INSTITUTIONS AND DEMOCRATIC INVENTION IN 19TH CENTURY: EVIDENCE FROM THE GREAT INVENTORS' OF THE UNITED STATES, 1790-1930

by

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In recent years there has been a revival of concern with the impact of patent institutions on the rate and direction of inventive activity, and of technological change more generally. Much of the analysis has focused on what seem to be the most direct effects of granting an exclusive property right in technological knowledge: the enhanced returns that inventors can extract by enjoying a state-mandated monopoly on discoveries they make, and the higher costs that those who might choose to employ the new technologies have to bear as a result of a society recognizing property rights in information. In this paper, however, we highlight another feature whose significance has received little attention. We argue that defining and enforcing a tradable asset in new technological knowledge is also important because it encourages the evolution of a market in technology, and because it extends and increases incentives for investment in inventive activity to segments of the population that would otherwise find it difficult to directly extract returns from their technological creativity.

The framers of the U.S. patent institutions quite self-consciously made major changes to the structures employed in Europe, and nearly all of their alterations can be viewed as extending effective property rights in technological discoveries to classes of the population that would not have enjoyed them under traditional intellectual property institutions. Not only did the U.S. break from Old World precedent in reserving the right to a patent to "the first and true" inventor anywhere in the world, as opposed to his employer or to the first to import the technology into the respective country, but from the very beginning the U.S. laws required that the specifications of patented inventions be made public immediately, and set the fee for obtaining a patent at a level far lower than anywhere else (less than 5 percent of the level in Britain).[1]

[1] Telling examples of how seriously the patent law was enforced come from how disadvantaged groups such as slaves and married women were treated. Antebellum laws in many states regarded slaves and their output as the property of their owners; similarly, the property of married women belonged to their husbands. However, according to federal patent laws, a slave holder could not obtain a patent in his own name for a device that his slave had created, and neither could a husband obtain a patent for his wife's invention. In 1857, a slaveholder from Mississippi, Oscar J. E. Stuart, wished to given a patent in his own name for a cotton scraper plough invented by one of his slaves. Both the Patent Office and the Attorney General on appeal rejected Stuart's claim because, according to the patent laws, only the true inventor could be given a patent. Congress also failed to approve Stuart's plea "praying that the patent laws may be so amended as that a patent may issue to the master for a useful invention by his slave." See Khan 1995 and 2004.

Another consequential innovation, albeit one that was not permanent until 1836, was the introduction of an examination system, whereby applications were to be examined for novelty and appropriateness before a patent was granted.[2] This provision was of fundamental significance, because approval from technical experts reduced uncertainty about the validity of the patent, and meant that the inventor could more easily use the grant to either mobilize capital to commercially develop the patented technology, or to sell or license off the rights to an individual or firm better positioned to directly exploit it.[3] Private parties could always, as they did under the registration systems prevailing in Europe, expend the resources needed to make the same determination as the examiners, but there was a distributional impact, as well as scale economies and positive externalities, associated with the government absorbing the cost of certifying a patent grant as legitimate and making the information public.[4] Trade in patented technologies was, as a result, much more extensive – even on a per patent basis – in the U.S. than elsewhere (see Figure 1).[5] Technologically creative people without the capital to go into business and directly exploit the fruits of their ingenuity were major beneficiaries.

One would expect this system to have led to a more socially diverse composition of inventors and, in previous work, based on general samples of patentees, we showed how individuals from elite backgrounds accounted for a much smaller proportion of patentees in the

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[2] For the first few years after the Patent Act of 1790 was passed, a committee, composed of the Secretaries of State (Thomas Jefferson) and War (Henry Knox), and the Attorney General (Edmund Randolph), examined the patent applications. This provision proved unwieldy, imposing a particular burden on Jefferson, and was replaced by a registration system in 1793. Under this system, however, disputes about the validity of a patent were to be resolved by the judiciary, and this often handicapped inventors. Congress began to hold hearings about further reform during the early 1820s. These deliberations ultimately led to the Patent Act of 1836, under which the U.S. adopted the examination system that is still in use today, whereby each application is scrutinized by technically trained examiners to ensure that the invention conforms to the law and constitutes an original advance in technology.

[3] Under an examination system, an inventor who was able to obtain a patent would also be more secure about the possibility that infringement would dissipate his income stream. Court settlements would be easier to obtain, and competitors would thus be less likely to infringe.

[4] See Dutton 1984 and MacLeod 1988 and 1999.

[5] The markedly higher ratio of assignments to patents in the U.S. is all the more significant, both because the British figures are biased upward by the inclusion of licenses, and because the higher costs of obtaining a patent in Britain should, at least in principle (if screening by cost was a good substitute for screening by examination), have led to patents of higher average quality.

U.S. than they did in countries such as Britain during the early 19th century (Khan and Sokoloff 1998). Because many patents are of little or no value, however, this evidence may not conclusively demonstrate that providing broader and stronger incentives for inventive activity was of much technological significance (Sokoloff 1988; Sokoloff and Khan 1990; and Khan and Sokoloff 1993). Indeed, many observers, including those who were influential in maintaining the more socially restrictive patent systems that predominated in Europe until late in the 19th century, thought that little in the way of new technology that was novel or important could be expected from individuals who lacked sufficient capital to obtain patents and fund their commercial application:

> even with the present expense there are so many trifling patents taken out. If the fee was much higher, parties that are now taking out patents for little speculative things …would not take them out. They are something like the dog in the manger; they prevent the public from benefiting by the invention or improvements on it for fourteen years, and yet do not benefit themselves.[6]

It is for this reason we illustrate the significance of offering broad access to opportunities for deriving income from investment in inventive activity through an examination of the backgrounds and careers of a sample of so-called 'great inventors' active in the U.S. during the 19th and early 20th centuries. Our sample encompasses all of the 409 individuals recognized as important inventors in the Dictionary of American Biography who were born before 1886 and active in the U.S. For each person (408 men and 1 woman), we collected biographical information as well as the records of a substantial proportion of the patents (roughly 4500 out of 16,900) they were awarded over their respective careers. The focus on those inventors who achieved renown for their contributions to the advance of technology seems fully appropriate for assessing whether the democratic orientation of the U.S. system supported important advances in technology.

[6] So testified Charles Few to the Select Committee on the Law Relative to Patents for Invention, on May 15, 1829. See British Parliamentary Papers 1968, Reports from Select Committees on the Law Relative to Patents for Inventions, vol. 1, p.48.

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The education and training of the 'great inventors' suggest that initially most came from unassuming backgrounds. Figure 2 displays the distributions of patents across classes of 'great inventors' distinguished by the amount and type of formal schooling they received, and arrayed by birth cohort. It reveals that from the very earliest group (those born between 1739 and 1794) through the birth cohort of 1820 to 1845, roughly 75 to 80 percent of patents went to those with only primary or secondary schooling.[7] So modest were the educational backgrounds of these first generations of great American inventors, that 70 percent of those born during 1739-94 had at best a primary education, with the proportion dropping to only just above 59 percent among those who entered the world between 1795 and 1819. Given that these birth cohorts were active, and indeed, dominant until the very last decades of the 19th century, these figures unambiguously indicate that people of rather humble backgrounds were capable of making important contributions to technological knowledge. Those who had received some schooling at institutions of higher learning are admittedly over-represented (as they accounted for less than one percent of the overall population), but what is most striking is how individuals who had not enjoyed the advantages associated with a more advanced education accounted for such a large share of major inventions, and that those trained in engineering and/or the natural sciences (in college or beyond) did not play a major role until the birth cohort of 1846 to 1865. Moreover, in all of the birth cohorts, the great inventors who had only primary or secondary education received as many (and often more) patents over their careers as did their peers with more

[7] Those classified as receiving only a primary education encompass a range from those who spent no time in school to those who attended school until about age 12. Those who were identified as spending any years in an academy or who attended school after the age of 12 (but did not attend a college or seminary) were placed in the secondary schooled category. Those who spent any time at all in college were either counted in the college category, or – if they had attended a school with an engineering orientation or followed a course of study in medicine or a natural science – in the engineering/natural science

extensive formal schooling. The less-educated inventors also seem to have produced as valuable or technically significant inventions. Their patents were just as likely to be assigned, and just as likely to be cited in applications for patents from later inventors. Thus, the technologically creative seem to have been able to accumulate the skills and knowledge necessary to operate at the frontier largely on their own, or through their work experience as apprentices or younger employees, up until the Second Industrial Revolution.[8]

Some skeptics might suggest that the great inventors who had to make do with little or no formal schooling were not so disadvantaged. That is perhaps the point, at least as regards the sources of technological creativity, but this should not be interpreted as meaning that this class of great inventors was as well off in material terms as those who went to college. Matthias Baldwin, James Eads, George Eastman, Thomas Edison, and Elias Howe are among the many great inventors who were compelled to go to work at an early age to support themselves or their families, and thus to forego much in the way of formal schooling. A perhaps more fundamental question is whether this class of inventors was especially advantaged by the structure of the U.S. patent system, where the cost of obtaining a property right in the new technological knowledge one had discovered was low, the State supported strict enforcement of those rights, and where (between 1790 and 1793, and from 1836 onward) the patent office invested substantial resources in determining the validity of patents before they were granted. The biographies suggest that inventors with only primary or secondary schooling had more limited financial resources than those who were able to attend college. Given the financial institutions of that era, inventors lacking in wealth would surely have found it much more difficult to extract a return from their inventions, if they had to mobilize the capital to start or conduct a business on their own to

[8] The differences in patent systems had implications for how apprenticeship worked, and the effective rights of workers to technological improvements they generated, in Britain and the United States. See Fisk 1998 and MacLeod 1999.

exploit their idea directly without patent protection. The lower cost of obtaining a patent, and the certification that stemmed from having successfully passed an examination screening, should have made it much easier for inventors to market the new technology and either extract returns by selling off or licensing the rights to a firm better positioned for commercial exploitation or to attract investment (by offering shares in a firm whose assets consisted largely of the patent rights to the new technology or commitments by the inventor) to support the continued efforts of the inventor.

Our evidence does indeed suggest that these features of the U.S. patent system were highly beneficial to inventors, and especially to those whose wealth would not have allowed them to directly exploit their inventions through manufacturing or other business activity. The ability to obtain patents provided a means for individuals whose chief asset was technological creativity, or accumulated human capital that was conducive to inventive activity, to extract a return from their talents by focusing on invention. Table 1 shows that a remarkably high proportion of the great inventors, generally near or above half, extracted much of the income from their inventions by selling or licensing off the rights to them. Moreover, it was just those groups that one would expect to be most concerned to trade their intellectual property that were indeed the most actively engaged in marketing their inventions. The great inventors with only a primary school education were most likely to realize the income from their inventions through sale or licensing, whereas those with a college education in a non-technical field were generally among the least likely to follow that strategy.[9] With the exception of the birth cohort of 1739 to 1794, the college-educated inventors were much more likely than others to extract the returns to

[9] Although a bit less striking, it is notable that the inventors who had studied engineering or a natural science were also, for a time (the middle three birth cohorts), much more inclined to rely on sales or licensing of their inventions to realize income. This pattern might be explained as due to these inventors choosing to specialize in what their human capital gave them a comparative advantage in – inventive activity – and leaving it to others to carry out the commercial exploitation.

their technological creativity by being a proprietor or principal in a firm that directly exploited the technology in production.[10] Inventors who chose to realize the fruits of their technological creativity in this way might not seem to have been so affected by the patent system, but in fact even this group benefited. They were obviously helped by holding a monopoly on the use of the respective technology, but many of them were also aided in mobilizing capital for their firms by being able to report patents (or contracts committing patents granted in the future) as assets. Patent portfolios were especially useful as a signal for those who wished to attract venture capital for exceptionally innovative projects that might otherwise have seemed overly risky.

What stands out from an examination of the figures in Table 1 on the principal approaches used by the great inventors to derive income from their inventions is that the reliance on sales and licensing is quite high among the first birth cohort (51.4 percent on average), and remains high (62.1, 44.0, and 66.0 percent in the next three cohorts), until a marked decline among the last birth cohort, those born between 1866 and 1885. The proportion of great inventors who relied extensively on sales or licensing of patented technologies fell sharply from the levels of preceding cohorts, and there was a rise in the proportion that realized their returns through long-term associations (as either principals or employees) with a firm that directly exploited the technologies. This finding parallels that of Lamoreaux and Sokoloff (1999), whose analysis of different data indicated that there was a substantial increase in the likelihood of the most productive inventors forming long-term attachments with a particular assignee over the late-19th and early 20th centuries.[11]

[10] It is interesting to note that many of the college educated of the 1739-94 birth cohort were evidently not so concerned with realizing a return from their inventions. Fourteen percent of the college educated, and more than one third of those who studied engineering or natural science chose not to pursue returns to their inventions. This attitude, however admirable, was not shared by inventors that came from less privileged backgrounds.

[11] Although deeply impressed with how well this result fits with the work of Lamoreaux and Sokoloff 1999 and 2003, some caution may be warranted. Because the Dictionary of American Biography was originally prepared during the 1920s, our sample does not include as many great

The patterns of variation over educational class and time in the relative prevalence of different means employed by inventors in realizing the returns to their inventive activity, and in the relative productivity or prominence of different sub-groups at invention, are both fascinating and complex. We have highlighted the role of a revolutionary, low-cost, examination-based patent system, which encouraged a broad range of creative individuals and firms to invest more in inventive activity, but was especially crucial for those who began without much in the way of resources except for their technological creativity. A key feature of the story, however, is that much of the population possessed some familiarity with the basic elements of technology during this era. Moreover, apprenticeship or the widespread practice of leaving home during adolescence to pick up skills in a trade, a traditional social institution for the transmission and accumulation of more detailed technological knowledge, was both widely accessible and capable of adapting to many of the new developments and to the general quickening of the pace of advance over the 19th century. Technologically creative individuals without the resources to attend institutions of higher learning thus had avenues for acquiring the skills and knowledge necessary to be effective at invention, and could later take advantage of the access to opportunities for inventive activity grounded in the patent system. Good things generally come to an end, eventually, and in this case circumstances changed over time with the evolution of technology. Formal knowledge of science became increasingly important for making significant contributions at the technological frontier, particularly with the so-called Second Industrial Revolution, and the cost of carrying out inventive activity rose. Both of these developments served to narrow the range of the population that could generate important inventions, at least to the extent that technologically creative individuals from humble origins found it difficult to gain access to the programs in engineering or natural sciences which proliferated with the expansion

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inventors born after 1865 as we would like. We would feel a bit more secure with more observations.

of land-grant state universities during the late-19th century. Given the much higher costs of conducting inventive activity, those who were supplying the capital to fund such endeavors may have reasonably desired more in the way of credentials, as well as long-term commitments, from those they were supporting. This interpretation is obviously somewhat speculative, but it does seem to be consistent with the major patterns in the data.

An alternative perspective is that many of the phenomena we have noted could be explained by changes in the sectoral composition of the economy. In this view, there were always some industries in which formal schooling in a technical field was nearly a prerequisite for significant invention, while in others inventors could make do with little or no formal schooling. The latter industries, such as agriculture or light manufacturing, may have featured prominently in the early industrial economy, and thus created opportunities at invention for the under-schooled, but over time the more capital-intensive and science-based industries grew in importance. The sectoral shifts then led to the dominance among great inventors of those trained in engineering or the natural sciences, as well as to the rise of R & D laboratories in large integrated companies. Although some aspects of this account ring true, the estimates presented in Table 2 of variation in the educational backgrounds of the great inventors across sectors (and over time) suggest that changes in the sectoral composition of the economy offer little explanatory power. Although inventors in the electrical/communications sector (that is, electrical machinery and equipment, telegraph, telephone, radio, etc.) were always slightly more likely to have studied engineering or a natural science, in general the differences across sectors seem very small. Instead, the most striking pattern is that the educational backgrounds of inventors tended to move together over time, with each sector characterized by a marked increase in reliance on inventors educated in engineering or natural sciences during the last two birth cohorts. Although our classification of patents by sector is more aggregated than we would like, the data appear to indicate that the change in the composition of inventors overall was likely

driven more by developments that extended across all sectors, rather than by movements in the relative importance of different sectors.

III

Invention was a remarkably democratic activity in the United States throughout the 19th century. Although individuals who had been able to study at institutions of higher learning were over-represented among great inventors, those with little in the way of formal schooling were major contributors to the progress of technology. As we have argued before, this era of democratic invention owed much to the broad access to economic opportunities available in an environment where enterprises operated on a small scale, markets were rapidly expanding, and there were relatively modest barriers to entry. In this paper, however, we call attention to a crucial institution whose role has not been fully appreciated. The U.S. patent system was revolutionary in its extension of property rights in technology to an extremely wide spectrum of the population. Moreover, it was exceptional in recognizing that it was in the public interest that patent rights, like other property rights, be clearly defined, well enforced, and easy to transact in. These were radical notions in a world accustomed to technology being a free good to all who had the capital to exploit it, except as limited by the authority of the government to arbitrarily grant a monopoly over it. It should be no surprise that they encountered fierce resistance in Old World Europe, at least until the exhibition at Crystal Palace intensified concern with the logic and design of intellectual property institutions.[12]

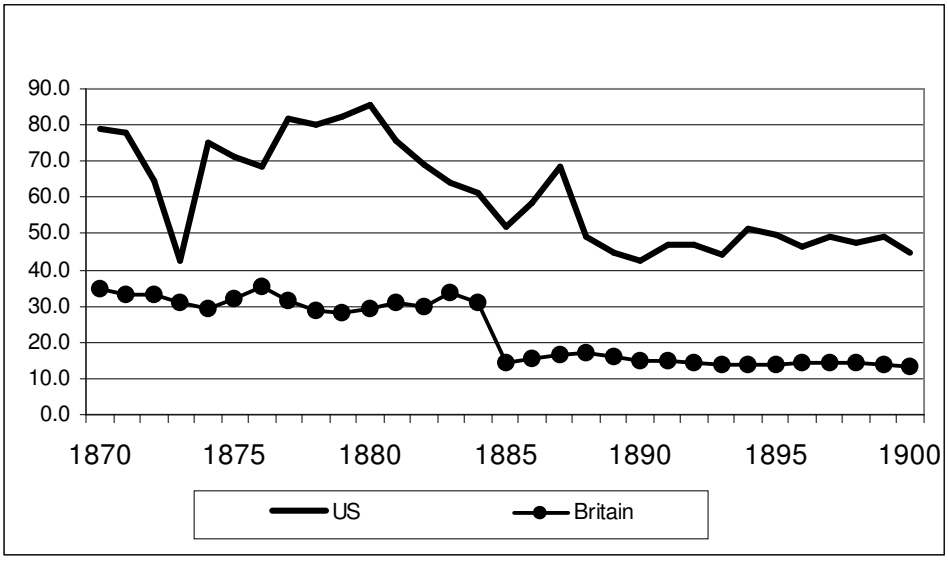
We have demonstrated that those 19th century skeptics who contended only an elite segment was capable of truly important invention, and therefore that an extension of property rights in technology to the general population would have no beneficial effect on the pace of

[12] Machlup and Penrose 1950; Penrose 1951; and Rosenberg 1969.

technical progress, were wrong. Although few of the celebrated inventors in Britain were of humble origins, by design such individuals were well represented among the great inventors of the United States. In the U.S., this group was more likely to invest in inventive activity, not only because of the relatively lower cost of obtaining a patent, but also because the examination system facilitated the use of a patent as a general asset that could be sold, licensed, or offered as collateral for finance. This latter feature was of profound importance for technologically creative individuals who lacked the financial resources to exploit inventions directly. In short, the patent system was a key institution in the progress of technology, but it also stands out as a conduit for creativity and achievement among otherwise disadvantaged groups.

FIGURE 1

THE RATIO OF ALL ASSIGNMENTS TO PATENTS IN THE U.S.,
AS COMPARED TO THE RATIO OF ALL ASSIGNMENTS AND LICENSES TO PATENTS
IN BRITAIN, 1870 TO 1900

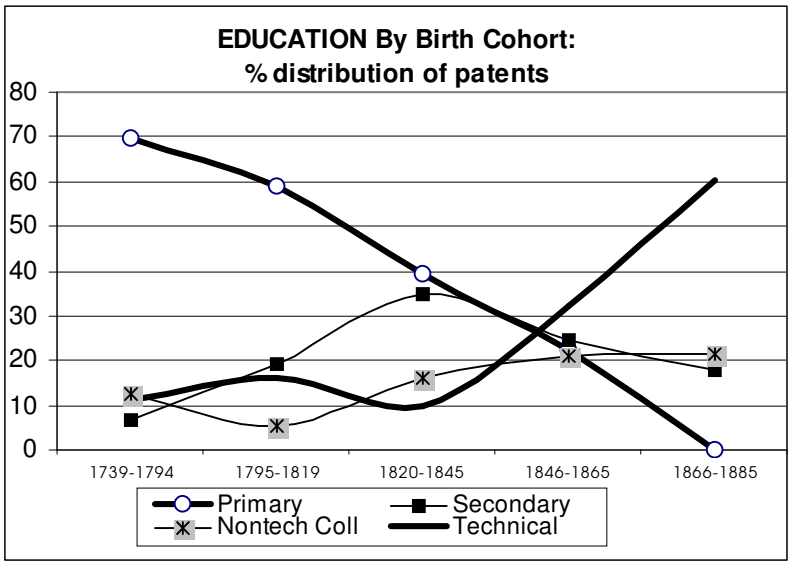


Sources: U.S. Patent Office, Annual Report of the Commissioner of Patents. Washington, D.C.: G.P.O., various years; and Great Britain Patent Office. Annual report of the Commissioners of Patents [after 1883: Annual Report of the Comptroller-General of Patents, Designs and Trade Marks.] London: H.M.S.O., various years.

FIGURE 2

THE DISTRIBUTION OF 'GREAT INVENTOR' PATENTS

BY FORMAL SCHOOLING AND BIRTH COHORT



Notes and Sources: See the note to Table 1 and text.

TABLE 1

DISTRIBUTION OF 'GREAT INVENTOR' PATENTS BY LEVEL OF EDUCATION AND THE MAJOR WAY IN WHICH THE INVENTOR EXTRACTED RETURNS OVER THEIR CAREERS: BY BIRTH COHORTS, 1739-1885

Birth Cohort		Level of Education				
		Primary		Second.		
College	Eng/NatSci.	Tot				
1739-1794 (row %)	69.5	6.8	12.5	11.3	*400*	
avg. career patents		5.6	3.8	6.5	5.2	*75*
sell/license (col. %)	54.9	11.1	84.0	17.7	51.4%	
prop/direct (col. %)	36.5	74.1	2.0	44.7	35.6%	
employee (col. %)	6.2	7.4	--	--	4.8%	
1795-1819 (row %)	59.1	19.3	5.4	16.2	*709*	
avg. career patents		20.0	14.4	17.3	12.1	*80*
sell/license (col. %)	58.2	81.0	42.1	60.4	62.1%	
prop/direct (col. %)	33.2	10.2	47.4	24.3	28.1%	
employee (col. %)	8.4	8.8	--	13.5	8.8%	
1820-1845 (row %)	39.2	34.7	16.3	9.7	*1221*	
avg. career patents		41.8	44.0	29.4	23.7	*145*
sell/license (col. %)	50.7	31.8	37.4	72.8	44.0%	
prop/direct (col. %)	42.3	55.2	47.7	19.3	45.5%	
employee (col. %)		7.7	13.0	14.9	7.0	10.2%
1846-1865 (row %)	22.2	24.5	20.9	32.4	*1438*	
avg. career patents		158.3	73.6	78.6	55.3	*80*
sell/license (col. %)	94.5	68.5	46.2	57.1	66.0%	
prop/direct (col. %)	5.5	18.6	52.8	16.9	22.6%	
employee (col. %)	--	12.9	--	23.6	10.4%	
1866-1885 (row %)	0.2	17.9	21.4	60.5	*574*	

avg. career patents	--	144.5	53.6	155.7	*26*
sell/license (col. %)	--	1.0	46.3	40.1	34.3%
prop/direct (col. %)	100.0	98.1	49.6	18.7	39.7%
employee (col. %)	--	1.0	4.1	41.2	26.0%

Notes and Sources Table 1: See the text. The table reports: the distribution of great inventor patents across the schooling class of the patentee, by the birth cohort of the inventor; the average number of patents received by each inventor, by birth cohort and schooling class; and the distribution of patents across the principal method of the inventor extracting income, by birth cohort and schooling class. The numbers of patents and great inventors are reported in italics for each birth cohort. The classification of the way income was extracted was arrived at through a close reading of the biographies, and refers to the overall career of the inventor (all of his or her patents). The categories include: inventors who frequently sold or licensed the rights to the technologies they patented; those who sought to directly extract the returns by being a principal in a firm that used the technology in production or produced a patented product; and those who were employees of such a firm. We have omitted a category for those inventors who seem to have made no effort to extract income from their inventions. Our overall sample of 'great inventors' was constructed in two waves. In the first (160 inventors), consisting primarily of those born before 1821, we collected the information for all of the patents they received through 1865, and retrieved the information on the number they received after 1865 for our estimates of the total career patents. In the second wave (249 inventors), we collected patents from every fifth year through 1930, and thus will be missing the patents received late in the careers of those of our inventors who were born in the 1870s and 1880s.

TABLE 2

DISTRIBUTION OF 'GREAT INVENTOR' PATENTS ACROSS SECTOR AND EDUCATION OF INVENTOR: BY BIRTH COHORT, 1739–1885

	Agric	Const/Civ Eng	Elec/Comm	Manuf	Transp	Miscell
1739–1794 #patents	33	27	4	209	99	25
Sector share of Patents	8.3%	6.8%	1.0%	52.6%	24.9%	6.3%
Primary (col. %)	60.6	59.3	--	69.4	73.7	84.0
College (col.%)	9.1	11.1	100.0	12.4	13.1	4.0
Eng/Nat Sci. (col. %)	15.2	14.8	--	13.4	7.1	4.0
1795–1819 #patents	61	37	6	316	218	67
Sector share of Patents	8.7%	5.3%	0.9%	44.8%	30.9%	9.5%
Primary (col. %)	68.9	70.3	66.7	56.7	52.3	76.1
College (col.%)	21.3	5.4	--	5.4	--	9.0
Eng/Nat Sci. (col. %)	4.9	24.3	33.3	14.6	21.6	11.9
1820–1845 #patents	98	110	73	659	118	144
Sector share of Patents	8.2%	9.2%	6.1%	54.8%	9.8%	12.8%
Primary (col. %)	24.5	41.8	11.0	44.8	49.2	27.1
College (col.%)	23.5	6.4	23.3	10.8	17.8	38.2
Eng/Nat Sci. (col. %)	2.0	20.9	17.8	9.0	7.6	6.9
1846–1865 #patents	40	154	413	430	261	128
Sector share of Patents	2.8%	10.8%	29.0%	30.2%	18.3%	9.0%
Primary (col. %)	5.0	31.2	28.8	27.9	6.5	6.3
College (col.%)	7.5	19.5	7.8	13.3	35.3	66.4
Eng/Nat Sci. (col. %)	42.5	35.1	37.5	23.0	33.3	6.3
1866–1885 #patents	47	44	133	213	87	83
Sector share of Patents	1.2%	7.8%	23.5%	37.6%	15.3%	14.6%
Primary (col. %)	--	--	--	--	--	--
College (col.%)	28.6	6.8	49.6	23.0	--	2.4
Eng/Nat Sci. (col. %)	71.4	75.0	50.4	67.6	90.8	18.1

Notes and Sources: See the text and the note to Table 1. The distributions of patents across sectors of intended use are reported for each birth cohort of inventors. Within each sector and birth cohort, the table reports the distribution of patents across the educational level of the great inventor. The omitted schooling class is secondary schooling.

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