] We have not finished collecting this information, so we have not included precise numbers. But we do not expect the basic patterns to change.

[13] This gap is not the result of differences in the proportions of firms for which we are missing this information, which is about the same in the two regions.

enterprises—both the smaller category of firms included in Moody's and those in which the inventor was a principal—disproportionately occurred in the East North Central region. To the extent that such ventures received a stimulus from the growth of equity markets during the 1910s and 1920s, it was likely the regional exchanges that mattered. The boom on Wall Street seems to have mainly benefited large firms, which as Nicholas (2003, 2007, and 2008) has demonstrated, saw their stock prices soar along with their portfolios of patents.

Conclusion

We began this paper by discussing two literatures that have very different implications for our understanding of how the process of technological discovery was reorganized in the U.S. in the early twentieth century. On the one hand, the literature on the rise of industrial research labs claims that invention increasingly occurred in large firms' R&D facilities, where the ability to coordinate teams of researchers enhanced efficiency, as did better information flows between inventors and personnel in production and marketing. On the other hand, the literature on the growth of equity markets suggests that broadened access to funding enabled entrepreneurial firms to raise the capital they needed to play an ongoing role in technological discovery.

In this paper we used the systematic analysis of patent data to sort out these conflicting claims. We found that large firms with R&D labs obtained a growing share of patents by the end of the 1920s and that these patents were disproportionately in high-tech industries. But we also found that small firms accounted for an equivalent share of high-tech inventions during this period, and that the patents they acquired were just as likely as those of large firms to be important—that is, they were just as likely to be cited by late-twentieth-century patents. Moreover, our evidence leads us to downplay the role of industrial research labs during this period. The patents that went to large-firms were already disproportionately high-tech by 1910-11—when only a few of the giants had in-house R&D facilities—and, though most of the large firms in our sample built labs by the end of the 1920s, we find little evidence that these investments led them to organize discovery differently from small firms. For example, inventions acquired by large firms were no more likely to exhibit teamwork, as measured by the presence of more than one name on a patent, than those of small. And large firms still acquired a significant proportion of their patents from out-of-state inventors who would likely not have benefited from the superior flow of information inside the firm. As for entrepreneurial firms, we find that relatively few were located in the Middle Atlantic region, where they would have been best positioned to benefit from expanded access to the nation's main capital markets. Rather, those specializing in cutting-edge technologies were concentrated in the East North Central region. To extent that the expansion of capital markets mattered, therefore, attention should focus on regional exchanges such as Cleveland's.

The story that emerges from our data is that there were two high-tech regions in the U.S. in early twentieth century—the Middle Atlantic and the East North Central. The former region was dominated by large firms which, by the late 1920s, mostly had their own industrial research labs; the latter by entrepreneurial firms which mostly did not. Compared to large firms, these entrepreneurial ventures made approximately equivalent contributions to technological discovery during the 1920s, as measured by the number and importance of the high-tech patents they acquired. Why then have their contributions been ignored for so long?

The answer, we think, lies in the events of the Great Depression (see also Lamoreaux and Levenstein 2008). Figure 1 graphs five-year averages of patenting rates per million residents for different regions of the U.S. from 1900 to 1954. Not surprisingly, patenting rates in the Middle

Atlantic held up during the 1930s much better than those in the East North Central region.[14] The small-firm economy of latter region was hit particularly hard by the downturn, as were the local venture capitalists and financial institutions that had funded innovation during the 1920s. By contrast, the large firms located in the Middle Atlantic were both much less likely to fail and much less dependent on external financing.[15] Given the low levels of demand during the Great Depression, they did not find building new productive capacity very attractive, but they greatly expanded their investments in R&D (Bernstein 1987; Mowery and Rosenberg 1989). During World War II this trend was further encouraged (for all regions) by government policy (Blum 1976, Vatter 1985, Mowery and Rosenberg 1989). When the economy revived in the war's aftermath, therefore, the East North Central looked a lot more like the Middle Atlantic. Little remained of the alternative economy of 1920s, and the high-tech contributions that entrepreneurial Midwestern firms had made before the Great Depression have been largely erased from our historical memory. Instead, the scholarship of the late twentieth century has been written as if innovative regions such as Silicon Valley were something entirely new. Now that financial crises are once again buffeting the economy, it is useful to revisit this earlier history. The differential experience during the Great Depression of the large-firm economy of the Middle Atlantic and the entrepreneurial economy of the East North Central is an important reminder of the important role that macroeconomic shocks can play in the reorganization of technological discovery.

[14] Patenting rates in any given year reflect applications made several years before. Hence the rise in patenting rates in most regions during the early years of the depression was a consequence of inventions generated mainly in the late 1920s.

[15] On large firms' high survival rates from the 1920s to the 1960s, see Edwards 1975. See also Averitt 1968.

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Table 1. Distribution of Patents and Assignments by Type of Assignee, 1870-1929

		Distribution (row percentages)							Probability of being company assignment w.r.t. all assignment
				Assigned to company with financial report					
				Assets >=10 million		Assets <10 million			
Sample year	No. of observations	Not assigned	Assigned to individual	Had R&D lab	No R&D lab	Had R&D lab	No R&D lab	Assigned to other company	
Panel A: % of Patents									
1870-71	1,425	83.9	13.4	0.0	0.1	0.0	0.0	2.6	
1890-91	2,022	70.8	15.5	0.0	0.4	0.0	0.0	13.3	
1910-11	2,498	69.2	11.0	1.2	2.2	0.2	2.6	13.6	
1928-29	2,312	43.7	7.1	14.7	3.8	1.7	4.1	24.9	
Panel B: % of Assignments									
1870-71	229		83.4	0.0	0.4	0.0	0.0	16.2	0.17
1890-91	591		53.0	0.2	1.4	0.0	0.2	45.3	0.47
1910-11	770		35.8	4.0	7.1	0.5	8.4	44.0	0.64
1928-29	1,301		12.6	26.1	6.8	3.0	7.2	44.2	0.87

Sources and Notes: The observations are random samples of patents taken from the *Annual Reports of the Commissioner of Patents* for the years 1870-71, 1890-91, 1910-11, and 1928-29. We report only utility patents awarded to residents of the United States, excluding patents assigned to foreign companies and patents that were reissued. "Not assigned" means that the patent was not sold or otherwise transferred by the time it was issued. We break assignments at issue into categories according to the identity of the assignee: whether the assignee was an individual or a company, and if it was a company, whether it was a subject of a report in a financial publication (the *Commercial and Financial Chronicle* for the 1870-71 and 1890-91 cross sections; *Poor's Manual of Industrials* for 1910-11; and *Moody's Manual* for 1928-29. We divided companies for which financial reports existed into two classes according to the amount assets on their balance sheets. If no information on assets was reported, we used their total capitalization instead. Information on whether a company had a research lab came from the surveys published in the *Bulletin of the National Research Council* for 1921, 1927, and 1946. We considered the firm to have a research lab if it was listed as having one in a survey conducted before the year of the cross-sectional sample or if the 1946 survey, which included historical information, listed a founding date for the lab that was before the year of the cross section. A few firms in the category "other company" had industrial research labs, though to save space, we do not provide the breakdown in this table.

Table 2. Characteristics of Patents by Type of Assignee

Sample year	All patents	Not assigned	Assigned to individual	Assigned to company with financial report: Assets >=10 million: Had R&D lab	Assigned to company with financial report: Assets >=10 million: No R&D lab	Assigned to company with financial report: Assets <10 million: Had R&D lab	Assigned to company with financial report: Assets <10 million: No R&D lab	Assigned to other company
Panel A: Probability that patent was cited during 1975-2002								
1870-71	0.09	0.09	0.08	n.a.	0.00	n.a.	n.a.	0.03
1890-91	0.17	0.18	0.17	0.00	0.00	n.a.	0.00	0.13
1910-11	0.23	0.25	0.18	0.03	0.18	0.25	0.11	0.18
1928-29	0.33	0.36	0.35	0.24	0.31	0.33	0.29	0.31
Panel B: Probability that patent was high-tech								
1870-71	0.00			n.a.		n.a.	n.a.	
1890-91	0.00					n.a.		
1910-11	0.31	0.29	0.35	0.39	0.75	0.25	0.38	0.34
1928-29	0.49	0.36	0.59	0.76	0.51	0.56	0.49	0.53
Panel C: Probability that patent was collaborative								
1870-71	0.10	0.11	0.06	n.a.	0.00	n.a.	n.a.	0.11
1890-91	0.09	0.09	0.09	0.00	0.00	n.a.	0.00	0.08
1910-11	0.08	0.08	0.07	0.10	0.11	0.50	0.06	0.08
1928-29	0.10	0.07	0.14	0.14	0.08	0.10	0.12	0.11
Panel D: Probability that patentee was a principal of the company								
1870-71	0.01	n.a.	n.a.	n.a.	0.00	n.a.	n.a.	0.32
1890-91	0.04	n.a.	n.a.	0.00	0.00	n.a.	0.00	0.29
1910-11	0.04	n.a.	n.a.	0.06	0.02	0.50	0.22	0.26
1928-29	0.09	n.a.	n.a.	0.04	0.11	0.21	0.30	0.25

Sources and Notes: For information on the cross-sectional patent samples and categories of assignees, see Table 1. Data on citations for 1975-2002 come from Bronwyn H. Hall, “2002 Updates to NBER Patent Data,” http://elsa.berkeley.edu/~bhhall/bhdata.html, last updated 5 Sept 2006. For information on the patent citations in these datasets, see Hall, Jaffe, and Trajtenberg, “The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools,” NBER Working Paper 8498 (2001). We classify a patent as “high tech” if it pertained to electrical machinery and products, chemicals, petroleum, plastics and rubber, automobiles, primary metals, mining machinery, and transportation equipment. We defined a patent as collaborative if the number of patentees was greater than one. An inventor was considered to be a principal if information in a financial publication or city directory revealed that the inventor was an officer, director, or proprietor of the company obtaining the assignment. The designation n.a. (not applicable) means that there were no firms in those categories in our data. Blank cells mean that we do not have the relevant information.

Table 3. Distribution of Cited and High-Tech Patents by Type of Assignee

			Assigned to company with financial report				
			Assets >=10 million		Assets <10 million		Assigned to
Sample year	Not assigned	Assigned to individual	Had R&D lab	No R&D lab	Had R&D lab	No R&D lab	other company
Panel A: Distribution of patents that were cited during 1975-2002 (row percentages)							
1870-71	87.5	11.7	n.a.	0.0	n.a.	n.a.	0.8
1890-91	74.2	15.5	0.0	0.0	n.a.	0.0	10.3
1910-11	76.9	8.9	0.2	1.8	0.2	1.2	10.8
1928-29	48.3	7.7	11.0	3.7	1.7	3.6	24.0
Panel B: Distribution of high-tech patents (row percentages)							
1870-71			n.a.		n.a.	n.a.	
1890-91					n.a.		
1910-11	63.1	12.3	1.5	5.2	0.1	3.2	14.6
1928-29	32.2	8.4	22.7	3.9	1.9	4.0	26.8

Sources and Notes: See Tables 1 and 2.

Table 4. Determinants of Whether a Patent was Cited, High-tech, or Collaborative

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent was cited in 1975-2002			Patent was high-tech			Patent was collaborative		
High-technology patent	-0.028	-0.028	-0.024				0.007	0.007	0.005
	(1.44)	(1.42)	(1.22)				(0.57)	(0.55)	(0.40)
Large national firm	-0.039	0.002	0.001	0.054	-0.015	-0.018	0.005	-0.032	-0.031
	(1.07)	(0.03)	(0.03)	(1.35)	(0.27)	(0.33)	(0.18)	(0.81)	(0.78)
Small national firm	-0.013	-0.029	-0.034	-0.056	-0.039	-0.019	0.000	0.006	0.013
	(0.29)	(0.58)	(0.68)	(1.17)	(0.71)	(0.34)	0.00	(0.17)	(0.35)
Had R&D lab	-0.018	0.005	0.008	0.162	0.112	0.084	0.020	-0.006	-0.009
	(0.49)	(0.09)	(0.15)	(4.31)***	(1.89)*	(1.39)	(0.80)	(0.16)	(0.23)
Patentee was principal	0.013	0.014	0.011	-0.016	-0.019	-0.011	0.025	0.023	0.025
	(0.35)	(0.38)	(0.30)	(0.41)	(0.49)	(0.28)	(0.95)	(0.88)	(0.93)
Large national x R&D lab		-0.070	-0.068		0.130	0.134		0.073	0.073
		(0.94)	(0.90)		(1.60)	(1.65)*		(1.17)	(1.17)
Small national x R&D lab		0.046	0.050		-0.029	-0.011		-0.006	-0.007
		(0.44)	(0.48)		(0.26)	(0.09)		(0.09)	(0.09)
West			0.053			-0.123			-0.050
			(0.45)			(0.98)			(0.79)
West North Central			-0.012			0.108			-0.058
			(0.10)			(0.92)			(0.93)
East North Central			0.023			0.106			-0.062
			(0.24)			(1.05)			(1.06)
New England			0.032			-0.116			-0.063
			(0.31)			(1.05)			(1.15)
Middle Atlantic			-0.007			0.175			-0.043
			(0.07)			(1.75)*			(0.72)
South Atlantic			0.016			0.030			-0.045
			(0.13)			(0.23)			(0.65)
Observations	1137	1137	1137	1137	1137	1137	1137	1137	1137

Absolute value of z statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Sources and Notes: See Tables 1 and 2. Companies for which there were published financial reports are divided into two categories: large, if their assets were greater than or equal to $10 million; and small, if their assets were smaller. Regions are the locations of the assignees. New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont; the Middle Atlantic New Jersey, New York, and Pennsylvania; the East North Central Illinois, Indiana, Michigan, Ohio, and Wisconsin; the West North Central Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota; the South Atlantic Delaware, the District of Columbia, and Maryland; the South Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia; and the West Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Table 5. Distribution of Patentees within Each Region among Assignment (Row Percentages)

		% patents (row sum)							Probability of company assignment			Probability
				Assigned to company with financial report								
				Assets >=10 million		Assets <10 million						
Region	No. of patents	Not assigned	Assigned to individual	Had R&D lab	No R&D lab	Had R&D lab	No R&D lab	Assigned to other Company	Made by principal	with missing principal information	To out of state assignee	In high-tech industry
Panel A: 1870-71												
West	30	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	
West North Central	64	90.6	9.4	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	
East North Central	318	86.5	12.3	0.0	0.0	0.0	0.0	1.3	0.50	0.50	0.00	
New England	306	77.8	16.7	0.0	0.0	0.0	0.0	5.6	0.24	0.71	0.12	
Middle Atlantic	567	82.2	15.0	0.0	0.2	0.0	0.0	2.6	0.38	0.44	0.06	
South Atlantic	45	93.3	6.7	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	
South	95	91.6	7.4	0.0	0.0	0.0	0.0	1.1	0.00	1.00	0.00	
Panel B: 1890-91												
West	117	75.2	20.5	0.0	0.0	0.0	0.0	4.3	0.40	0.20	0.00	
West North Central	192	82.3	12.5	0.0	0.0	0.0	0.0	5.2	0.20	0.40	0.20	
East North Central	515	70.3	15.1	0.0	0.0	0.0	0.0	14.6	0.36	0.27	0.23	
New England	317	59.9	16.7	0.0	1.6	0.0	0.0	21.8	0.22	0.66	0.30	
Middle Atlantic	666	71.0	14.9	0.2	0.5	0.0	0.2	13.4	0.26	0.64	0.27	
South Atlantic	59	69.5	22.0	0.0	0.0	0.0	0.0	8.5	0.20	0.80	0.00	
South	156	76.3	14.1	0.0	0.0	0.0	0.0	9.6	0.33	0.60	0.53	
Panel C: 1910-11												
West	266	80.1	12.0	0.0	0.4	0.0	0.0	7.5	0.43	0.43	0.14	0.31
West North Central	281	83.6	8.5	0.0	1.4	0.0	1.4	5.0	0.27	0.41	0.27	0.31
East North Central	652	68.6	10.1	0.8	1.2	0.0	2.5	16.9	0.31	0.21	0.14	0.33
New England	242	54.1	12.8	0.4	0.4	1.2	8.3	22.7	0.26	0.46	0.25	0.26
Middle Atlantic	744	60.9	10.5	3.2	5.5	0.1	3.2	16.5	0.09	0.45	0.39	0.35
South Atlantic	53	64.2	20.8	1.9	0.0	0.0	0.0	13.2	0.13	0.50	0.50	0.38
South	260	82.7	13.1	0.0	0.0	0.0	0.4	3.8	0.55	0.18	0.18	0.24
Panel D: 1928-29												
West	238	69.3	10.5	1.7	1.7	0.0	1.3	15.5	0.23	0.44	0.10	0.36
West North Central	159	61.0	12.6	1.9	1.9	1.9	1.3	19.5	0.29	0.19	0.17	0.45
East North Central	696	38.2	4.7	13.9	4.6	1.9	6.8	29.9	0.22	0.21	0.11	0.53
New England	230	29.6	6.5	16.1	6.5	3.9	9.6	27.8	0.20	0.19	0.12	0.34
Middle Atlantic	780	36.9	5.8	24.4	4.4	1.5	2.3	24.7	0.11	0.21	0.25	0.56
South Atlantic	57	28.1	14.0	14.0	0.0	1.8	3.5	38.6	0.21	0.48	0.67	0.58
South	152	73.0	11.8	0.7	0.7	0.7	0.0	13.2	0.26	0.35	0.13	0.48

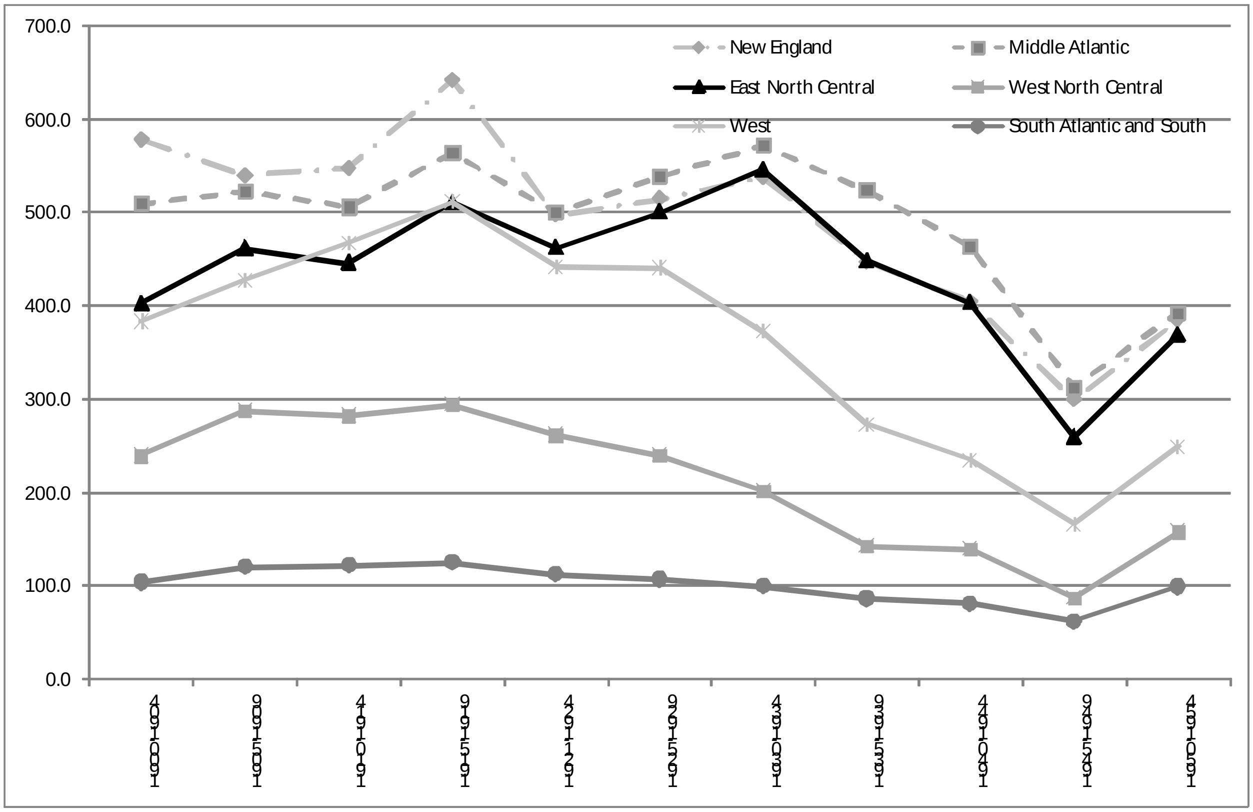
Notes and Sources: See Tables 1, 2, and 4.

Table 6. Regional Share of Patents by Assignee Type (Column Percentages)

		For each type of assignment									
				Assigned to company with financial report							
Region	No. of patents	Not assigned	Assigned to individual	Assets >=10 million	Assets <10 million	Assigned to other Company	Company assignment made by principal	Company assignment with missing principal information	Company assignment to out of state assignee	Patent in hi-technology industries	Patent cited during 1975-2002
Panel A: 1870-71											
West	2.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3
West North Central	4.5	4.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1
East North Central	22.3	19.3	2.7	0.0	0.0	10.8	16.7	16.7	0.0	0.0	20.3
New England	21.5	16.7	3.6	0.0	0.0	45.9	33.3	100.0	66.7	0.0	21.1
Middle Atlantic	39.8	32.7	6.0	100.0	0.0	40.5	50.0	58.3	33.3	0.0	40.6
South Atlantic	3.2	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9
South	6.7	6.1	0.5	0.0	0.0	2.7	0.0	8.3	0.0	0.0	8.6
Panel B: 1890-91											
West	5.8	4.4	1.2	0.0	0.0	1.9	2.6	1.3	0.0	0.0	4.9
West North Central	9.5	7.8	1.2	0.0	0.0	3.7	2.6	5.2	2.7	0.0	9.5
East North Central	25.5	17.9	3.9	0.0	0.0	28.0	35.1	26.0	23.0	0.0	26.4
New England	15.7	9.4	2.6	55.6	0.0	25.7	20.8	63.6	29.7	0.0	17.2
Middle Atlantic	32.9	23.4	4.9	44.4	100.0	33.2	31.2	77.9	33.8	0.0	32.4
South Atlantic	2.9	2.0	0.6	0.0	0.0	1.9	1.3	5.2	0.0	0.0	2.9
South	7.7	5.9	1.1	0.0	0.0	5.6	6.5	11.7	10.8	0.0	6.9
Panel C: 1910-11											
West	10.6	8.5	1.3	1.2	0.0	5.9	8.5	8.5	2.2	10.5	12.3
West North Central	11.2	9.4	1.0	4.7	5.8	4.1	5.7	8.5	4.3	11.0	9.4
East North Central	26.1	17.9	2.6	15.1	23.2	32.4	40.6	27.4	14.5	27.1	27.9
New England	9.7	5.2	1.2	2.3	33.3	16.2	19.8	34.9	14.5	8.0	9.1
Middle Atlantic	29.8	18.1	3.1	75.6	36.2	36.3	18.9	90.6	60.1	32.8	29.5
South Atlantic	2.1	1.4	0.4	1.2	0.0	2.1	0.9	3.8	2.9	2.6	2.1
South	10.4	8.6	1.4	0.0	1.4	2.9	5.7	1.9	1.4	8.0	9.8
Panel D: 1928-29											
West	10.3	7.1	1.1	1.9	2.3	6.4	5.4	10.4	2.4	7.5	11.5
West North Central	6.9	4.2	0.9	1.4	3.8	5.4	5.9	4.0	3.3	6.3	7.4
East North Central	30.1	11.5	1.4	30.1	45.1	36.2	43.6	42.1	21.3	32.1	29.4
New England	9.9	2.9	0.6	12.1	23.3	11.1	14.4	13.9	8.5	6.9	9.4
Middle Atlantic	33.7	12.5	1.9	52.2	22.6	33.6	24.3	46.0	52.6	37.9	33.3
South Atlantic	2.5	0.7	0.3	1.9	2.3	3.8	3.5	7.9	10.4	2.9	1.9
South	6.6	4.8	0.8	0.5	0.8	3.5	3.0	4.0	1.4	6.4	7.0

Sources and Notes: See Tables 1, 2, and 5

Figure 1. Patenting Rates by Region



Notes and Sources: Patent rates are number of patents per million residents of the region. Patent counts come from U.S. Commissioner of Patents, *Annual Reports*, 1900-1925, 1946, and 1955. Population figures are from U.S. Census Bureau, "Demographic Trends in the 20th Century," Census 2000 Special Reports, Series CENSR-4, http://www.census.gov/prod/2002pubs/censr-4.pdf (released 2002).