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INVENTORS, FIRMS, AND THE MARKET FOR TECHNOLOGY: U.S. MANUFACTURING IN THE LATE NINETEENTH AND EARLY TWENTIETH CENTURIES

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ABSTRACT

Recent scholarly literature explains the spread of in-house research laboratories during the early twentieth century by pointing to the information problems involved in contracting for technology. We argue, by contrast, that these difficulties have been overemphasized—that, in fact, a substantial trade in patented inventions developed over the course of the nineteenth century, much of it taking the form of transactions conducted at arms-length through the market. This expansion of trade in technology made possible a growing division of labor, as inventors increasingly took advantage of their greater ability to sell off rights to patented technologies and focused their energies and resources on invention itself. Firms in turn responded to the expansion of this trade by developing capabilities that enabled them to learn about and assess externally generated inventions. Although it is true that large firms were also beginning by the early twentieth century to invest in developing their internal inventive capabilities, in doing so they faced a number of significant problems. Most importantly, they had to overcome resistance to contracts requiring employees to sign over patents to their employers, and they had to reduce the high turnover rates that made such requirements effectively unenforceable. The increased costs of inventive activity and the greater risks borne by independent inventors by the early twentieth century helped firms make their case. But there was still a lot of organizational learning involved. Hence where other scholars have emphasized the difficulties of contracting for technology in the market and the relative ease of integrating invention and production within the firm, we reverse the story. Economic actors at that time had a great deal of experience contracting for new technological ideas in the market; what they did not know how to do, and had to spend a great deal of time and energy learning, was managing creative individuals within the firm.

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Inventors, Firms, and the Market for Technology: U.S. Manufacturing in the Late Nineteenth and Early Twentieth Centuries

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Much of our understanding of the process of technological change derives from two polar models of the inventive process, each of which is rooted in a different historical epoch. The first is based largely on research on the early-nineteenth-century economy. It portrays the inventor as a creative individual who responds to market opportunities by coming up with new technological ideas and then either exploits them directly himself or reaps the proceeds by assigning partial rights to others.[2] The second, which grows out of

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[1]We would like to express our appreciation to Marigee Bacolod, Dalit Baranoff, Yael Elad, and Svjetlana Gacinovic. Without their able research assistance we would not have been able to write this article. We would also like to thank Marjorie Ciarlante and Carolyn Cooper for teaching us how to access the Patent Office's assignment records in the National Archives. In writing up our research, we benefited as well from the helpful comments of Cameron Campbell, David Hounshell, Adam Jaffe, Zorina Khan, Rebecca Menes, Daniel Raff, Jean-Laurent Rosenthal, William Summerhill, Peter Temin, Ross Thomson, Steven Usselman, Mary Yeager, and participants in the NBER Conference that generated this volume. Financial support for this research was provided by the National Science Foundation and the University of California, Los Angeles.

[2]See, for example, Carolyn Cooper, *Shaping Invention: Thomas Blanchard's Machinery and Patent Management in Nineteenth-Century America* (New York: Columbia University Press, 1991). See also Kenneth L. Sokoloff, "Inventive Activity in Early Industrial America: Evidence from Patent Records,

scholarship on large-scale enterprises in the early twentieth century, sees invention as occurring in vertically integrated R&D laboratories. There groups of salaried employees engage in the systematic resolution of problems—either questions derived from the pursuit of basic research, difficulties faced by the firm's production and marketing departments, or challenges resulting from strategic considerations.[3] These two models are well established in the literature and convincingly supported by evidence. However, when considered together as stages in a sequential pattern of development, they raise the important question of how the economy moved from one dominant form of invention to the next.

Another way of posing essentially the same question is to ask where inventive activity should be located to maximize its efficiency. Should it be concentrated within firms? That is, are there significant advantages to be derived from integrating the process of coming up with new technological ideas with the processes of developing and commercializing those ideas? The conventional answer to this question is yes. As David Mowery has argued, "much of the knowledge employed in industrial innovation flows

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1790-1846," *Journal of Economic History*, 48 (December 1988), pp. 813-50; and B. Zorina Khan and Kenneth L. Sokoloff, "'Schemes of Practical Utility': Entrepreneurship and Innovation Among 'Great Inventors' in the United States, 1790-1865," *Journal of Economic History*, 53 (June 1993), pp. 289-307.

[3]For examples in this tradition, see David A. Hounshell and John Kenly Smith, Jr., *Science and Corporate Strategy: Du Pont R&D, 1902-1980* (New York: Cambridge University Press, 1988); Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926* (New York: Cambridge University Press, 1985); and Margaret B. W. Graham and Bettye H. Pruitt, *R&D for Industry: A Century of Technical Innovation at Alcoa* (New York: Cambridge University Press, 1990).

from the firm's production and marketing activities." This knowledge is largely firm-specific. It results from interactions among personnel responsible for different functions within the firm and "is not easily transferred across organizational boundaries." In addition, problems of asymmetric information make contracting for technology in the market difficult and costly. For example, firms may hesitate to purchase new technologies without full information about how they work, but inventors may balk at providing this level of detail for fear of losing control of their intellectual property. Moreover, contracting for future research is likely to be even more problematic than purchasing already existing inventions, with the difficulties increasing along with the complexity and uncertain nature of the technology.[4] According, to this view, then, the emergence of large in-firm R&D laboratories during the twentieth century owed to the superiority of this organizational arrangement for minimizing the information problems associated with increasingly complex and expensive forms of technological change.

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[4]David C. Mowery, "The Boundaries of the U.S. Firm in R&D," in Naomi R. Lamoreaux and Daniel M. G. Raff, eds., *Coordination and Information: Historical Perspectives on the Organization of Enterprise* (Chicago: University of Chicago Press for NBER, 1995), pp. 149-52. See also Mowery, "The Relationship Between Intrafirm and Contractual Forms of Industrial Research in American Manufacturing, 1900-1940," *Explorations in Economic History*, 20 (October 1983), pp. 352-7. For a general theoretical treatment, see David J. Teece, "Technological Change and the Nature of the Firm," in Giovannie Dosi et al., eds., *Technical Change and Economic Theory* (London: Pinter Publishers, 1988), pp. 256-281. See also Kenneth J. Arrow's classic article, "Economic Welfare and the Allocation of Resources for Invention," in Richard R. Nelson, ed., *The Rate and Direction of Inventive Activity* (Princeton: Princeton University Press, 1962), pp. 609-625; and Richard Zeckhauser, "The Challenge of Contracting for Technological Information," *Proceedings of the National Academy of Sciences*, 93 (12 Nov. 1996), pp. 12743-12748.

In this essay, we offer a different perspective and argue that scholars have overemphasized the information problems associated with trade in inventions. Contrary to what one might expect from the literature, an extensive trade in new technological ideas did develop over the course of the nineteenth century, supported by the development of markets and other institutions that promoted the exchange of technological information, making it possible for inventors to sell their devices to arms-length buyers. The growth of this market for technology had important implications, we show, for the extent to which invention was integrated with development. Early inventors, of course, typically engaged in both sets of activities—either commercializing their ideas themselves or joining with outside investors to form enterprises to exploit their patents. This combination of activities certainly continued and, indeed, was even facilitated where the growth of the market made it easier to gain financial backing. But the expansion of trade in technology also made possible a new division of labor, as inventors increasingly took advantage of their greater ability to sell off rights to patented technologies and focused their energies and resources on invention itself. Firms in turn responded to the expansion of this trade by developing capabilities that enabled them to learn about and assess externally generated inventions. In an environment where many inventions were protected by patents and where this kind of property right was vigorously enforced, maintaining one's competitive position often meant purchasing (or at least contracting for the right to use) patented technology. Indeed, a wrong decision about the value of a patent could mean that a competitor gained control of vital technology.[5]

[5] As Steven Usselman's essay in this volume shows, in well-organized industries like railroads

During the late nineteenth and early twentieth centuries, particularly in the "high-tech" industries of the time, firms devoted a considerable part of their energies and resources to keeping on top of technological ideas originating outside their bounds. As time went on, however, they increasingly turned their attention to developing their own internal inventive capabilities. The investments in personnel and facilities that they had made in order to monitor ideas in the external economy could easily be turned to the support of research and development activities within the enterprise. Moreover, the highly productive inventors who had emerged as a result of the growth of market trade in technology were increasingly attractive resources that firms could seek to internalize. Perhaps more important, by the turn of the century the greater complexity of technology and the rising cost of invention, in terms of both human and physical capital, made it increasingly difficult for inventors to operate independently, encouraging them to take employment positions within firms.

In order to reap the fruits that might be derived from bringing inventors within the enterprise, however, firms had to learn how to manage creative individuals so as to elicit their loyalty and enhance their productivity. Entrepreneurially oriented inventors initially moved in and out of employment positions and, even worse from the standpoint of firms, often tried to exploit personally inventions that they came up with on company time. Firms had to learn how to tighten up their contractual relations with employee inventors and also how to convince them that advancement within the enterprise was an attractive

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firms sometimes formed patent pools to lower the risks of making wrong decisions and to prevent technological blackmail.

alternative to self-employment. Such learning was a prerequisite for the massive investments in R&D that would occur later in the century. Hence where other scholars have emphasized the difficulties of contracting for technology in the market and the relative ease of integrating invention and production within the firm, we reverse the story. During the late nineteenth and early twentieth century there was a well-functioning market for invention, but significant organizational learning had to occur before inventors could function productively within firms.

The Patent System and the Market for Technology

The patent system provided the institutional framework within which trade in technology evolved over the course of the nineteenth century. Consciously designed with the aim of encouraging inventive activity—and thus technological progress—the U.S. system provided the first and true inventor of a device with an exclusive property right for a fixed term of years. One important feature of the law was that inventors had to be individual men or women; firms could not receive patents for ideas developed in their shops. These individual inventors then had the option of exploiting their property rights themselves, or they could assign (sell) or license them to others, whether individuals or firms. From the beginning responsibility for enforcing patent rights was left to the federal courts, and as B. Zorina Khan has shown, judges quickly evolved an effective set of principles for protecting the property rights of patentees and also of those who purchased or licensed patented technologies. As a result, not only did thousands of inventors pay

rather substantial fees to obtain patents, but large numbers of individuals and firms paid even greater amounts to purchase or license patent rights.[6]

Although one purpose of the patent system was to stimulate invention by granting creative individuals secure rights to their intellectual property, another was to promote the diffusion of technological knowledge. The law required all patentees to provide the Patent Office with detailed specifications for their inventions (including, where appropriate, working models), and the result was a central storehouse of information that was open to all. Anyone could journey to Washington and research others' inventions in the Patent Office files. In addition, more convenient means of tapping this rich source of information soon developed. The Patent Office itself published an annual list of patents issued, and private publications emerged by the middle of the nineteenth century to improve upon this service. One of the most important was *Scientific American*, published by Munn and Company, the leading patent agency of the nineteenth century. Beginning with its first number in 1845, *Scientific American* featured articles about major technological improvements, printed complete lists of patents issued on a weekly basis, and offered to provide its readers with copies of specifications for a small fee.[7] Over time, moreover, in industry after industry specialized trade journals appeared that, among other features, kept producers informed about patents of interest. The *Journal of the*

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[6]B. Zorina Khan, "Property Rights and Patent Litigation in Early Nineteenth-Century America," *Journal of Economic History*, 55 (March 1995), pp. 58-97.

[7]The fee fell steeply over time. For example, in 1870 *Scientific American* charged a range of fees for specifications, but the most common seems to have been $1.25. By 1890 the cost of this service had dropped to $0.25.

Society of Glass Technology, for example, provided detailed descriptions of all patents taken out in the United States and Britain that were relevant to the manufacture of glass.

Patent agents and solicitors also became important channels through which individuals and firms far from Washington could exploit the information in Patent Office files. Their numbers began to mushroom in the 1840s, first in the vicinity of Washington and then in other urban centers, especially in the Northeast. Solicitors in different cities linked themselves together through chains of correspondent relations (similar to those that characterized the banking system at the same time), thereby providing their local clients with access to agents in Washington and also information on patenting activity throughout the country.[8]

The patent system's dual missions of stimulating invention by granting monopoly rights to patentees, on the one hand, and of promoting the diffusion of information about technology, on the other, were to some degree at cross purposes. The extent to which the two actually counteracted each other is difficult to judge and obviously varied from one invention and industry to the next. It is important to realize, however, that the very act of establishing exclusive property rights in invention not only protected patentees but also promoted the diffusion of information about technology. To see why, it is useful to engage in a thought experiment and imagine a world in which there was no patent system

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[8]The growth and geographic spread of patent agents and solicitors can be followed through city directories. For insight into the correspondent relations of these agents, see the papers of the firm of Wright, Brown, Quinby & May, Patent Solicitors, in Wright, Brown, Quinby & May Correspondence Files, Mss. 598, Case 2, Waltham Watch Company, 1854-1929, Baker Library, Harvard Graduate School of Business Administration.

to guarantee inventors property rights to their discoveries. In such a world, inventors would have had every incentive to be secretive and to guard jealously their discoveries from competitors. Moreover, though competitors would had have some incentive to seek knowledge of each other's inventions (which could, of course, be copied with impunity), on another level the incentive to gather information about technological developments would have been greatly reduced. Before investing in a technology, for example, it would not have been necessary to find out whether anyone anywhere else in the country (even in another industry) owned patents on which the invention might infringe. By contrast, in a world where property rights in invention were protected, the situation would be very different. Inventors would now feel free to promote their discoveries as widely as possible so as to maximize returns either from commercializing their ideas themselves or from assigning rights to the idea to others. Competitors would still have an incentive to keep tabs on what their rivals were doing, but now in addition they could not risk investing in an invention without finding out how their discovery related to (and whether it replicated) technological developments in other sectors of the economy. The protections to intellectual property offered by the patent system would thus be an important a stimulus to the exchange of technological information in and of themselves. Moreover, it is likely that the cross-fertilization that resulted from these information flows would itself be a potent stimulus to technological change.

In any event, there is plenty of anecdotal evidence to suggest that the channels of information made possible by the patent system worked effectively to diffuse technological knowledge. Inventors scanned patent lists in search of developments in their fields and subscribed to periodicals relevant to their interests. For example, Elias E.

Reis reported that when he read in the *Official Gazette* in 1886 about a patent issued to Elihu Thomson for a method of electric welding, there "immediately opened up to my mind a field of new applications to which I saw I could apply my system of producing heat in large quantities."[9] Charles H. Roth, an inventor of bicycle tires, subscribed to two papers, "Bicycling World" and "Bearings" in order to keep abreast of technological developments related to cycling. He also "read other papers at the bicycle stores and at the Crescent Wheel Club Rooms, of which club I was a member."[10] To give a different kind of example, the journals of Wright, Brown, Quinby & May, patent solicitors, were filled with notations of payments received from clients for searches of Patent Office records. For instance, when the officers of the Waltham Watch Company decided to explore the possibility of producing self-winding clocks and watches, they asked Wright, Brown, Quinby & May to conduct a search for them so they could learn about techniques already in use and reduce the risk of being sued for infringement.[11]

Even more interesting for our purposes, these various information channels were also used by patentees to market their inventions. Advice manuals recommended that "if

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[9]See "Record of Elias E. Ries," p. 8, *Thomson v. Ries*, Case 13,971, Box 1,845, Interference Case Files, 1836-1905, Records of the Patent Office, Record Group 241, National Archives.

[10]"Record of Roth," p. 6, *Roth v. Brown & Stillman*, Case 17,930, Box 2,488, Interference Case Files, 1836-1905.

[11]The example is from a letter from the Waltham Watch Co. to Wright, Brown, Quinby & May, 25 Jan. 1915, Waltham Watch Company, 1854-1929, Wright, Brown, Quinby & May Correspondence Files, Case 2. For numerous other instances, see Journal 1, Wright, Brown, Quinby & May, 1881-1950, MSS 831. Both collections are at Baker Library.

the inventor can afford it, it is well to have the invention illustrated and described in one or more of the scientific and mechanical publications of the day, of which the Scientific American and American Artisan, of New York, and the Scientific Press, of San Francisco, are notable examples." This announcement of the invention might then, if necessary (and the manuals claimed that further advertisement often would not be necessary), "be followed up by ordinary advertising . . . in the paper or papers which are designed to meet the eye of the class or classes of persons to whom the invention is of special interest." Advertisements in trade papers in turn might be followed by personal solicitations to potential buyers, whose names could be obtained from "men in New York and other large cities, who make it their business to furnish, for a reasonable consideration, full and complete lists of all parties engaged in any particular trade, occupation, profession, or manufacture throughout the country."[12]

Patentees who did not feel able or willing to devote so much of their time to marketing their inventions often turned to intermediaries for assistance. Virtually any businessman could perform this function, as records of patents offered for sale to important firms show.[13] But it was most common for patent solicitors and agents to play

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[12]See, for example, William Edgar Simonds, *Practical Suggestions on the Sale of Patents* (Hartford, Conn., 1871 [privately printed]), pp. 19, 24-6.

[13]For example, the Nicholson File Co. was offered the opportunity to buy a patent for a rasp by a manufacturer of engine governors who had acquired it for resale. Similarly, intermediaries with main businesses as diverse as textile manufacturers and engineering consultants submitted inventions for sale to AT&T. See correspondence between the Nicholson File Co. and Stillman B. Allen, 1873-75, Patent Records from Trunk, Nicholson File Co., MSS 587, Rhode Island Historical Society Manuscript

the role of middlemen. Although the original function of these specialists was to shepherd applications for patents through the official review process and (in the case of solicitors) to defend previously issued patents in interference and infringement proceedings, as time went on they acquired additional functions and often began to serve as intermediaries in the sale of technology. There appears to have been some disagreement among solicitors about whether such activity was proper, but many moved in this direction, advertising in the main scientific journals their willingness to sell patents on commission.[14] Some solicitors, in fact, became known for this service, and inventors would seek them out to find buyers for their patents. For example, a party with an interest in a "Patent Self Oiler" for railroad cars wrote an agent named Lemuel Jenks to solicit his assistance in marketing their device: "We intend to sell it to one person for the six New England States and I therefore wish you would give me your opinion in that

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Collections; and T. D. Lockwood, Reports of Inventions (Not Approved), 1904-8, Box 1383, AT&T Corporate Archives.

[14]H. W. Boardman & Co., Solicitors of American and European Patents, stated unequivocally that the firm rigidly adhered to a rule "never to take contingent interests in applications for Patents, nor to negotiate sales of Patent rights, or become the owners in whole or in part of them. We deem all such to be deviations from that rigid professional course necessary to insure the strictest honor and integrity toward a client." See *Hints to Inventors and Others Interested in Patent Matters* (Boston, 1869 [privately printed]), p. 13. Simonds took a similar position, advising patentees to sell their inventions themselves and not be seduced by the promises of such agents. See *Practical Suggestions on the Sale of Patents*, pp. 7-9. See also W. B. Hutchinson and J. A. E. Criswell, *Patents and How to Make Money Out of Them* (New York: D. Van Nostrand Co., 1899), pp. 161-2; and F. A. Cresee, *Practical Pointers for Patentees, Containing Valuable Information and Advise on the Sale of Patents* (New York: Munn & Co., 1907), pp. 41-3.

matter: to viz what price you think we should ask; what would we have to pay you for your assistence in carrying and effecting a sale."[15] The records of important concerns such as the American Telephone and Telegraph Company (AT&T) contain numerous letters from inventors offering their own patents for sale, but also a nearly equivalent number of approaches from patent agents and solicitors marketing inventions on behalf of their patentee clients.[16]

A Quantitative Picture of the Market

The extent to which the market for patented technology was already well developed by 1870, especially in the Northeastern regions of the country, can be seen from Table 1, which reports descriptive statistics for a sample of assignment contracts.[17] Although the volume of trade in patented technology (as reflected in the number of assignment contracts) increased steadily over the course of the century, the ratio of the total number of contracts to the total number of patents actually peaked by 1870, and the estimated ratio of assignments to patents fell from 0.83 in 1870-71 to 0.71 in 1890-91 and

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[15]Letter of 30 April 1870 from Aug. H. Fick [last name not completely legible] to Jenks, Box 3 Folder 59, Lemuel Jenks, 1844-1879, MSS 867, Baker Library, Harvard Graduate School of Business Administration.

[16] See T. D. Lockwood, Reports of Inventions (Not Approved), 1904-8, Box 1383, AT&T Corporate Archives.

[17]In this paper we focus on the national aggregates. In other work we deal with the issue of why the market for technology did not develop uniformly across the nation. See Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Long-Term Change in the Organization of Inventive Activity," *Proceedings of the National Academy of Sciences*, 93 (12 Nov. 1996), pp. 12686-92.

1910-11.[18] The relatively high proportion early on of what we are calling "geographic assignments"—that is, sales of patent rights that were restricted to some (often distant) subregion of the United States—suggests, moreover, that a significant amount of arms-length trading was already occurring by mid-century. Although the proportion of geographic assignments dropped dramatically between 1870-71 and 1910-11, this change did not mean that market trade in technology was falling off. Rather the decline should be seen as a consequence of the growth of national product markets. Once manufacturers in a single location could retail their products nationally, it no longer made much sense to try to sell geographically exclusive rights to producers in different parts of the country. Producers were now more interested in purchasing full national rights that would give them a competitive edge over rivals elsewhere.[19]

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[18]One cannot infer from the peak in 1871 of the ratio of total assignment to total patents that the proportion of patents ever assigned decreased afterwards. The declines over time in secondary assignments and in the proportion of geographic assignments would tend to reduce the ratio even if the overall proportion of patents ever assigned remained constant.

[19]In addition, the marketing of geographical assignments had always posed information problems that could be avoided once it became possible to dispose of national rights in one fell swoop. For example, the relationship between inventors and the itinerant agents who sometimes marketed their patents in other parts of the country presented many opportunities for opportunism and even outright fraud, and disreputable agents were accused of a variety of crimes—from misrepresenting the value of patents, to collecting commissions on bogus sales, to embezzling funds rightfully due inventors. Further, contemporary writers claimed that patentees who disposed of their rights piecemeal risked the possibility that familiarity with the device would stimulate some other inventor to patent a substitute or an improvement that would reduce the value of the original patent and therefore the proceeds from later sales.

Two related changes are also apparent in the table. In 1870-71 secondary assignments—that is, sales of patents where the assignor was neither the patentee nor a relative of the patentee—accounted for more than a quarter of total sales. By 1910-11, the figure had fallen to 12 percent. In other words, there was less reselling of patents as time went on; an increasingly large proportion of sales were being made by the patentee him or herself. More important, the proportion of assignments that occurred after the date the patent was issued dropped from 72.3 percent of the total in 1870-71 to 36.5 percent in 1910-11. That is, as time went on patentees were able to sell their inventions earlier and earlier—even in many cases before their patents were actually issued.

We can get a better idea of what was going on from Table 2, which reports the frequency of various types of assignments made at (or before) the time of issue, including the proportion that went to a group in which the patentee was involved and the proportion that went to companies. The table also provides a summary measure of the extent to which patentees retained a stake in their inventions—that is, the total number of patents not assigned at the time of issue plus the number of those assigned that went to groups including the patentee. When combined with the information from the first table, the figures in Table 2 suggest a progression of stages. Initially, patentees' behavior was rather well accounted for by the first of the models discussed above—that is, inventors not only came up with new technological ideas but also developed and commercialized

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For this reason they advised inventors to dispose of a patent in its entirety "as soon as possible after its issue." Simonds, *Practical Suggestions on the Sale of Patents*, pp. 28-9; An Experienced and Successful Inventor, *Inventor's Manual: How to Work a Patent to Make It Pay* (New York: Norman W. Henley & Co., 1901), pp. 58-9; Cresee, *Practical Pointers for Patentees*, pp. 26-7, 61.

them, sometimes by starting their own businesses, sometimes by selling partial rights to their ideas to producers in different geographical markets, and sometimes by doing both. As the market for technology expanded and matured, moreover, inventors seem at first to have employed it to facilitate their local business activities. For example, assignments at issue typically involved the sale of shares of patent rights to individuals who were not coinventors, but who generally resided in the vicinity of the patentee, and it is likely that the partial assignment compensated local partners for advances of capital to support the development and commercialization of the invention. Over time, however, this pattern gave way as patentees increasingly relinquished all property rights to their inventions by the time of issue, assigning their rights in particular to companies. The shift can be seen as a drop in the proportion of patents in which the patentee retained a direct stake—from 92 percent in 1870-71 to 80 percent in 1910-11. Because many of the patents not assigned at issue were of limited economic value, however, the change can be seen more clearly in the fall in the proportion of assignments that included the patentee—from 52 percent in 1870-71 to 25 percent in 1910-11.

These changes in the pattern of assignments were accompanied by dramatic increases in the productivity of patentees. As Table 3 shows, the early 1800s were a relatively democratic era of invention; the typical inventor filed only one or two patents over his or her lifetime, and efforts at technological creativity were only one aspect of an individual's work, if not a sideline altogether. Although such 'part-time' inventors continued to be significant contributors to technological change, their share of patents fell

sharply between the 1830s and 1870s—from over 70 percent to less than 40 percent.[20] Conversely, the share of patents accounted for by patentees with ten or more career patents rose from less than 5 percent to more than 20 percent. Even more telling, however, is the higher productivity of patentees who assigned their patents to companies. As Table 4 shows, the patentees who consistently received the most patents in a given year were those who assigned their patents at issue to companies.

Inventors and Firms

Both the growing tendency of inventors to assign away all rights to their patents at issue to companies and the rising productivity at invention of patentees, particularly those who disposed of their patents in this way, raise the important question of the identity of these inventors and the nature of their relationship with the companies to which they assigned. There are three main possibilities: first, that the inventors were independent agents who sold their patents in arms-length transactions; second, that they were principals (for example, officers or proprietors) of the firms to which they assigned; and third, that they were employees of their assignees. These three possibilities have different implications for the extent to which invention was integrated with development. The first case, of course, implies a clear division of labor between those who invented and those who developed the inventions commercially. The second case is more ambiguous, because we cannot tell from this kind of information alone whether the patentees formed companies in order to integrate invention with commercial development or whether they

[20]The incomplete nature of the sample actually biases downward this measure of increased specialization over time.

were seeking to provide themselves with a better vehicle to support their specialization in inventive activity. The third case is the one most favorable to those who would argue for an increased integration of invention and development. However, it is also possible that the higher productivity of patentees who assigned to their employers resulted simply from their greater ability to specialize in invention within the firm or from cost savings derived from economies of scale in carrying out invention or in filing patent applications.

Unfortunately, because assignments of patents typically take the same contractual form whether they involve arms-length sales, grants of patent rights by principals to their associated firms, or the acquisition by firms of employees' inventions, it is difficult to get a sense of the relative importance of these different kinds of transactions over time. We can, however, conclude with reasonable confidence that the third option does not explain the patterns. In the first place, assignments that occurred in the context of the employment relationship were likely to occur at the time the patent was issued for the simple reason that the company commonly assumed responsibility for patenting the invention, paying all the necessary fees and providing legal counsel, in exchange for an immediate assignment. Nonetheless, as Table 5 shows, there was nothing remarkable about the propensity of companies to obtain assignments at issue. Although the proportion of assignments that occurred at issue increased over time, as did the proportion of assignments that went to companies, as late as 1911 there was only about a six-point difference in the proportion of assignments to companies that occurred at issue compared to those that went to individuals.

Second, there is evidence that many of the most productive inventors maintained considerable independence throughout their careers. As Table 6 shows, patentees who

assigned to companies displayed significant "contractual mobility," defined as the number of different assignees the patentee dealt with over his or her career. The most highly productive patentees, those with 20 or more career patents, were not in fact tied to single assignees. When one computes the figures over inventors, only 20.6 percent of the patentees used one assignee over their careers. When one computes the analogous figure over patents, the proportion falls to 17.8 percent. These numbers themselves seem small enough to undercut the argument that productive patentees were working in research divisions of companies, but the results are even stronger when one recognizes that the percentages in the table pertain only to those patents that were actually assigned at issue. The highly productive patentees in this group (those with 20 or more career patents) actually assigned on average less than 50 percent of their patents at issue—that is, in the majority of cases they maintained control of their property rights and the ability to sell them at will. Given the remarkable contractual mobility of these inventors (roughly 40 percent had four or more assignees over their careers), it is difficult to believe that the high productivity at patenting we observe owed to a stable employment relationship that allowed for the integration of invention with development.

In order to get a more direct understanding of the relationship between patentees and their assignees, we traced through city directories the inventors in the sample underlying Table 6 and recorded the occupation and/or place of employment for those we were able to locate. Although the resulting subset may not be representative of the general population of patentees, the greater detail we obtained in this manner about who these people were, as well as whether and how they were associated with their assignees, is nevertheless very informative. In Table 7, we present for each time period the distribution of this urban

subset of patentees (based on one randomly selected patent per patentee) and the distribution of all of their patents, broken down by both occupational classes and type of relationship between the patentee and the assignee. Not surprisingly, the data indicate a considerable variety of associations between patentees and assignees, as well as dramatic changes over time. Before 1890, the most common circumstance (over 50 percent of assignments in the patentee distribution, and nearly 40 percent in the distribution of patents) was for a patentee to assign to an individual or firm with which he had no formal association. By contrast, during this period only 1.5 or 2.0 percent (depending on which distribution is used) of all patents, or less than 10 percent of assignments, involved patentees transferring rights to their employers. It should be emphasized, moreover, that because the table records only assignments at issue—the type most likely to reflect exchange between parties with a formal association—this evidence of extensive arms-length trade in patented technology for the period before 1890 is quite telling.

However, it is also evident from Table 7 that there was a substantial shift in the pattern after 1890. First, regardless of whether one uses patents or patentees as the unit of observation, it is clear that there were increases in the proportion of patents assigned within each occupational class. More important, both the identity of and relationship between the parties to assignments at issue changed dramatically over time. In particular, the occupational composition of patentees shifted in the direction of a much larger share for principals in firms and a smaller share for unknown or independent operators. By contrast, the proportion of patentees who were employees was roughly constant at about 20 percent and was consistently less important than either of the other two groups (a result that holds whether one examines the distribution of patents or that of patentees). There was also a

significant increase in the fraction of patents that went to assignees with a formal association with the patentee, but this result was driven largely by a rise in the proportion of assignments made to firms in which the patentee was a principal, not by an increase in assignments from employees to their employers. For example, the fraction of patents (patentees) that were assigned to a firm in which the patentee was a principal rose from 4.6 (2.9) percent before 1890, to 19.2 (9.2) percent in 1890-1910, to 37.0 (13.5) percent after 1910. Even after 1890, however, the proportion of patents (or patentees) that involved assignments from employees to employers generally hovered around 6 percent and never rose over 9 percent.[21]

In Table 8, we report the distributions of patents and patentees across categories of association, broken down by occupational class and time period. As is immediately apparent from the lower percentages of patents assigned in the former distribution compared to the latter, those patentees who assigned their inventions at issue received more patents on average than those who did not, across all occupational classes and time periods. Although the difference was not very large in the unknown or independent inventor class during the two earlier sub-periods, the finding suggests that the empirical relationship between assignment behavior and higher productivity at patenting was not an artifact generated by a particular occupational class or type of association between patentees and

[21]Because there is a significant group of patent assignments for which we were unable to determine the association (or lack thereof) between the patentee and the assignee, the actual figures are likely somewhat higher. However, the qualitative result that patentees assigning to their employers did not account for a dominant share of the assignments of patented technologies seems firm. The bias owing to measurement error would almost certainly be offset by that attributable to our relying here on assignments at issue.

their assignees. The secular trend toward higher rates of assignment at issue was likewise not specific to a single occupational class; nor did it result from a change in the occupational composition of patentees.

The advantage of Table 8 over the preceding table is that it allows us to explore trends in assignment behavior within each occupational class. Once again, the most important change was the growth of assignments by patentees who were principals in firms to the companies with which they were associated, reflecting both the increasing percentage of patentees who were in this category, as well as increases in their propensities both to assign at issue and to assign their patents to their firms. Although this change might seem to reflect a reintegration within the firm of invention with commercial development, the evidence is not conclusive. When weighted by patents, two-thirds of these principals were presidents of their companies—companies that often bore their names and specialized in the machine tool or electrical industries. Hence the possibility exists that these firms had been set up as vehicles for highly productive patentees to specialize in inventing and developing new technologies, which would then either be sold off (sometimes embodied in capital equipment) or licensed after the patent was issued. This possibility is made more likely by our knowledge that these patentees had frequently worked for other firms and also assigned their patents to other assignees.

Although employees were the occupational category with the highest rates of assignment at issue, the estimates in Table 8 provide overall support for the idea that the transfer of patent rights by this group of patentees to their employers was not the major force behind the rise in assignment rates. Not only was the proportion of patentees who were employees relatively constant over time at a modest level (see Table 7), but when

employees sold their patents, they appear to have been more inclined than principals to assign to parties with whom they had no formal relationship. This inclination decreased over time; by our estimates, half or more (depending on the weighting) of the patents assigned by employee patentees before 1890 went to parties other than the employer, with this percentage dropping into the 15 to 20 percent range after 1910. Nevertheless, given that the share of patentees we can identify as employees had by then shrunk below 20 percent, and that employee inventors had a markedly lower rate of assignment to parties with whom they had a formal association, it is clear that the behavior of this group was not accounting for the aggregate patterns.

The evidence we have obtained from tracing patentees through city directories thus leads to several generalizations about the evolution of patent assignments in the late nineteenth and early twentieth centuries. First, this trade was extensive and growing in overall volume, often—if not generally—involving arms-length transactions until late in the nineteenth century. Neither the increase in the proportion of patents assigned, nor the association at the individual level between the prevalence of assignment and productivity at patenting, was limited to a specific occupational class of patentees. On the contrary, the relationship held for all of our categories of patentees—those who were principals of firms, those who were employees, and those who appear to have been independent inventors. Second, a major change in the patterns of assignment began to be apparent between 1890 and 1910 and was even more pronounced afterwards. Patentees who were principals or employees of firms became more inclined to assign their patents to the firms with which they were associated, and the relative share of this group among the population of all patentees grew substantially. Inventors who were principals in the firms to which they

assigned were the most prolific patentees of any group. Whether they were like the classic inventors who commercially exploited their inventions themselves (through firms that integrated invention with development and other general business activities) or whether they had organized firms that were specialized at generating new technologies remains unclear. Further research is required to determine whether this structural break reflects a renewed emphasis on integrating invention with other business activities, or an extension to the level of firms of the trend toward division of labor between those concerned with invention and those concerned with commercial exploitation.

Finally, the results of our analysis of this urban subset of patentees is consistent with the notion that trade in the rights to patented technologies involved broad segments of the industrial sector and that the growing proportion of patents that were assigned to companies did not simply result from employees in the R&D departments of large firms transferring their inventions to their companies. Further evidence for this view is provided by Table 9, which reports evidence on the frequency distribution of assignments among assignees for the years 1870, 1891, and 1911. These results, which were figured in such a way as to provide upwardly biased estimates of the degree of concentration, suggest that the assignment of patents was extremely unconcentrated during the first two of these years, though much less so in the third. Over 63 percent of patent assignments in 1870 went to assignees who received only one assignment in that year, and, though the fraction that went to assignees that received more than ten assignments was 8.7 percent (still a rather modest proportion), that figure would have been below 3 percent if it had not been for one outlier,

the Erwin Russell Manufacturing Company in Middlesex County, Massachusetts.[22] Although there was a major shift between 1891 and 1911 toward greater concentration, over 40 percent of assignments still went to assignees with only one such transaction in the year, and over 60 percent to assignees with no more than three. Nonetheless, the increase in the proportion of assignments to firms with more than ten assignments from under 10 percent in 1870 and 1891 to over 25 percent in 1911 (when General Electric alone received over 300 patent assignments) is an indication that the character and organization of trade in patented technologies had begun to change during the intervening years.

Inventors Within Firms

We can get a better idea of what was going on, both early on and at the end of our time period, by looking at the behavior of the firms themselves. The case of the American Bell Telephone Company offers an instructive example. Bell's patent department issued annual reports detailing the number of patents it evaluated from both inside and outside sources. For example, in 1894, it investigated 73 patents submitted "by the public" and 12 brought to its attention by employees.[23] The company filed patent applications for virtually all of the employees' inventions—not apparently because the patent department found the ideas particularly valuable, but for morale reasons and because the cost of

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[22]This company, which evidently produced doors, door knobs, and related products, had nearly 30 patents (over half of which were design patents) assigned to it in 1870 by a single patentee.

[23]It also investigated 26 inventions originating with employees of the local phone companies to which Bell licensed its technology. Annual Report of the Patent Department, 1894, p. 7, American Bell Telephone Co., Box 1302, AT&T Corporate Archives.

obtaining patents in this way was low (typically the company paid bonuses of $50 to employees whose inventions it patented).[24] The asking price for outside inventions was often thousand of dollars, and the department recommended against purchasing almost all of them. Consequently, if one were to divide the company's patents into those purchased from outsiders and those that originated within the firm, the latter would be numerically preponderant. Nonetheless, it is clear that, during this early period at least, it was on the assessment of outside inventions that the department spent much of its energies and resources. Company records contain numerous reports evaluating the novelty and importance of inventions offered by the public for sale. These reports were by no means pro forma; rather they included a great deal of technical detail that was specific to the invention at hand. Moreover, the company seems to have devoted the same painstaking attention to the messy, handwritten submissions of unknown inventors as it did to the more polished presentations of high-priced patent solicitors.[25] It seems, in other words, that the company was determined not to overlook any possible source of technological

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[24]As the director of the patent department, T. D. Lockwood, wrote in his 1894 annual report, "So far as concerns the devices gotten up by our own employees . . . , the practice of the year has been, in a general way, to file an application for patent on nearly every device presented for consideration; . . . and to keep all questions of merit, and the presence, or extent of invention, largely in the background . . ." (p.). See also the statements by Lockwood extracted in the 22 Nov. 1949 "Memorandum for Messrs. Root, Ballantine, Harlan, Bushby & Palmer: Statements of Objectives and Practices of AT&T Patent Department, 1877-1937," p. 15, Western Electric Collection, Location 108 07 02, Folder 1, AT&T Corporate Archives.

[25]See T. D. Lockwood, Reports of Inventions (Not Approved), 1904-8.

advantage that might be obtained by purchasing the patents of independent inventors, even though it found most of the inventions it reviewed not worth pursuing.

Indeed, documents extant in the company's records suggest that American Bell attached much greater importance in its early years to assessing inventions that originated in the external environment than it did to promoting inventive activity within the firm. The architect of this policy was T. D. Lockwood, long-time head of the company's patent department, and a vigorous opponent of what we would now call investment in R&D. As Lockwood wrote in an 1885 letter to the company's general manager, "I am fully convinced that it has never, is not now, and never will pay commercially, to keep an establishment of professional inventors, or of men whose chief business it is to invent; or a corps of electricians who are assumed or expected as a part of their duty, to invent new and valuable telephones or telephonic appliances, in their employ."[26] Lockwood's vision, as embodied in his summary later that same year of the duties of the patent department (and in the department's actual practice) placed emphasis first and foremost on examining "patents or inventions submitted by the public for consideration" and second on examining "descriptions of inventions forwarded by the company's employees." Only at

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[26]The text of the letter is included in a September 11, 1952 memo by Lloyd Espenschied, "Early Company Inventing—A Revealing Letter," Western Electric Collection, Location 91 05 140, Folder 6. Lockwood was not completely consistent, however. He brought Stephen D. Field into his department in 1897 after the company bought some of Field's patents: "I engaged his services in 1897 or thereabouts, to make other inventions of the same kind. . . . Prior to that time he had been for a long time a sort of guerilla [sic] inventor on his own hook . . . ." Testimony of Lockwood in *Read v. Central Union Telephone Company*, abstracted in ?, Divestiture Collection, Location 451 01 01, Folder 17, p. 68.

the end of the report, seventh in a list of miscellaneous duties appended after a lengthy discussion of the department's library, did he include the responsibility for suggesting "special and suitable lines of experimentation" within the firm. Much more important in his mind was the duty to "receive copies of electrical patents from Patent Office . . . , bringing to the attention of the company, such as may commend themselves for novel or striking features," "to constantly acquire information upon all classes of electrical patents," and to maintain a well-stocked library. In other words, Lockwood was mainly concerned with building American Bell's capacity to learn about and assess the merits of inventions generated elsewhere in the economy. The central mission of the company's patent department under Lockwood's long tenure (he headed the department for more than thirty years) was to collect information from a wide variety of sources so as to maintain familiarity with (and be in a better position to evaluate) technological developments occurring throughout the economy.[27]

Bell's policy, as articulated by Lockwood, was undoubtedly extreme, but George Wise has argued that Westinghouse and Edison Electric/General Electric (two other high-

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[27]T. D. Lockwood, "Duties of Patent Department," 23 Nov. 1885, Box 1302, AT&T Corporate Archives. Lockwood's sense of his own duties was confirmed by T. N. Vail, AT&T's president in 1908 testimony: "Mr. Lockwood's duties were, first to examine every patent that was issued—I mean connected with the telephone or electricity—to see whether it had any bearing on our business, and if so we tried to get some rights under it and possession of it. Next he was to examine all the devices in the carrying on of the business . . . . Of course new devices in the new business were all the time occurring to the people. Those were submitted to us from our licensees, and Mr. Lockwood would examine them as to the patentability and as to the value, and whether they had been gone over before, and all that sort of thing." Extracted in "Memorandum for Messrs. Root, Ballantine, Harlan, Bushby & Palmer," p. 30.

tech firms of the period) followed a similar strategy in the late nineteenth century of "purchas[ing] patents and short-term consulting services from independent inventors" rather than developing their own R&D facilities.[28] Two decades into the twentieth century, moreover, Standard Oil of New Jersey was still operating in this way. As George S. Gibb and Evelyn H. Knowlton argued in their study, *The Resurgent Years, 1911-1927*, the company had long shown little interest in promoting research and development internally and had been lax as well in building the capacity to assess and gain control of technological ideas originating in the external environment. In 1918, E. M. Clark, the new general manager of the company's Bayway refinery began a campaign to improve the company's knowledge of outside technologies. His first step was to arrange for its patent work to be shifted to the Chicago firm of Dyrenforth, Lee, Chritton & Wiles, patent solicitors, a firm that had a great deal of expertise in petroleum refining technology. He then, in consultation with Frank A. Howard, a member of this firm, developed and promoted the creation within Standard of a Development Department whose purpose was to collect information about and assess new technologies originating outside the firm. According to Gibb and Knowlton, the new department was founded 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. . . . [T]he new plan was not aimed at fostering creative research." What Standard did, in essence, when it created this department was to

[28]George Wise, *Willis R. Whitney, General Electric, and the Origins of U. S. Industrial Research* (New York: Columbia University Press, 1985), pp. 69-70.

internalize the services of its patent solicitors (Howard himself was brought in as manager) so as to acquire capabilities (similar to those developed much earlier at Bell) for keeping abreast of outside inventions. Only in the next decade would Standard make an serious effort to promote internal R&D.[29]

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[29]George Sweet Gibb and Evelyn H. Knowlton, *The Resurgent Years, 1911-1927: History of Standard Oil Company (New Jersey)* (New York: Harper & Brothers, 1956), pp. 113-114, 122-123, 522-525. We are indebted to David Mowery for suggesting this reference. Despite Mowery's emphasis on the difficulties of contracting for technology in the market, he recognized that one of the most important functions of early R&D facilities was to assess externally generated inventions. See Mowery, "The Boundaries of the U.S. Firm in R&D."

Smaller firms without the funds to build their own capabilities for assessing externally generated technology typically turned to patent solicitors for this service. The Waltham Watch Company, for example, relied heavily for advice on the firm of Wright, Brown, Quinby & May. The solicitors' detailed, highly technical reports assessing the patentability of inventions (generated both inside and outside the company) are evidence that they were providing technological as well as legal services. In addition, the firm performed a variety of other functions for its manufacturer client: it brought new inventions to the attention of the company, compiled lists of all patents in force on particular subjects, searched out inventors in other parts of the country, and negotiated assignments with inventors both inside and outside the company. See for example Arthur H. Brown's 27 July 1912 report on the patentability of an instrument invented by George H. Lang and manufactured by the Stover & Lang Instrument Company. See also the 3 Mar., 30 Mar., and 6 May, 1905 letters from Wright, Brown, Quinby & May to the American Waltham Watch Company, and the 31 Mar. 1913 letter from Olaf Ohlson, the 16 Nov. 1914 letter from George T. May, Jr., and the 25 Jan. 1915 letter from the Waltham Watch Company to the solicitors. Wright, Brown, Quinby & May Correspondence Files, Case 2.

The extensive efforts made by firms, including those in high-tech industries, to gain information about and evaluate inventions originating outside their bounds are strong evidence against the notion that information problems made it difficult to contract for technology at arms length. To the contrary, the evidence suggests that contracting problems were if anything more problematic within the firm than without. As we shall see, it took many firms quite a long time to gain property rights to their employees' inventions. Here, however, Bell was an exception on the progressive side. As early as the 1880s the firm required its employees to sign contracts giving it first right of refusal on their inventions. There are a few examples of similar arrangement in other firms during the last two decades of the nineteenth century. We know, for example, that William R. Baker, a foreman at McCormick Harvester, had this type of employment contract in the 1880s, as did William T. Smith, a foreman at William Knabe & Company's piano works in the 1890s.[30] But contracts that required employees to assign their patents to their companies were relatively rare until much later. According to testimony by Lockwood in 1916, even within the telephone industry the practice was limited to a few firms: the New England, Chicago, and Central Union Telephone Companies, in addition to Bell. As Lockwood put it, "the making of such contracts was not very common," and he went on

[30]"Record of William R. Baker," p. 10, *Baker v. Miller*, Case 9,957, Box 1,402, Interference Case Files, 1836-1905; "Record in Behalf of William T. Smith," p. 20, *Smith v. Perry v. Keidel*, Case 16,028, Box 2,212, Interference Case Files, 1836-1905.

to describe an instance where Bell purchased a patent awarded to an employee of another firm which did not have this type of arrangement with its staff.[31]

Some employment contracts explicitly mentioned patents, but gave the employing firms the right only to use—not own—inventions devised by their employees. For example, inventors in the employ of the Waltham Watch Company typically agreed only to grant the company an exclusive right to the use of their patents during the term of their employment. When the company was reorganized in 1907, it tried without much success to acquire property rights to the patents it was using, but could do little more than ask its solicitors to write polite notes inquiring whether the inventors would now be willing to make assignments:

> We were requested by that firm to look after the assignment of all patents in which the Company is interested, which have been issued recently without being transferred to the new Company. . . . We shall be glad if

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[31]Testimony of T. D. Lockwood in *Read v. Central Union Telephone Company*, abstracted in ?, Divestiture Collection, Location 451 01 01, Folder 17, p. 69. According to Lockwood, the "New York Company [the inventor's employer] never had the inventive bee in its bonnet" (p. 71). Even Bell was willing to acquiesce in the entrepreneurial independence of some it its employees. As late as the 1930s, for example, AT&T (Bell's successor) negotiated special agreements with employees who preferred "to retain the license [themselves], especially for operating in further than the telephone field" and also with employees who claim their "rights are so valuable that they should be paid more than a mere bonus." Similarly, at least in the early years the university scientists it kept on retainer were not required to give the company "first call" on their inventions. Testimony of G. E. Folk, General Patent Attorney, before the FCC, abstracted in ibid., pp. 125-26; and testimony of T. D. Lockwood in *Read v. Central Union Telephone Company*, abstracted in ibid., p. 68.

> you will kindly advise us if you wish an assignment made . . . and we will send you the papers for signature. If, on the other hand, the entire interest is to remain in your own name, we shall appreciate it if you will kindly let us know . . .[32]

At least some key employees flatly refused to assign their patents to the watch company. For example, the firm's general superintendent responded that "he has an agreement with the Company, providing for the use of his inventions, but that he does not expect to make formal assignments relating to them."[33]

Inventors at many other firms had no contractual obligations whatsoever to provide their technology to their employers and, indeed, felt little compunction about

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[32]Letter from Wright, Brown, Quinby, & May to Ezra C. Fitch, 29 Jan. 1907, Wright, Brown, Quinby & May Correspondence Files, Case 2. See also the letter from the same parties to Edward A. March, dated 23 Jan. 1907.

[33]Apparently, some of the Waltham Company's contracts required employees to assign their patents to the firm, but these agreements do not seem to have been well enforced. So much is clear from a 1906 letter written by patent solicitors for the Waltham Watch Company to the widow of one of the firm's employees: "You are doubtless aware that under an agreement entered into between your late husband and the American Waltham Watch Company, several patents now standing in his name are to be assigned to the Company, the agreement providing that all his inventions made during a period which has not yet expired, relating in any way to Watches or to the Manufacture of Watches, shall be assigned to the Company. A large number of the patents have already been assigned; but those that have been granted since 1896 have not yet been assigned." Letter from Wright, Brown, Quinby & May to Mrs. Duane H. Church, 24 Jan. 1906, and from Wright, Brown, Quinby & May to Matthews, Thompson & Spring, 28 Feb. 1907, Wright, Brown, Quinby & May Correspondence Files, Case 2.

exploiting their inventions themselves, even if they came up with the ideas while working in their employers' shops. August Makert, who worked as a carpenter for A. P. Lorrilard & Company (a tobacco manufacturer), reasoned that the company had a right to his inventions when its managers instructed him to work on a particular problem and told him how to go about it, but that things were different "when I got it out of my own head." Makert claimed that he had invented a device for tagging plug tobacco. When the foreman to whom he showed the machine attempted to take credit for the invention and applied for a patent for the benefit of the company, Makert filed his own application and initiated interference proceedings against his employers.[34] Another inventor, M. V. Smith, testified in an interference suit that, after he came up with the idea for a new furnace while working as superintendent for the National Rolling Mill Company in McKeesport, Pennsylvania, "I regarded it to my best interest to keep the employees of the National

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[34]"Testimony on Behalf of Makert," pp. 10, 12, *Hieatt and Hearn v. Markert*, Case 8,290, Box , Interference Case Files, 1836-1905. The Patent Office's interference files contain numerous cases where applications for letters patent were filed both by an employee and his employer, with the former challenging the latter's claim to an invention developed while he worked for the firm. For example, S. T. Schofield contested with H. C. Cragg over which of the two men actually invented a screw feed mechanism developed while he was in the employ of the H. C. Cragg Manufacturing Co. Elmer A. Sperry found himself tied up in an interference proceeding with a draftsmen he had formerly employed in his factory, and Charles A. Lindstrom had a similar experience with a draftsmen he hired. See "Testimony on Behalf of S. T. Schofield," *Cragg v. Schofield*, Case 25,592, FP Box 3,319, ROPO Interference Case Files, 1900-1925; "Sperry's Record," p. , *Sperry v. Eickemeyer v. Morgan*, Case 16,498, Box 2,269-72, and "Testimony on Behalf of Lindstrom," *Lindstrom v. Larson*, Case 20,284/20,293, Box 2,744, Interference Case Files, 1836-1905.

Tube Works as much as possible from knowing anything about my improvement on that furnace, and resigned my position with said company, as superintendent, before I ordered the Patent Office drawings made."[35] Two employees of the American Sheet and Tin Plate Company invented a catcher for tinning machines, building the device on company time with company resources and testing it in the company's Gas City, Indiana, plant. When the machine proved promising, they quit their jobs, reasoning that "if we ever got together again in an independent plant we would have a better opportunity of obtaining suitable remuneration for the patent." The two men subsequently accepted employment with the Carnahan Tin Plate and Sheet Company, one of American's competitors. The Carnahan Company promised to bear the expense of patenting the machine in exchange for a license to use it, with the inventors retaining ownership of the patent.[36] Even "high-tech" firms of the period experienced similar problems. Westinghouse, for example, hired William Stanley to develop a transformer, only to have him claim that a new type of lighting he invented while working on the project was his sole property. Similarly, the manager of the Edison Machine Works in Schenectady, New York, complained to the company's lawyers in 1890 that employees were obtaining patents but refusing to assign them to the firm.[37]

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[35]"Testimony . . . in the Matter of the Interference of John Pedder vs. Martin V. Smith", pp. 25-26, *Pedder v. Smith*, Case 9,448, Box, Interference Case Files, 1836-1905.

[36]"Record of Ernest L. Cronemeyer," p. 46, and "Lewis & Williams Record," pp. 4-8, *Lewis and Williams v. Cronemeyer*, Case 24,270, PF Box 3,133, ROPO Interference Case Files, 1900-1925.

[37]These last two examples are from Wise, *Willis R. Whitney*, pp. 70-72. By 1900 General Electric required its employees to sign contracts promising to assign their inventions to the company. Wise argues

It is important to note that firms' lax policies with respect to their employees' inventions cannot simply be explained as a function of their belief that they owned title to the patents as a matter of common sense or common law. Inventors hotly contested firms' assertions that they deserved such ownership rights, and the courts typically backed inventors over their employers. Indeed, by the turn of the century it was well established that the mere fact of an employment relationship did not entitle a firm to an employee's inventions, even if the invention was developed at company expense. If the inventor was hired for the specific purpose of building a particular machine or improving a particular product, then the employer had a right to the invention (the reason being that the employee had "only produced that which he was employed to invent. His invention [was] the precise subject of the contract of employment.") More generally, however, the courts refused to hold that a contract of employment, "albeit [one that] covers a field of labor and effort in the performance of which the employee conceived the invention," entitled the firm to an assignment of the patent.[38] This latter rule applied even to cases

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that this practice was a "social invention" made possible by the growth of large, centrally controlled firms—that smaller firms "lacked the legal skills to write such a contract. And even if they hired lawyers to do the writing, enforcing the contract might require too much of the time of the owner and his few assistants." Although it is undoubtedly the case that the cost of such contractual arrangements fell over time as both firms and employees gained experience with them, it is unlikely that, even early on, the expense was as prohibitive as Wise suggests. As we saw above, small firms were among those pioneering in the use of such contracts.

[38]*United States of America v. Dubilier Condenser Corporation*, U.S. Supreme Court Reports, 77 Lawyers' Edition 1114. This 1933 case contains an excellent summary of the case law. See also 16 *American Law Reports, Annotated* (hereafter *ALR*) 1177; 32 *ALR* 1037; 44 *ALR* 593; 85 *ALR* 1512; 153

where a firm had employed someone with technical skills "to take charge of its works, and to devote his time and services to devising and making improvements in articles there manufactured." As the majority of the Supreme Court decided in the 1893 case *Allen G. Dalzell et al. v. Dueber Watch Case Manufacturing Company*, "in the absence of an express agreement" by which the employee promised to assign all his patents to the firm, the company could not claim ownership of the patents.[39] In other words, by their very laxness in not requiring or enforcing such "express agreements," firms jeopardized their rights to inventions developed in their shops.

Firms, however, might still obtain a use right, or shop right, to these inventions. As a principle of equity, the courts often granted firms a non-exclusive, non-transferable license to use, without payment of royalty, inventions developed by their employees on company time with company resources.[40] Even here, however, the courts found it easier to enforce the principle in the presence of an express agreement with the employee, and this fact inspired at least one firm (the Pullman Company) to rethink its employment

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ALR 983; and 61 *ALR 2nd* Series 356; and Edwin J. Prindle, *Patents as a Factor in Manufacturing* (New York: Engineering Magazine, 1908), pp. 84-102. Employees could not, however, claim ownership of inventions for which they had merely made suggestions that did not amount "to a new method or arrangement which in itself is a complete invention." See Nathan C. Johnson, "Patent Law and the Nature of Patents," *Sibley Journal of Engineering*, 27 (January 1913), p. 189.

[39]U.S. Supreme Court Reports, 37 Lawyers' Edition 749.

[40]Key cases included the 1886 *Charles H. Hapgood et al. v. Horace L. Hewitt*, US Supreme Court Reports, 30 Lawyers' Edition 369, and the 1896 *Jabez H. Gill v. United States*, ibid., 40 Lawyers' Edition 480. For a summary of the case law, see *United States of America v. Dubilier Condenser Corporation*; and 61 *ALR 2nd* 356.

contracts. After learning about such a case in the fall of 1912, executives of the company began to worry that inventions developed by its employees were being patented "on the outside" and that rights to these devices were being assigned or licensed to the firm's competitors. The executives commenced an investigation into the extent of the problem and, at the same time, began to formulate a policy about inventions patented by employees. Interestingly, in the earliest drafts of the policy, the company claimed no ownership rights to its employees' inventions, seeking only to insure its legal "license to use devices on our own cars without royalty." In these early drafts, the company even planned to pay employee inventors half of any royalties it collected on cars constructed for outside companies and acknowledged that "other outside arrangements" could "be made direct by the inventor."[41] Only after several months and several drafts had gone by did the company decide on a policy to require employees to "give the Company preference in disposing of the title to such invention and the patent therefor, in addition to the shop-right which the law implies." In exchange, the company offered to pay a bonus of $250 for any invention which it decided should be patented.[42] There is no evidence that the articulation of this policy was accompanied by any new research and development initiatives; it was simply an attempt to insure the company control of inventions produced by its employees. The final draft differed from the initial versions mainly in the

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[41]See the minutes of the 22 Oct. 1912 and 7 Jan. 1913 meetings of the Committee on Standards, Operating Department, Chief Engineer, Equipment Standards and Testing Records, 1889-1956, Box 2, Folder 4, Pullman Co. Archives, Newberry Library.

[42]"Policy and Procedure in Patent Matters," 21 Nov. 1913, Secretary & Treasurer, Office of the Secretary & Treasurer, Box 1, Folder 2, Pullman Co. Archives.

company's decision to claim full property rights to employees' inventions and thus deny competitors' access to this technology.[43]

Interestingly, the Pullman Company's attempt to gain control of the inventions of its employees was part of a more general move to improve its ability to assess the value of new technologies. The centerpiece of this policy was the creation of a new Committee on Standards in 1912. The committee consisted of senior managers with considerable technical expertise, and was charged with evaluating the inventions of employees and deciding which ones were worth attempting to patent. The committee was further charged with responsibility for deciding which outside patents the company should purchase: "no letter recommending a particular invention should be written by an official in this Company without the approval of the Committee on Standards."[44] The committee had additional duties (for example, testing the properties of inputs into the firm's production process and setting and enforcing quality standards for its products) but in other respects functioned much like the patent department that AT&T had set up earlier. It was part of the process by which the firm learned to improve its ability to tap new technologies, whether they were generated inside the enterprise or out.

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[43]The new policy was articulated in part as an effort to encourage improvements by employees, but this language was mainly an attempt to make more palatable what was really a radical and unilateral change in the nature of the employment contract. The circumstances under which the policy was formulated—and the bulk of the document's provisions—make it clear that the purpose of the policy was to impose restrictions on employees' behavior.

[44]Policy and Procedure in Patent Matters, p. 8.

Although the evidence suggests that employment contracts giving a company ownership of its employees' inventions were not yet routine during the first two decades of the twentieth century, by the 1930s such agreements were commonplace. The Committee on Patents of the U.S. House of Representatives held hearings in 1936 about proposed revisions to patent law. As part of its investigation, the Committee sent inquiries to a number of companies that included a question about employees' contractual obligation to assign inventions to the company. Fourteen of the responses (ranging from giant firms such as Standard Oil and International Harvester to a number of small aviation companies) were reprinted as appendixes to the hearings. In almost all cases the firms reported that the great majority of the patents they owned originated with their own employees who had contractual obligations to assign their inventions to the company.[45]

Learning by Firms

Although the sources of this shift toward increasing reliance on internally generated technologies are complex, to some extent the change can be understood as an outcome of the processes we have been describing. In the first place, as firms tightened

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[45]U.S. Congress, House, *Hearings Before the Committee on Patents . . . on H. R. 4523, A Bill Providing for the Recording of Patent Pooling Agreements and Contracts with the Commissioner of Patents* (Washington, DC: Government Printing Office, 1936), Parts II, III, and IV. The firms reporting were Beech-Nut Packing, Curtis Aeroplane and Motor, Douglas Aircraft, Great Lakes Aircraft, Hercules Powder, Ingersoll Rand, International Business Machines, International Harvester, North American Aviation, Socony-Vacuum Oil, Standard Oil, Sun Oil Company, Western Union, and Wright Aeronautical Corporation.

up their internal affairs, they were in a better position to exploit the inventive talent already present in their organizations. In the second, the capabilities they built to assess externally generated inventions could be put to good use within the firm as well—could be employed, for example, to pinpoint fruitful areas of research in which the company might itself engage. Moreover, firms that invested in such expertise had to invest as well in facilities to develop and commercialize the inventions they purchased. These facilities could just as easily be turned to the development of internally generated inventions and could then be expanded into departments devoted more broadly to R&D. Indeed this was the sequence of events that occurred at Standard Oil.

Perhaps more important, as the complexity of technology increased by the end of the nineteenth and especially by the early twentieth century, it became more and more difficult for inventors to maintain their independence. Even though the growth of the market for technology had made it easier for patentees to sell off their property rights at an early date and also to form corporations to exploit their inventions, they still faced a great deal of financial uncertainty—especially in those sectors of the economy where the costs of invention, in terms of both human and physical capital, were likely to be greatest. In the electrical field, for example, Elias E. Reis was unable to patent (let alone develop) all his inventions for exploiting the heat generated by electrical currents, because even the preliminary expenses of building models and applying for patents for all of them were too much for his backer to bear. Although Reis "repeatedly" explained "that not only was their filing of great importance, but that unless we did so . . . the applications that have already been filed . . . would suffer very materially, and, perhaps, to an irretrievable extent," his patron would not put up additional money until revenues from the earlier

patents he had financed began to materialize. "Had I the means available to enable me to file some of these applications," Reis claimed, "I should certainly have done so long since, but as matters stand, and have stood, I . . . do not find myself at liberty to seek the assistance of others." Desperate for funds, Reis had assigned his backer rights to all his inventions in exchange for financial help. Support of this kind was sufficiently hard to get, Reis felt, that he was not willing to jeopardize the relationship by seeking other sources of aid.[46]

It is, of course, possible that Reis had difficulty obtaining financing for his inventions because they were not thought to be very valuable, but other inventors whose ideas had proven worth experienced similar difficulties.[47] A good illustration is Charles J. Van Depoele, developer of electric motive systems for trolleys. Van Depoele was perennially short of the capital he needed to commercialize his inventions, and he repeatedly signed away his rights for what appear in retrospect to be paltry sums. In 1880, for example, he assigned the Canadian patents for all his inventions and any additional ones he would devise over the next thirty years to one Reuben G. Lunt, in exchange for a cash payment of $5000 (much of it conditional on the success of Lunt's enterprise). When the cash was not forthcoming, he was forced to take ten percent of the company's stock as payment. Earlier that same year he tried to form a joint-stock

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[46]"Record of Elias E. Ries," pp. 26-30, 52, *Thomson v. Ries*, Box 1,845, Case 13,971, Interference Case Files, 1836-1905.

[47]Moreover, the infringement suit between Reis and Elihu Thomson shows that Reis's ideas were similar to those developed and exploited commercially by Thomson. See "Testimony on Behalf of Elihu Thomson" in ibid.

company capitalized at $100,000 to exploit his American patents. The agreement allocated $70,000 of the stock to George N. Chase "for Services rendered in organizing Said Company & to be sold for Working Capital." The aim of this manipulation was to acquire a working capital of a mere $10,000. Whether this company ever got off the ground is not clear, but in 1885 Van Depoele formed a partnership with William A. Stiles and Albert L. Sweet, to each of whom he assigned a one-third interest in his inventions. The partnership's capital consisted of little more than his patents, though Sweet was to advance the firm $1000 to get the business started. Finally, in 1888 Van Depoele gave up trying to exploit his inventions himself and took a job with the Thomson-Houston Electric Company, accepting in exchange for assignments of his past and future inventions a salary of $5000 a year, plus a royalty of $5 for every railroad car the company equipped with electric motive power during the life of his patents. Thomson-Houston had the capital and access to financing that Van Depoele was unable to obtain on his own, despite the undoubted value of his patents.[48]

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[48]Articles of agreement between Charles Joseph Van Depoele, Electrician, and Albert Wahl, both of Detroit, and Reuben Greenliff Lunt of Toronto, 27 Nov. 1880; Agreement dated 4 Mar., 1880; Copartnership Agreement between Charles J. Van Depoele, Albert L. Sweet, and William A. Stiles, June 6, 1885, Agreement between Thomas J. Van Depoele and the Thomson-Houston Electric Co., 1888; all in Folder labeled Business Papers—Agreements, etc. 1877-1889, Unbound Papers, Charles J. Van Depoele, 1877-1892, MSS 867, Baker Library, Harvard University Graduate School of Business Administration. The folder also included several other propositions aimed at raising capital, none of which seem to have been successful. According to W. Bernard Carlson, the Thomson-Houston Company, as part of the deal, acquired the Van Depoele Electric Manufacturing Company, which was purchased for its "railway and

Few inventors were able to obtain such lucrative contracts, and as a result few were willing to agree, as Van Depoele did, to assign all past and future inventions to the company. When the Edison Machine Company's manager complained in 1890 that employees were refusing to turn over their patents to the firm, the company's lawyers responded that the solution was to institute contracts requiring employees to make such assignments as a matter of course. The lawyers hastened to add, however, "We fear our suggestion is somewhat impracticable."[49] Employee resistance was just too high. That at least is the implication as well of a 1908 book on patents written by Edwin J. Prindle and published by the *Engineering Magazine*, one of the earliest trade journals to address managers' concerns. Concluding a chapter on "The Patent Relations of Employer and Employee," Prindle urged manufacturers to follow the example of some leading firms and require that "every employee who is at all likely to make inventions" sign contracts providing for the assignment of patents to the company. Prindle admitted that it was often difficult to induce employees to sign such agreements, but he argued that the resistance might be overcome if officers set good examples by binding themselves in the same way.[50]

A 1912 letter from a consulting engineer named William Wright to Pullman's president, J. S. Runnells, makes a similar point that personnel issues were at the heart of the problem. According to Wright, in "recent years many of the large manufacturing

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motor patents." See *Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870-1900* (New York: Cambridge University Press, 1991), p. 216.

[49]Quoted in Wise, *Willis R. Whitney*, p. 71.

industries in this country have established systems for . . . receiving new ideas from employees." Without such systems in place, employee inventors typically acted on their own:

> If one of them thinks of an invention, he is afraid to let it be known to anyone else because of the danger of his ideas being appropriated, and so he works them out in secret and sends them to the Patent Office and if successful in obtaining a patent he generally finds himself in possession of something that is impossible for him to handle to advantage, or he disposes of it to some outside concern for a consideration.[51]

Thus reducing resistance to employment contracts requiring the assignment of patents also depended on firms' ability to tighten up their management hierarchies and so assuage workers' fears that superiors would steal their ideas.

Even if resistance to this type of employment contract was overcome, such agreements were really only meaningful if inventors worked for the same firm for an extended period of time. Otherwise it would be much too difficult for the company to demonstrate that a particular invention was devised during the patentee's term of employment. Certainly, high rates of turnover among inventors were a significant problem for firms during the late nineteenth and early twentieth centuries. Superstars like Nikola Tesla and William Stanley chafed under the restrictions of employment—neither

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[50]Prindle, *Patents as a Factor in Manufacturing*, p. 101.

[51]William Wright to J. S. Runnells, 21 Oct. 1912, Operating Department, Chief Engineer, Equipment Standards and Testing Records, 1889-1956, Box 3, Folder 21, Pullman Co. Archives.

man stayed very long at Westinghouse, for example.[52] But the problem seems to have been just as acute for less important inventors. Entrepreneurially oriented, and constantly searching for the main chance, they moved in and out of employment positions in response to financial exigencies. A good example is Rollin Abell. Abell clearly thought of himself as an independent inventor, but from time to time found it desirable to seek employment within firms. In 1899 he worked for the General Electric Company in Lynn, Massachusetts, but he left the firm in order to go into a partnership with a Dr. Beard to develop a coaster break he had invented. A year later he opened his own office in Boston "to make drawings and design machinery." Apparently, this business was not successful enough to pay the office rent, and after attempting to continue it out of his home, he gave up and took a job with the Sub-Marine Signal Company of Boston. After a short stint at that firm, he "resumed working for myself on patent drawings and designing machinery," spending several months in 1903 developing a carpet loom in Worcester, Massachusetts. A couple of years earlier, he had met some businessmen at an automobile show in New York who were interested in steam vehicles. Subsequent follow-up conversations led in 1903 to his employment by a Mr. Newcomb to design a steam touring car in New Jersey. Later that same year he was in Boston again designing a car for someone named Barlow. The task completed, he returned to the "business of making drawings and designing machinery as before," and there our knowledge of him ends.[53] The Patent Office's interference records contain a wealth of examples of inventors with similarly high

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[52]Wise, *Willis R. Whitney*, p. 70.

[53]Deposition of Rollin Abell, "Testimony on Behalf of Randall & Bates," pp.78-82, *Lemp v. Randall & Bates*, Case 24,587, PF Box 3,309, Interference Case Files, 1900-1925.

turnover rates. To give a few examples, William E. Forster, an inventor of sole levelling machines for the shoe industry, worked for at least five different firms between 1887 and 1894; Arthur F. Randall, an inventor of a steam motor vehicle, worked independently and for at least three firms (including a patent solicitor) between 1897 and 1899; and William W. Wilson, an inventor of adding machines, worked for five different companies in that business between 1901 and 1906.[54]

As these case histories suggest, before firms could reap the fruits that might be obtained from internalizing the process of invention, they had to learn to solve a number of important personnel problems. In particular, they had to reduce both employee turnover and inventors' resistance to signing over the fruits of their creativity to their employers. That is, they had to learn how to convince inventors, who had long regarded independent entrepreneurship as the key to upward mobility, that steady employment offered both rewards and opportunities for advancement. In addition, firms had to learn how to tighten up their managerial hierarchies so that they could credibly guarantee inventors that no one else in the firm would steal their ideas.[55]

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[54]"Preliminary Statement and Record in Behalf of William E. Forster," pp. 1-2, 65, *Forster v. Judd*, Case 16,542, Box 2,278, Interference Case Files, 1836-1905; "Testimony on Behalf of Randall & Bates," pp. 4, 31, 33, *Lemp v. Randall & Bates*, Case 24,587, PF Box 3,309, and "Wilson's Record," pp. 5-7, *Putnam v. Wilson*, Case 27,129, PF Box 3,255, ROPO Interference Case Files, 1900-1925.

[55]This process paralleled in important ways the more general learning about how to manage large numbers of employees that became embodied in personnel departments during the early twentieth century. See, for example, Sanford M. Jacoby, *Employing Bureaucracy: Managers, Unions, and the Transformation of Work in American Industry, 1900-1945* (New York: Columbia University Press, 1985).

Although it is beyond the scope of this essay to describe how these tasks were accomplished, we conclude this discussion by emphasizing how much learning there was in fact to be done. In order, for example, to overcome employees' resistance and reduce the negative effect that the requirement to assign patents might have on their incentive to invent, firms typically offered employees monetary rewards for inventions that led to patents. Such bonuses, however, could themselves be a source of difficulty. As one of Western Electric's executives later testified, such a system "put a tremendous incentive" on employees to work "at counterpoints to their own associates," creating a situation where "men would not work with each other, they would not confide with each other, yet the problem which was before us was a problem which required team action." Even worse, bonuses encouraged employees to "work for themselves at the expense of their employer."

> The incentive was to get out as many patents that would pass the Patent Office as possible. An invention was made. It could be covered by one strong patent or it could be covered by a dozen minor patents. It was to the company's advantage to have it one strong patent, but it was to the employee's advantage to have a dozen minor patents, because he profited in a monetary sense . . . . Then, in addition to that, it is only a small fraction of the things which are done in a research and development laboratory that come within the purview of the patent law. It is only those

things which are new and novel, and which have not been practiced before, which come within the things which the law says can be patented.[56]

In order to encourage its employees to work together, to build cases for single strong patents rather than multiple weak ones, and to work assiduously on problems that were not likely to lead to patentable solutions (problems that as Stephen Usselman tells us, were an increasingly important part of the work of large firms), Western Electric, its parent company AT&T, General Electric, and other similar firms stopped awarding their research employees bonuses for patents. Instead employees in the relevant departments received straight salaries by way of compensation. Patents became only one of the factors that was taken into account in promotion decisions, and firms now faced new difficulties both in measuring the output of their research employees and creating credible incentives to encourage their productivity.[57]

Conclusions

Recent scholarly literature explains the spread of in-house research laboratories during the early twentieth century by pointing to the information problems involved in contracting for technology. We have argued, by contrast, that these difficulties have been overemphasized—that in fact a substantial trade in patented inventions did develop over the course of the nineteenth century, much of it taking the form of transactions conducted at arms-length through the market. Towards the end of the century, however, the nature

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[56]Testimony of Dr. Frank Baldwin Jewett, U.S. Congress, House, *Hearings for the Committee on Patents*, Part I, pp. 276-277.

of these exchanges began to change as sales of patents increasingly took the form of assignments at issue and as a growing fraction of these assignments involved patentees and assignees who were formally associated with each other in some way. Although this change may have betokened a reintegration of inventive and developmental activities within the firm, possibly driven by the kind of information problems discussed in the recent literature, this interpretation is by no means certain. In the first place, the change was largely accounted for by the increasing tendency of inventors who were principals in companies to assign their inventions to their firms. In the second, it is possible that the growing number of patentees who behaved in this manner were forming companies mainly to facilitate their specialization in invention. One thing we can say with some certainty is that pattern was not accounted for by the rising tendency of employees to assign their inventions to their employers. Although the proportion of employee inventors who transferred patent rights to their companies increased after 1890, the numbers of these patentees were still too small to account for the aggregate patterns.

Although it is true that large firms were beginning by the early twentieth century to invest in developing their internal inventive capabilities, in the process they faced a number of significant difficulties. Most importantly, they had to insure that they obtained the property rights to inventions conceived on company time with company resources. The solution to this problem was to require employees to sign contracts in which they obligated themselves to assign their patents to the firm. Before such contracts could become routine, however, a number of nontrivial difficulties had to be resolved. Firms

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[57]Ibid., and testimony of Gerard Swope, p. 324.

had to overcome employee resistance, and they had to reduce the high turnover rates that made such requirements effectively unenforceable. In other words, entrepreurially oriented inventors had to be convinced that loyal service to a firm offered a combination of security and opportunities for advancement superior to that which might likely result from self-employment. The increased costs of inventive activity and the resulting greater risks borne by independent inventors by the early twentieth century helped firms make their case. But there was still a lot of organizational learning involved. Hence, in important ways, the story we tell for the early twentieth century turns the recent literature on its head. Economic actors at that time had a great deal of experience with contracting for new technological ideas in the market; what they did not know how to do, and had to spend a great deal of time and energy learning, was managing creative individuals within the firm.

TABLE 1

DESCRIPTIVE STATISTICS ON ASSIGNMENTS MADE BEFORE AND AFTER ISSUE OF PATENTS

	1870-71	1890-91	1910-11
New England			
Assignment to Patenting Index	115.1	109.5	132.4
% Assigned After Issue	70.4	31.2	30.1
% Secondary Assignments	26.6	14.8	12.0
% Geographic Assignments	17.1	0.8	0.0
Middle Atlantic			
Assignment to Patenting Index	100.7	94.8	116.3
% Assigned After Issue	70.9	44.4	37.9
% Secondary Assignments	33.3	16.4	11.0
% Geographic Assignments	19.1	1.9	0.7
East North Central			
Assignment to Patenting Index	96.3	118.1	104.9
% Assigned After Issue	77.7	48.5	32.8
% Secondary Assignments	18.1	18.4	11.8
% Geographic Assignments	34.3	5.7	1.8
West North Central			
Assignment to Patenting Index	90.7	110.1	73.5
% Assigned After Issue	77.4	48.6	42.6
% Secondary Assignments	32.3	19.2	11.0
% Geographic Assignments	41.9	13.0	2.6
South			
Assignment to Patenting Index	60.0	68.9	68.0
% Assigned After Issue	74.4	42.3	48.2
% Secondary Assignments	27.9	11.3	19.1
% Geographic Assignments	20.9	6.2	2.5
West			
Assignment to Patenting Index	150.0	67.2	81.5
% Assigned After Issue	59.1	57.4	36.0
% Secondary Assignments	22.7	11.4	10.4
% Geographic Assignments	18.2	7.4	1.2
Total Domestic			
Assignment to Patenting Index	100.0	100.0	100.0
% Assigned After Issue	72.3	44.1	36.5
% Secondary Assignments	27.8	16.4	12.0
% Geographic Assignments	22.8	4.6	1.2
Assignments to Patents Ratio	0.83	0.71	0.71
Number	794	1,373	1,869

Sources and Notes: In order for sales of patents to be legally binding, copies of the assignment contracts had to be deposited with the Patent Office in Washington. These contracts are now stored at the National Archives. Our sample consists of all contracts filed with the Patent Office during the months of January 1871, January 1891, and January 1911—a total of about 4,600 contracts. The assignment to patenting index is based on the ratio of assignments originating in the respective regions (based on the residence of the assignor) to the number of patents filed from that region in 1870, 1890, and 1910 respectively. In each year the index has been set equal to 100 for the national average. The percentage of secondary assignments refers to the proportion of assignments where the assignor was neither the patentee nor a relative of the patentee. The percentage of geographic patent assignments refers to the proportion of assignments where the right transferred was for a geographic unit smaller than the nation.

TABLE 2

ASSIGNMENT OF PATENTS AT ISSUE, 1870-1911

	1870-71	1890-91	1910-11
Number of Patents	1,563	2,031	2,512
% of Patents Assigned	18.4	29.3	31.1
% of Assignments that Went to Companies	23.6	47.1	64.2
% of Assignments to Group Including Patentee	52.1	41.5	25.4
% of Patents Not Assigned or Assigned to Group Including Patentee	92.2	86.3	79.7

Sources and Notes: The table is based on three cross-sectional samples drawn from the *Annual Report of the Commissioner of Patents* for the years 1870-71, 1890-91, 1910-11. The three samples total slightly under 6,600 patents. The numbers of observations in the respective cells are reported within parentheses. The category "% of Assignments to Group Including Patentee" consists of patents assigned to a group of individuals that included the patentee, to an individual with the same family name as the patentee, to an individual specifically designated as an agent for the patentee, or to a company which seemed to be named after the patentee.

TABLE 3

DISTRIBUTION OF PATENTS BY PATENTEE COMMITMENT TO PATENTING, 1790-1930

	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	21.7	17.1	10.5	16.4	10.5	23.7
1890-1891	23.2	16.0	6.7	10.3	12.4	31.4
1910-1911	39.6	16.3	7.8	9.4	7.3	19.6

Sources and Notes: 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 a longitudinal sample that follows over their entire patenting careers all of the 562 patentees in the cross-sectional samples (see Table 2 for a description) whose family names began with the letter "B." The data set is not yet complete. We report here on information retrieved for just over 4,200 patents from 53 of the years from 1834 to 1936. The incomplete nature of the sample understates the shares of the more active patentees, especially for 1910-11.

TABLE 4

AVERAGE NUMBER OF PATENTS AWARDED TO VARIOUS TYPES OF PATENTEES, 1870-1911

	1870-71	1890-91	1910-11
Year Total of Patents For All Patentees	1.92 (1,563)	2.29 (2,031)	2.00 (2,512)
Year Total of Patents For Patentees Who Maintained a Stake	1.90 (166)	2.59 (317)	2.33 (271)
Year Total of Patents For Patentees Who Assigned to Companies	4.97 (68)	4.10 (280)	3.43 (502)
Year Total of Patents For Patentees Who Did Not Assign	1.67 (1,275)	1.99 (1,436)	1.61 (1730)

Sources and Notes: The table is based on three cross-sectional samples drawn from the *Annual Report of the Commissioner of Patents* for the years 1870-71, 1890-91, 1910-11. The numbers of observations in the respective cells are reported within parentheses.

TABLE 5

RELATIVE NUMBERS OF PATENTS ASSIGNED AFTER AND AT ISSUE TO INDIVIDUALS AND COMPANIES

	After Issue		At Issue		
	No.	Row %	No.	Row %	Total
1871					
To Individuals	454	73.2	166	26.8	620
To Companies	112	68.3	52	31.7	164
Total	566	72.2	218	27.8	784
1891					
To Individuals	370	45.6	441	54.4	811
To Companies	230	41.8	320	58.2	550
Total	600	44.1	761	55.9	1361
1911					
To Individuals	307	40.4	453	59.6	760
To Companies	369	33.6	728	66.4	1097
Total	676	36.4	1181	63.6	1857

Source: For a description of the sample, see Table 1.

TABLE 6

CONTRACTUAL MOBILITY AMONG PATENTEES, BY THEIR PRODUCTIVITY AT PATENTING

Number of Patents by Patentee	% Assigned	% Assigned to Companies	Number of Different Assignees: 0		1		2-3		4-5		6+		Total	
			#	%	#	%	#	%	#	%	#	%	#	%
			Distribution of Patentees											
1	19.7	7.6	159	80.7	31	15.7	7	3.6	---	---	---	---	197	35.1
2-5	21.1	6.9	129	59.2	54	24.8	30	13.8	4	1.8	1	0.5	218	38.9
6-10	31.4	15.7	31	44.2	15	21.4	21	30.0	3	4.3	---	---	70	12.5
11-19	47.6	31.0	4	9.5	13	31.0	14	33.3	6	14.3	5	11.9	42	7.5
20+	44.1	20.6	3	8.8	7	20.6	10	29.4	7	20.6	7	20.6	34	6.1
Total			326	58.1	108	19.3	82	14.6	20	3.6	13	2.3	561	100.0
			Distribution of Patents											
1	20.1	8.0	160	80.8	31	15.7	7	3.5	---	---	---	---	198	5.6
2-5	24.0	9.2	357	55.6	166	25.9	104	16.2	11	1.7	4	0.6	642	18.5
6-10	30.4	23.1	225	41.2	126	23.1	173	31.5	23	4.2	---	---	546	15.7
11-19	47.4	35.3	49	8.2	189	31.8	183	30.7	95	16.0	79	13.3	595	17.1
20+	66.8	58.0	107	7.2	266	17.8	541	36.3	272	18.2	306	20.5	1,492	43.0
Total			898	25.9	778	22.4	1,007	29.0	401	11.5	389	11.2	3,473	100.0

Sources and Notes: The sample is the same as in Table 3—that is, it is the incomplete longitudinal sample of patents granted to patentees in our cross-sections whose names began with the letter "B." The first panel presents the distribution of the 561 inventors in our sample, broken down by the total number of patents received and by the total number of different companies and individuals (excluding the patentee) who received assignments at issue. The second panel presents the distribution of patents, by the total number of patents received by each patent's patentee and by the number of different assignees' for the patentee's inventions.

Table 7

OCCUPATIONS OF PATENTEES AND RELATIONSHIPS TO ASSIGNEES
AS INDICATED BY CITY DIRECTORIES

		Before 1890	1890-1910	After 1910	All Years
Occupations:					
Principals and Officers of Firms	% of Patents	37.2	46.5	60.5	49.0
	% of Patentees	20.6	33.9	40.4	30.8
Employees	% of Patents	18.1	25.9	17.3	20.7
	% of Patentees	20.6	36.9	19.2	28.0
Unknown or Independent	% of Patents	44.7	27.6	22.2	30.3
	% of Patentees	58.8	29.2	40.4	43.2
Total	No. of Patents	454	641	603	1,698
	No. of Patentees	68	65	52	185
Relationship Between Patentee and Assignee:					
No Assignment	% of Patents	75.1	49.0	29.7	49.1
	% of Patentees	77.9	53.9	51.9	62.2
Patentee to Employer	% of Patents	2.0	8.9	6.6	6.2
	% of Patentees	1.5	6.2	5.8	4.3
Patentee is Principal or Officer in Assignee Firm	% of Patents	4.6	19.2	37.0	21.6
	% of Patentees	2.9	9.2	13.5	8.1
Patentee and Assignee Are Related by Name	% of Patents	1.3	1.4	0.5	1.1
	% of Patentees	0.0	4.6	0.0	1.6
Unknown Relation	% of Patents	7.5	7.2	21.1	12.2
	% of Patentees	5.9	10.8	23.1	12.4
Patentee Has No Relation to Assignee	% of Patents	9.5	14.4	5.1	9.8
	% of Patentees	11.8	15.4	5.8	11.4

Notes and Sources: The data on which Tables 7 and 8 are based were constructed by searching the available city directories for information on the occupation and place of work of the patentees in our "B" sample. Our "B" sample consists of a partial listing of all the patents ever filed by those patentees in one of the cross-sectional samples from 1870-71, 1890-91, and 1910-11 whose surnames begin with the letter "B." This effort yielded information on 185 patentees, who were responsible for 1698 patents in our partial listing of their career patents. The information retrieved from the city directories was then used to classify each patentee at the year of each patent in our sample by occupation and by relationship to the assignee of the

patent (if the patent was assigned at issue). Three occupational classes were defined. A patentee was classified as a 'principal' in a firm if he was listed in the respective directory as an officer (president, vice-president, treasurer, secretary, or general manager) in a firm, or with an occupation that seemed to indicate that he was a proprietor of a firm (for example, manufacturer or inventor). A patentee was classified as an employee if he was listed in the respective directory with an occupation that suggested a subordinate in a firm (for example, manager, superintendent, salesman, clerk, chief-engineer, or foreman). A patentee was classified in the independent or unknown category if the occupation seemed ambiguous as to whether the individual was an independent proprietor or employee (for example, agent, architect, engineer, machinist, brewer, cabinet-maker, chemist, clothier, confectioner, draftsman, druggist, electrician, jeweler, metal-works, mechanical engineer, or printer), and if no firm was listed as a place of work. As for the classification of the relationship between the patentee and the assignee, six categories were defined, with the first being for those cases where the patent was not assigned at issue. An assignment was classified as being from a patentee to an employer if the patentee was an employee and the assignee had the same or a similar name as the firm listed as the place of work. A patent assignment was classified as from a "principal" to his firm if the patentee was a "principal" in the firm to which the patent was assigned. An assignment was classified as one that involved no relationship between the patentee and the assignee if a place of work was listed that was different from the name of the assignee, or if the assignee was another individual with a different surname. An assignment was classified as a case of a patentee assigning to a family member if the patentee and the assignee had the same surname. The classification "unknown relation" was used when there was no report of a place of work and the patentee was classified in the unknown or independent category. It was also used in miscellaneous cases where it was unclear whether or not the patentee and the assignee had a formal relationship.

Table 8

DISTRIBUTION OF PATENTS AND PATENTEES BY OCCUPATIONAL CLASS AND RELATIONSHIP TO ASSIGNEE, BASED ON INFORMATION FROM CITY DIRECTORIES

		Before 1890			1890-1910			After 1910			All Years		
		Principal or Officer	Em-ployee	Unknown or Inde-pendent	Principal or Officer	Em-ployee	Unknown or Inde-pendent	Principal or Officer	Em-ployee	Unknown or Inde-pendent	Principal or Officer	Em-ployee	Unknown or Inde-pendent
No Assignment	% Patents	78.7	64.6	76.4	46.1	40.4	61.6	33.1	14.4	31.3	47.2	38.4	59.5
	% Patentees	85.7	78.6	75.0	50.0	50.0	63.2	61.9	30.0	52.4	63.2	54.2	66.3
Patentee to Employer	% Patents	----	11.0	----	----	33.7	----	----	38.5	----	----	29.8	----
	% Patentees	----	7.1	----	----	16.7	----	----	30.0	----	----	16.7	----
Patentee is Principal or Officer in Assignee Firm	% Patents	12.4	----	----	41.3	----	----	61.1	----	----	44.1	----	----
	% Patentees	14.3	----	----	27.3	----	----	33.3	----	----	26.3	----	----
Patentee and Assignee Are Related by Name	% Patents	0.6	3.7	1.0	2.0	----	1.7	0.8	----	----	1.2	0.9	1.0
	% Patentees	----	----	----	9.1	----	5.3	----	----	----	3.5	----	1.3
Unknown Relation	% Patents	----	11.0	12.3	2.7	11.5	10.7	0.3	39.4	63.4	1.1	19.6	25.1
	% Patentees	----	7.1	7.5	----	12.5	21.1	----	30.0	42.9	----	14.6	20.0
Patentee Has No Relation to Assignee	% Patents	8.3	9.8	10.3	7.4	14.5	26.0	4.4	7.7	5.2	6.3	11.4	14.4
	% Patentees	----	7.1	17.5	13.6	20.8	10.5	4.8	10.0	4.8	7.0	14.6	12.5

Notes and Sources: See Table 7.

Table 9

DISTRIBUTION OF ASSIGNED PATENTS BY THE NUMBER OF ASSIGNMENTS RECEIVED BY THE ASSIGNEE IN THE YEAR (PERCENT)

	1 Assignment	2-3 Assignments	4-5 Assignments	6-10 Assignments	> 10 Assignments
1870	63.1	20.3	5.4	2.5	8.7
1891	54.8	23.5	8.1	8.3	2.2
1911	41.5	19.0	7.3	6.5	25.7

Notes and Sources: These estimates of the distribution of assigned patents were calculated from a data set constructed by collecting the number of assignments received by the assignee in the respective year for all patent assignments appearing on every other page of the *Annual Report of the Commissioner of Patents* for 1870, 1891, and 1911 (assignees, like patentees, were listed in alphabetical order). Because we ran over to the off pages in order to get a complete accounting of all the patent assignments received by the assignees sampled, our procedure is likely to overstate the concentration of patent assignments across assignees.