Of Patents and Prizes: Great Inventors and the Evolution of Useful Knowledge in
Britain and the United States, 1750-1930

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A fundamental and enduring concern of organized society is the design of institutions that encourage would-be inventors, innovators, and investors to contribute to the advance and diffusion of technological knowledge. Although never universally accepted, the dominant stream of thought among economists has long held that the dynamic gains associated with more rapid rates of technological progress, induced by strong protection of intellectual property, typically outweigh the static losses suffered because of slower diffusion of the patented technologies. Indeed, Douglass North went as far as suggesting that its patent system was a crucial reason why Britain was the first country in the world to industrialize. Skepticism about the importance of patent institutions has increased of late, however. On one front, contemporary debates about whether patent systems should be harmonized throughout the world have focused attention on how the effectiveness of various instruments or policies in stimulating inventive activity may vary across different contexts. On another, some economic historians, particularly those who focus on the experience in Europe, have questioned whether patent institutions played any significant role in accounting for the acceleration of technological progress during the 19th century, other than perhaps affecting the direction of the path. Finally, a number of economists have been persuaded by the results from theoretical models of prizes and subsidies and have begun to lobby for these policies as superior alternatives to patent institutions. Although the issues are of great concern, systematic empirical investigation has been limited and many of the key issues about the effects of different features of patent systems and prizes remain poorly understood.

1 See, for example, Mokyr (1990).
Our research program, of which this paper is but a very preliminary report, seeks to improve understanding by turning to the natural experiment that the late-18\textsuperscript{th} and 19\textsuperscript{th} centuries provide for studying the emergence, evolution, and effects of patent systems and prizes. Appreciation of the potential importance of policies aimed at spurring technical advances grew throughout the world during this era, as it became clear that ongoing technological progress was feasible, capable of altering the fate of nations, and responsive to material incentives. Many sorts of schemes were proposed, and a variety of institutions and policies were adopted, or experimented with, by a wide range of countries. Moreover, as empirical evidence accumulated, and economic and political interests shifted, over time many countries modified their policies regarding rewards and incentives for innovation. Considerable convergence occurred, but rather gradually, and it was not until well into the 20\textsuperscript{th} century that many of the features central to the modern patent system came to be embraced by all of the leading industrial economies. The variation in intellectual property regimes over the long-19\textsuperscript{th} century can be studied to evaluate the evolution of knowledge-generating institutions, as well as their sources and their consequences.

Among the issues at the core of the 19\textsuperscript{th} century controversies over knowledge-generating institutions were questions about which segments of the population were capable of producing significant inventions, and whether patents or other types of incentives such as prizes, grants or subsidies, could be effective in increasing the rate at which they made discoveries.\textsuperscript{2} In the leading countries of Europe, such as Britain and France, the dominant view held that only a very narrow group of the population was

\textsuperscript{2} See Machlup and Penrose 1950; Khan and Sokoloff 2004.
capable of truly important contributions to technological knowledge, and that members of this special class were the sort that would have ready access to the large amounts of capital needed to absorb the high costs of obtaining a patent and commercially develop an invention of significance. The British patent system was representative in featuring high transactions and monetary costs that restricted access. It was well understood that patent systems with these sorts of features would mean that only a rather small number of inventions would receive patent protection, but the implications of the design were routinely defended:

> 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.³

In other words, the basic conception was that broadening access to patent protection would do little or nothing for increasing the pace of advance of technical knowledge, and perhaps might even retard technological progress. Although it was recognized that inventors responsible for discoveries of great import to society might not always be able to recoup the costs they had incurred in developing their ideas, it was presumed that in such special cases inventors could be rewarded, if not made whole, through conferral of honors or monetary prizes.

The patent system introduced in the U.S. stood in stark contrast to the one in Britain. Reflecting the democratic orientation of the new Republic, the framers of its

³ So testified Charles Few to the Select Committee on the Law Relative to Patents for Invention, on May 15, 1829. Few rejected the idea of an examination system, but thought that challenges to a patent would be referred to a commission whose members would be paid by fees assessed on the patentees. See British Parliamentary Papers 1968, Reports from Select Committees on the Law Relative to Patents for Inventions, vol. 1, p.48.
intellectual property and other institutions believed that a wide range of individuals, whatever their social origins and standing, were capable of making significant contributions to the advance of technological knowledge. Providing broad access to property rights in inventions, as well as to economic opportunities more generally, would allow society to better realize this potential. Nearly all of the innovations they made in setting up the U.S. patent institutions can be viewed as enhancing the asset value of patent grants, and making it easier for inventors of all classes to obtain them. Crucial departures from the practice in Europe included low fees and the introduction of an examination system, whereby applications were to be examined for novelty and appropriateness before a patent was granted. Creating a well defined asset in new technological knowledge through this sort of certification facilitated commercialization and markets in invention, features which were of course of much greater significance to those who were creative but lacking in financial capital.

This paper employs two parallel data sets of so-called ‘great inventors’ from Britain and the United States, the two leading industrial nations of the period. Our goals here are rather modest. We confine our attention primarily to testing the hypothesis that the differences between the British and American patent systems were in part manifested in the socioeconomic composition of those generating significant new technological knowledge, if not overall rates of invention more generally. In our view, patent institutions had important effects on whether technologically creative individuals chose to invest in the exploration of their ideas, and that the far more restricted access to patents in Britain meant that inventors (both patentees and non-patentees) in that country would accordingly be disproportionately drawn from wealthier backgrounds than their
counterparts in the U.S.. We also examine relevant to the issues of how well alternative social schemes for promoting invention, such as the award of prizes, performed, and whether they tended to work in favor of those from privileged backgrounds.

PATENT SYSTEMS IN THE EARLY INDUSTRIALIZERS

At the beginning of the 19th century, Britain stood out for having a patent system in operation for a longer period than any other in the world (Macleod 1988 and Dutton 1984). As set forth in the 1624 Statute of Monopolies, patents were granted “by grace of the Crown” and were subject to any restrictions that the government cared to impose, including the expropriation of the patent without compensation. The fees for a patent that held in England, Scotland, and Wales, and was taken to term, amounted to over ten times annual per capita income until well into the 19th century. To a large degree by design, features such as extremely high fees and a lack of examination of applications implied that British patent institutions offered rather limited incentives to inventors who did not already command substantial capital or to creators of incremental inventions. Prizes for technological discoveries were also common, and in general the orientation of the overall British approach to encouraging private agents to invest in discovering and developing new technologies reflected a view that significant (in the sense of technologically important, and not being easily discoverable by many people) advances in technical knowledge were unlikely to come from individuals who did not already have access to the means to absorb the high cost of obtaining a patent or to exploit the invention directly through a commercial enterprise.
Although there were calls for reform of the British system, and a series of parliamentary hearings, change did not come until after the Crystal Palace Exhibition of 1851, where the U.S. deeply impressed observers with the creativity of their inventors and called attention to its innovative patent institution. As a direct result, in 1852 the British patent laws were revised in the first major adjustment of the system in two centuries. The patent application process was greatly simplified, and a renewal system was adopted, making it cheaper to initially obtain a patent (though one taken to full term remained just as costly as before). Before 1852 patent specifications were open to public inspection only on payment of a fee per patent but afterwards, following the U.S. model, they were indexed and published. It was not until the 1880s that the cost of obtaining a patent taken to term was significantly lowered. Although these changes were significant, the system remained one based on registration rather than examination through the end of the 19th century, and this absence of an examination system may have been very important. Without examination, there was great uncertainty about what a patent was really worth, and this increased the transactions costs involved in either trading the rights to the underlying technology or in using the patent to mobilize capital. It is therefore not surprising that the prevalence of assignments (sales of patents) and licenses was significantly lower throughout the 19th century in Britain than in the U.S., which had moved early to such a regime.

From what record of their thinking survives, the framers of the U.S. Constitution and of its early laws were intent on crafting a new type of patent system that would promote learning, technology, and commercial development, as well as create a repository of information on prior art. Their chosen approach to accomplishing these
objectives was based on providing broad access to property rights in technology, which was achieved through low fees and an application process that was impersonal and relied on routine administrative procedures. Incentives for generating new technological knowledge were also fine-tuned by requiring that the patentee be “the first and true inventor” anywhere in the world. Moreover, a condition of the patent award was that the specifications of the invention be available to the public immediately on issuance of the patent. This latter condition not only sped the diffusion of technological knowledge, but also -- when coupled with strict enforcement of patent rights -- aided in the commercialization of the technology. That strict enforcement was indeed soon forthcoming. Within a few decades the federal judiciary evolved rules and procedures to enforce the rights of patentees and their assignees, and clearly considered the protection of the property right in new technological knowledge to be of vital importance to the promotion of progress in the “useful arts” (Khan 1995 and 2005).

Another distinctive feature of the U.S. system of great significance was the requirement that all applications be subject to an examination for novelty. Each application was to be scrutinized by technically trained examiners to ensure that the

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4 The law employed the language of the British statute in granting patents to “the first and true inventor,” but unlike in Britain, the phrase was used literally, to grant patents for inventions that were original in the world, not simply within U.S. borders. This feature of the U.S. was another way in which the technologically creative without much wealth were offered more incentives than were their counterparts in Britain. In the latter country (effectively), and in most of the rest of the world, the first able to file and pay the fee had a right to the patent. This seems to have meant that employers could obtain patents on inventions their employees had actually invented.

5 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 as such cases were purported to clog the courts and 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.
invention conformed to the law and constituted an original advance in technology. 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. 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’s absorbing the cost of certifying a patent grant as legitimate and making the information public. One would, accordingly, expect technologically creative people without the capital to go into business and directly exploit the fruits of their ingenuity to be major beneficiaries under an examination system such as the one the U.S. pioneered.

EMPIRICAL BACKGROUND, DATA, AND EARLY RESULTS

One reason for believing that the design of the patent system, and of other institutions relevant to the rewards individuals can realize from their contributions to technology, should matter for who generate new technological knowledge is the now substantial accumulation of evidence that inventive activity in 19th century America was indeed responsive to the prospects for material returns. Working with a general sample of patent records (and manufacturing firm data from 1820, 1832, and 1850), Sokoloff

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6 When coupled with effective enforcement of the rights of the “first and true inventor,” this meant that inventors could advantageously reveal information about their ideas to prospective buyers even before they received a patent grant. By the mid-1840s, trade in patents (and patenting) was booming, and growing legions of patent agents or lawyers had set up shop in major cities and other localities where rates of patenting were high. Although these agents focused initially on helping inventors obtain patents under the new system, it was not long before they assumed a major role in the marketing of inventions (Lamoreaux and Sokoloff 1996, 1999, 2001, and 2003; Khan and Sokoloff 1993 and 2001; and Khan 2005).
(1988 and 1992) argued that both the geographic and cyclical patterns of inventive activity in early industrial America were profoundly influenced by the extent of the market, and had measurable impacts on manufacturing productivity. Skeptics objected that analyses based on patent counts were flawed by the inability to distinguish between important and trivial inventions, but our study of the behavior of 160 great inventors born before 1820 showed that these inventors were even more attuned to economic conditions than were ordinary inventors (Khan and Sokoloff 1993). Not only were these great inventors energetic in their use of the patent system to appropriate the returns to their efforts, but their inventive activity was also heavily concentrated in geographic areas with low-cost transportation access to markets (in this pre-railroad era, this meant navigable waterways). If technologically creative individuals are indeed sensitive to the prospects for material returns, then one would expect that the existence and specific design of a patent system would influence the rate and/or direction of inventive activity. The salient responsive by great inventors in Britain to the 1852 change in that country’s patent law is a testament to that notion (see Figure 1).

Another indication that the design of a patent system matters has to do with the contrast between the U.S. and Britain in the volume of trade in patented technologies. For reasons outlined above, the examination and legal systems in the U.S. would be expected to have been more conducive to the development of a market in technology than was the registration system in Britain. As seen in Figure 2, trade in patents was indeed

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7 Such locations must have been particularly attractive to technologically-creative individuals seeking to extract the returns to their talents, and part of the high patenting by ‘great inventors’ in these locations was due to in-migration. However, since the ‘great inventors’ were disproportionately born in the same areas, the extent of markets does seem to have had real independent effects on the rates of inventive activity. Overall, the strong association of patenting with the market, in the case of both ordinary patentees and (even more) ‘great inventors’, supports the notion that potential returns played a major role in the processes generating inventions -- big and small.
much more extensive – even on a per patent basis – in the U.S. than in Britain. The markedly higher ratio of assignments to patents displayed for the U.S. is all the more striking, both because the British numbers are biased upward by the inclusion of licenses, and because the higher costs of obtaining a patent in Britain should, at least in principle, have led to patents of higher average quality.

We have long been interested in whether the different structures of intellectual property institutions between the U.S. and Britain mattered for the relative involvement by different social groups in invention, and in previous work with samples of ordinary patentees, we showed how individuals from elite backgrounds accounted for a much smaller proportion of patentees in the U.S. than they did in countries such as Britain during the early 19th century (Khan and Sokoloff 1998). This work was subject to the criticism, however, that not all patentees produce inventions of significance and some important technological discoveries are never patented. It is largely because of the imperfect measures of invention that come from relying on general samples of patent records that we decided to collect information on the great inventors (and their inventions, patented or not) from the U.S. and Britain.

Our U.S. sample consists primarily of all the individuals born before 1886 and listed in the *Dictionary of American Biography* on the basis of their career as an inventor. For each of the 409 U.S. inventors (all men except for one woman), we

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8 A small number of inventors, that we came across in the process of cross-checking, were added from other sources, such as dictionaries of engineers, and a few entries from the Dictionary of American Biography were dropped because closer examination implied that they had been listed for reasons other than the significance of their inventions. As a way of examining whether there might have been a bias resulting from the procedures the editors (at Columbia University) of the *DAB* followed in selecting which inventors to include (such as a lower threshold for the inclusion of inventors from New York, or from urban areas generally), we examined whether the number of modern patent citations to our great inventors varied with their characteristics (such as residence), and found that the only significant correlation was with the
collected biographical information (including places and dates of birth and death, family background – such as father’s occupation, level and course of formal schooling, a series of variables reflecting work experience and means – if any – of realizing a return on inventions, years of -- if any -- first and last patent, and total numbers of patents ever received), as well as the individual records of a proportion of the patents (roughly 4500 out of 16,900) they were awarded over their careers (roughly 97 percent received at least one). The individual patent records not only provide a description of the invention (which we have classified by industry) and the residence of the inventor at the date of the patent award, but also the identity and location of the individual or firm to which the inventor assigned (if he did) his rights at the date the patent was issued.

Our parallel sample of great inventors from Britain includes 434 men and one woman who made significant contributions to technological products and productivity, and who produced at least one invention between 1790 and 1930. The British sample (of which upwards of 85 percent -- increasing in the later cohorts -- received a patent over their career) was compiled from a broader series of biographical dictionaries, including the 2004 *Oxford Dictionary of National Biography (DNB)*, and the *Biographical Dictionary of the History of Technology (BD)*, among others. Our objective was to compile a sample of individuals who had made significant contributions to technological products and productivity. This accorded more with the intent of the *BD*, whose contributing authors were specialists in the particular technological field that they

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9 Partially because the sample was collected in two waves, at different times, all of the patents ever received were collected for the great inventors born before 1821, but for those born after we compiled their individual patent records by sampling every fifth year.

examined. The DNB's objective was somewhat different, for its editors intended to incorporate "not just the great and good, but people who have left a mark for any reason, good, bad, or bizarre." Because of this difference in objective (which was also quite different from the classification of inventions in the DAB), and because of the inconsistent terminology in the description of occupations and basis for inclusion of its biographies, we had to make much more use of other sources (other historical dictionaries) and carry out much more cross-checking to compile our sample of great inventors in Britain than we had to do for its U.S. counterpart. 11 We therefore supplemented these two volumes with other biographical compilations, and numerous books that were based on the life of a specific inventor. 12 Although a few of the entries in any such sample would undoubtedly be debatable, we have been very careful, and hope that our triangulation of sources minimizes the possibility of egregious error.

The resulting data set on British great inventors is quite comparable as regards biographical information to the one we have collected for the United States. 13 One of the most interesting differences, however, is that we have information on all of the prizes or

11 For instance, their listings included Walter Wingfield ("inventor of lawn tennis"); Rowland Emett (cartoonist and "inventor of whimsical creations"); as well as the inventors of Plasticine, Pimm's cocktail, self-rising flour and Meccano play sets. At the same time, Henry Bessemer is described as a steel manufacturer, Henry Fourdrinier as a paper manufacturer, and Lord Kelvin as a mathematician and physicist. A large fraction of the technological inventors are featured in the DNB as engineers even though the majority had no formal training. Other inventors are variously described as pioneers, developers, promoters or designers. Edward Sonsadt is omitted altogether although elsewhere he is regarded as an "inventive genius." See Ian McNeil (ed), Encyclopaedia of the History of Technology, London: Routledge, 1990, p. 113.

12 These include the Encyclopaedia Britannica; David Abbott (ed), Biographical Dictionary of Scientists: Engineers and Inventors, London: Blond Educational, 1985; Dictionnaire des Inventeurs et Inventions, Larousse: Paris, 1996; and other compilations. Approximately 15 percent of our sample from these sources was missing altogether from the DNB.

13 Although we have obtained the years and descriptions of all the patents they ever received, we are still in the process of collecting the other details for each of the individual patents (such as residence, assignee, and – the British data are actually better here – occupation).
other sorts of official recognition the British great inventors received, including membership in the Royal Society.

We can use these two data sets to examine changes in the evolution of useful knowledge during the critical transition from the First to the Second Industrial Revolutions. In the current paper, we examine the hypothesis that the rules and standards of patent institutions in the two leading industrializers were associated with significant differences between the U.S. and Britain in the socioeconomic backgrounds of those responsible for generating significant new technological knowledge. Perhaps the most straightforward approach is to employ the information available on the occupation of the father of the great inventor to characterize the social origins of the individuals who were making important discoveries. The comparison presented in Table 1 suggests that throughout most of the 19th century the great inventors in the U.S. were indeed drawn from a much broader spectrum of the population than were their British counterparts. For example, among the great inventors born between roughly 1820 and 1845, nearly 43 percent of those in Britain had fathers who were in elite or professional occupations, whereas less than 19 percent of those in the U.S. came from such privileged backgrounds. The substantial disparity in the social origins of those responsible for important inventions continued until the cohort born after 1865 – a group who would have been most active at invention after the major reforms of the British patent system during the 1880s and 1890s. It must be noted, however, that much of this convergence seems not to be attributable to a shift in the social origins of British great inventors, but rather an increased proportion of their counterparts in the U.S. whose fathers were of elite, professional, or other white collar occupations. This reflects in part the growing
importance for becoming a productive inventor of having attained a high level of formal schooling, and the pattern that children of such fathers were more likely to attend institutions of higher learning than children of different backgrounds.

Indeed, another way of gauging the social class of the great inventors is to utilize the information we have on the formal schooling they received. For most of the 18th and 19th centuries, whether (and how far) an individual advanced beyond primary schooling was highly correlated with the income and social class of his parents. Another reason for examining the formal schooling attained by the great inventors is that it bears directly on the notion underlying many of the European intellectual property institutions of the 19th century – so ably depicted by Dava Sobel in her book *Longitude* -- that people from humble backgrounds without much in the way of formal schooling (or scientific knowledge) were generally not capable of making truly significant contributions to technological knowledge. Those adhering to such views, as well as those who believe that advances in science were the driving force behind the progress of early industrialization, might well be surprised by the distributions of the U.S. great inventor patents, arrayed by birth cohort and the amount and type of formal schooling they received, in Table 2. It is striking 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. 14 So modest were the educational backgrounds of these first generations of great U.S. inventors, that 70 percent

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14 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 group.
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 numbers unambiguously indicate that people
of rather humble backgrounds were capable of making important contributions to
technological knowledge.\textsuperscript{15}

Up until the Second Industrial Revolution, the technologically creative of this era
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. 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. Although they began with little else other than their
intelligence, these talented men were able to realize large returns to their technological
creativity by taking advantage of the broad access to opportunity that the patent system
and other American institutions provided.

Although extraordinary inventors, these men may not be so exceptional in the
benefit they drew from the U.S. patent system. The biographies suggest that inventors
with only primary or secondary schooling had more limited financial resources than those
who were able to attend college.\textsuperscript{16} Given the financial institutions of that era, inventors

\textsuperscript{15} 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 it is notable 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.

\textsuperscript{16} Historians of education argue, and the biographies confirm, that the age at which a young male left
school and began to work was strongly associated with the economic resources of the parents during the
19th century. This pattern stemmed both from most of the nation’s secondary schools and universities being
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 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. As seen in Table 2, 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. Specifically, it was the great inventors with only a primary school education who 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. Overall, the reliance on sales and licensing was quite high among the first private and thus requiring significant tuition until late in the 1800s, as well as the opportunity cost of an individual at school in lieu of at work. See Cubberley 1920, for a discussion of how the schools, and the backgrounds of the students who attended them, evolved over the 19th century.

17 With the exception of the birth cohort of 1739 to 1794, the college-educated inventors were much more
birth cohort (51.4 percent on average), and remained 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 then fell sharply, 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.  

A key feature of the story, however, is that much of the population possessed some familiarity with the basic elements of technology during the early industrial era. 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 take advantage of the access to opportunities for inventive activity grounded in the U.S. patent system.

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likely than others to extract the returns to their technological creativity by being a proprietor or principal in a firm that directly exploited the technology in production. It is interesting to note that many of the college educated in the 1739-94 birth cohort were evidently not as 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, nor by the most active inventors once economic growth got under way in the mid-19th century. In preliminary work with the British great inventors, we find very similar patterns of behavior.

18 This finding parallels that of Lamoreaux and Sokoloff (1999 and 2005), whose analysis of different data indicates 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. They argue that this change in the organization of inventive activity was due in large part to it facilitating the mobilization of capital to support R & D.
Consistent with what we would expect from the design of their patent system, British institutions do not appear to have been nearly as favorable to those who did not, or could not, attend universities. As indicated in Figure 3, despite Britain lagging the U.S. considerably in literacy and other gauges of schooling amongst the general population (thus, biasing the results against the case we are making), individuals with low levels of schooling were far less well represented, and those with university degrees in technical fields such as engineering, natural sciences, or medicine far more represented, amongst the great inventors of that country than they were amongst those in the U.S..

Among the great inventors born in the U.S. between 1820 and 1845, those with no more than a primary school education accounted for roughly 40 percent of the patents that were granted to that cohort, while those with university educations in a technical field garnered only 10 percent. The analogous shares for the British great inventors (computed over inventors because many did not patent) were roughly 20 percent and over 30 percent respectively. The contrast is dramatic, and the implication is that the great inventors in the U.S. were much more likely to obtain the familiarity with the technological frontier through channels or institutions other than formal schools than were their British counterparts. This pattern is consistent with the view that a much narrower class of the population was involved in generating new technological knowledge in Britain than was the case in the U.S., especially since our evidence (see Figure 4) on the occupations of the fathers of the great inventors who attended university suggests that the universities in the former country recruited their students from far more privileged backgrounds than did those in the latter (particularly after 1820).
Circumstances changed over time with the evolution of technology. Knowledge of science clearly became more increasingly important, particularly beginning in the late 19th century with the beginning of the Second Industrial Revolution, for making significant contributions at the technological frontier and perhaps (when certified by university degrees in technical fields) for obtaining the resources to carry out programs of R & D. This development is evident in the rapid rise to dominance of individuals with technical degrees amongst the later birth cohorts of great inventors in both countries (Figure 5). Although there is substantial convergence in the distributions of great inventors by formal schooling during this period, this likely overstates the extent to which the social origins of the inventors likewise converged. As reported above, the great inventors in Britain who received degrees at universities seem to have continued to be drawn overwhelmingly from extremely privileged backgrounds. The U.S. educational institutions may have evolved more readily to support broader access to the increasingly valuable training in technical field than did those in Britain. Land-grant state universities

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19 An alternative story is that the phenomenon could be explained by changes in sectoral composition. In this view, there were always some industries in which schooling in a technical field was a prerequisite for significant invention, while in others inventors could make do without. The latter industries, such as light manufacturing say, may have featured prominently in the early industrial economy, and thus created opportunities at invention for the under-schooled, but over time the more science-based industries grew in importance. 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 labs in large integrated companies. Our work thus far suggests, however, that changes in the sectoral composition of the economy offer little explanatory power. 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.

20 The British patent records are consistent with the notion that at least until 1870 a background in science did not add a great deal to inventive productivity of British great inventors. If scientific knowledge gave inventors a marked advantage, it might be expected that they would demonstrate greater creativity at an earlier age than those without such human capital. Inventor scientists are marginally younger than nonscientists, but both classes of inventors were primarily close to middle age by the time they obtained their first invention (and note that this variable tracks inventions rather than patents). Productivity in terms of average patents filed and career length are also similar among all great inventors irrespective of their scientific orientation. Thus, the kind of knowledge and ideas that produced significant technological contributions during British industrialization seem to have been rather general and available to all creative individuals, regardless of their scientific training.
began expanding rapidly in the United States during the late-19th century, and these institutions of higher learning are recognized both for offering broad access as well as for having a disproportionate number of programs in the natural sciences and in engineering (Cubberley 1947). Britain was much slower in extending access to educational opportunities, as well as in establishing new universities, and the emphasis was decidedly on a more “classical” orientation. Thus, even after the patent systems in the U.S. and Britain became much more similar, the contrasts in the social origins of those active at invention may have persisted because of other institutional differences.

WHAT DID PRIZES DO?

In recent years, economists have paid increasing attention to prizes as alternatives to patent institutions as a means of encouraging and rewarding creativity and innovation without incurring deadweight losses. In the absence of asymmetries in information regarding costs and benefits, theoretical models suggest that prizes, public funding or payment on delivery might be preferable to the monopoly offered by intellectual property rights (Maurer and Scotchmer 2004). Wright (1983) found that prizes are optimal if the success probability is moderately high, if the supply elasticity of inventions is low, and where awards can be adjusted ex post. Shavell and van Ypersele (1998) argued that

21 The sources of creativity are still not well understood, despite investigations by researchers in psychology, sociology, and the humanities. Some distinctions are made between the objectives of pure scientists, applied practitioners, and contributors to science and to useful knowledge. For instance, Robert Merton proposed that scientists are motivated by the recognition of their peers, and philosophers of science point to the innate satisfaction that analysts like Sir Humphry Davy and Lord Stanhope derived from resolving previously intractable problems. By implication, discoverers who are compelled by the desire for enhanced reputation and the quest for truth might be expected to shun or at least be unresponsive to inducements based on commercial gains. These allegedly altruistic contributions to knowledge might best be rewarded by non-monetary honorific prizes, medals, or “adulatory odes” rather than through the potential for commercialization or competitions for financial gain.
subsidies might be the most effective means of calibrating rewards for innovations according to social value. Some versions of this subsidy mechanism center on discounting the price to consumers who value the patented product above its marginal cost. Kremer (1998) suggested an ingenious hybrid that transforms the patent into a prize that is auctioned to the highest bidder in a process that reveals the underlying value of the invention; the government would then engage in patent buyouts of high-valued discoveries and turn them over to the public domain. Taylor (1995) offered a model where contestants compete for a pre-specified prize, by creating an invention that offers the highest value to the sponsor of the tournament. The theoretical problems with prizes are well recognized, however, and they include problems in assessing the value of the invention (such as those that arise from asymmetric information, delays in the determination of value, and the difficulty of aggregating benefits which might accrue from sequential innovations). Even if these were resolved, the credibility or efficiency of bureaucrats in holding to contracted promises might be questioned, leading to a diminution in the expected return from a prize.

Much of this work has relied on illustrative anecdotes, such as the prizes offered for margarine and food preservation, or the process to make soda from sodium chloride.22 Perhaps the most often cited case relates to the prize for finding a solution to the problem of determining longitude at sea, and the experience of John Harrison with the Board of

22 Premiums from the state did not preclude inventors from also pursuing profits through other means, including patent protection. For instance, Napoleon III offered a prize for the invention of a cheap substitute for butter that allegedly induced Hippolyte Mège to make significant improvements in margarine production. In assessing the efficacy of this prize it should be noted that many inventors worldwide were already pursuing the idea of a cheap and longer-lasting substitute for butter. Mège not only won the prize but also obtained patent protection for fifteen years in France in 1869, and patented the original invention and several improvements in England, Austria, Bavaria, and the United States.
Longitude. Closer inspection of the historical records gives ample reason to question the efficacy of administered centralized awards, especially in the case of inventors who were not politically astute or who were more likely to have been drawn from the “lower classes” than the great inventors.

In the United States the statutes from the earliest years ensured that the progress of science and useful arts was to be achieved through a complementary relationship between law and the market in the form of a patent system. Numerous proposals were repeatedly submitted to Congress throughout the nineteenth century to replace the patent system with more centralized systems of national prizes, awards, or subsidies by the government. Such proposals failed to persuade, because it was argued that the process of democratization was most likely to be attained through decentralized decision making.

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23 See Sobel 1995 for more details. The Longitude Act awarded as much as £20,000 for a "Practical and Useful" means of determining longitude at sea. Candidacy for the award was judged by a Board of Longitude, members of whom were drawn from the scientific, military and public elite, some of whom were themselves competing for the prize. These individuals were scornful of Harrison as a common uneducated artisan, and hindered his attempts to collect the prize, which was never actually awarded. Instead, as Harrison was close to death, the King intervened and provided payment for achieving the task that had eluded the finest theoretical scientific minds up to that date.

24 In 1775 the French government and the Académie des Sciences offered a prize of 2400 livres for a process of making artificial soda from sodium chloride. Numerous attempts were made to solve the problem until Nicholas Leblanc finally succeeded and obtained a patent for the discovery in 1791. However, he never obtained the prize from the Académie, his factory was seized and he died as an impoverished suicide in 1806. The British government promised Lord George Murray £16500 pounds for his telegraph but they only gave him £2000 and he died in debt. As for the famed Henry Shrapnel, the DNB notes that “a narrow, bureaucratic interpretation of the terms of the award ensured that, in reality, he enjoyed scant financial gain.”

25 For instance, Charles B. Lore of Delaware submitted H.R. 5,925 in 1886 to set up an alternative system of rewards for inventors, to be administered by an “Expert Committee.” As the editors of Scientific American pointed out [Scientific American, v 54 (14), p 208, 3 April 1886], “The Expert Committee would have a very delicate duty to perform in fixing the cash valuations, and they would constantly be subjected to risks and probabilities of making egregious errors. For instance, if they were to allow $10,000 as the value of the patent for the thread placed in the crease of an envelope to facilitate opening the same, how much ought they to allow for the second patent, that was granted for the little knot that was tied on the end of the thread, so that the finger nail could easily hold the thread? Then, again, how much ought the committee allow for a simple device like the patent umbrella thimble slide, a single bit of brass tubing that costs a cent and a quarter to make? Probably the committee would think that one thousand dollars would be a most generous allowance, while two hundred thousand dollars – the limit of the bill – would, of course, be regarded as a monstrous and dishonest valuation. But the real truth is, the patent for this device is actually worth nearer one million dollars than two hundred thousand.”
by inventors themselves, and through enforcement by judges confronting individual conflicts on a case by case basis. This was not the case in Europe, where extensive arrays of prizes were offered to “deserving” inventors.

The biographies of the British great inventors include information about honors and awards. Altogether, 171 of the inventors in our sample received such recognition, ranging from the recipients of gifts of silver plate from the Crown to two winners of the Nobel Prize (Sir Edward Appleton and Guglielmo Marconi). These data offer more systematic insights into the advantages and drawbacks of patents and alternative incentive/reward mechanisms. Table 3 presents the results of logistic regressions where the dependent variable is the likelihood that an inventor is also the recipient of at least one prize (we do not distinguish here between different types of awards). The coefficients on the independent variables in the table report the antilog or the odds of having received a prize (rather than the log odds) conditional on the vector of independent variables. Prizes and medals, in particular, might be more effective inducements to the generation of significant new technological knowledge than patents if scientist-inventors differed from patentees and were motivated by the recognition of their peers and less by financial incentives. However, the regression results indicate that prizes and medals tended to be awarded to the same individuals who had already received patents and, indeed, the likelihood of receiving a prize increased with the number of patents the individual received. That the marginal effects of these non-patent awards

26 For details on the extensive array of prizes in France, see Khan, Democratization.
27 The odds refer to P/1-P, where P is the probability of being the recipient of a prize. An odds ratio of 1.025 would therefore imply a 2.5 percent change in the odds and, if we consider the marginal change centered on a probability of 0.5, is equivalent to a change in the probability from 0.497 to 0.503; a value of 2.014 in the odds ratio corresponds to a 101.4 percent change in the odds.
were low is supported by the observation that the majority of premia were made later in life to those who had already attained eminence.

The regressions also highlight the potential inefficiencies of administered awards, which might be subject to the possibility of bias, personal prejudices, or even corruption. The likelihood that an inventor had received prizes and medals was higher for scientific men, more so for those who had gained recognition as famous scientists or Fellows of the Royal Society.\textsuperscript{28} An interesting facet of the relationship between privilege, science, and technological achievement in Britain is reflected in the 90 great inventors who were also appointed as Fellows the Royal Society. The Royal Society itself was the target of persistent criticism throughout this period, including scathing assessments by its own members such as William Grove and Charles Babbage.\textsuperscript{29} Many were disillusioned with these award systems, attributing outcomes to arbitrary factors such as personal influence, the persistence of one's recommenders, or the self-interest of the institution making the award. Sir William Robert Grove, a great inventor and member of the Royal Society,

\textsuperscript{28} The Royal Society was founded in 1660 as an "invisible college" of natural philosophers who included Isaac Newton, Christopher Wren, Robert Hooke and Robert Boyle. Fellows of the Society were elected and many of the members consisted of individuals who were not professional scientists but who were wealthy or well-connected. It also awarded many medals. Although the Royal Society was associated with the foremost advances in science, many of its projects were absurd and impractical. The Royal Society was widely criticized for its elitist and unmeritocratic policies. The Society long retained the character of a gentleman's club and, despite a series of reforms, did not become a genuine professional scientific organization until after the 1870s. Even in 1860 more than 66 percent of its membership consisted of nonscientists and practitioners, whose inclusion was not altogether merited on the basis of their scientific contributions.

\textsuperscript{29} Babbage (1830) regretted that "in England, particularly with respect to the more difficult and abstract sciences, we are much below other nations, not merely of equal rank, but below several even of inferior power. That a country, eminently distinguished for its mechanical and manufacturing ingenuity, should be indifferent to the progress of inquiries which form the highest departments of that knowledge on whose more elementary truths its wealth and rank depend is a fact which is well deserving of the attention of those who shall inquire into the causes that influence the progress of nations." In 1831 disillusioned scientists founded the British Association for the Advancement of Science as a more open alternative to the Royal Society. As late as 1860 there were 330 Fellows who were scientists and 300 who were not. Also, in 1860, 117 of that group of 330 scientist Fellows were physicians and surgeons, an overwhelming proportion of medical men which had been characteristic of the Society's membership from the first." The Royal Society awarded 173 medals between 1826 and 1914. See MacLeod 1971.
"lambasted both the Royal Society and the increasingly influential specialist scientific societies for their nepotism and corruption, calling for full-scale reform of England's scientific institutions."30 The bias towards elites was not limited to privileges for members of the Royal Society. William Sturgeon, an electricity pioneer who was the son of a Lancashire shoemaker, was snubbed by the scientific elites because of his background. The uneducated George Stephenson resolved the problem of a safety lamp using practical methods, whereas Sir Humphry Davy applied scientific principles. According to the DNB, "In 1816 Davy received a public testimonial of £2000 and Stephenson the relatively paltry sum of 100 guineas."31

As a number of scholars have reminded us, elites and talented innovators can engender social benefits and growth; however, rent-seekers in privileged positions might not only redistribute wealth but also have the potential to reduce growth (Murphy, Shleifer and Vishny, 1991). The grants of prizes to British great inventors seem to have been primarily connected to elite status rather than to factors that might have enhanced productivity. The most significant variable affecting the possession of a prize was an Oxbridge or elite education, which doubled the odds of getting an award (evaluated at the mean probability), despite the traditional hostility of such institutions to pragmatic or scientific pursuits.32 It is worth noting the contrast with specialized education or

30 Gillespie vol. 5, p. 559.
31 Stephenson’s peers were outraged at this blatant unfairness and organized a dinner to present him with a private subscription of £1000.
32 For an interesting analysis, see Roy Macleod and Russell Moseley 1980. As late as 1880 only 4 percent of Cambridge undergraduates read for the NSTs and most were destined for occupations such as the clergy and medicine. The method of teaching eschewed practical laboratory work; and there was a general disdain among the Dons for the notion that science should be directed toward professional training; so it is not surprising that only 4 percent of the NST graduates entered industry. Students who did take the NSTs tended to perform poorly because of improper preparation and indifferent teaching, especially in colleges other than Trinity, Caius and St. John's. Chairs in Engineering were created in Cambridge in 1875 and in Oxford in 1907, whereas MIT alone had seven engineering professors in 1891.
employment in science or technology which had little or no impact on the probability of getting a prize. Instead, such awards were far more closely linked to residence close to the capital, or to publications in the annals of the “learned societies” which resembled gentlemen’s social clubs where membership simply depended on connections and payment of significant dues.

Crosland and Galvez (1989) document how the French Academy of Sciences switched from a system of prestigious prizes toward more dispersed funding of projects for younger researchers. Similarly, by 1900 the Council of the Royal Society decided to change its emphasis from the allocation of medals to the financing of research. The growing disillusionment with prizes as an incentive for innovation is consistent with the coefficients on the time trend, which are no longer statistically significant after the second half of the nineteenth century. Thus, the data here seem to support those who view the Prize for Longitude as a cautionary tale rather than an exemplary parable, for John Harrison’s problems seem to have been more general than many economist theorists have acknowledged.

CONCLUSION

In this modest and preliminary paper, we have begun to use parallel data sets of great inventors from Britain and the U.S. to compare the patterns of inventive activity in these first two countries to industrialize and to explore the relevance for these patterns of

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33 The Council stated that its experience in the award of medals had revealed that adding to the number of such awards would be "neither to the advantage of the Society nor in the interests of the advancement of Natural Knowledge," MacLeod, 1971, p. 105.
intellectual property institutions. Three results stand out. First, the inventors in the U.S. were drawn from a much broader spectrum of the population than were their counterparts in Britain, consistent with the view that the narrower provision of property rights in new technological knowledge under the latter’s patent system did matter for who was involved in inventive activity. Although other differences in institutions and economy-wide circumstances probably contributed to this pattern, it is striking that so much of the important invention in the U.S. was carried out by individuals from humble backgrounds until very late in the 19th century.

Second, that so much of the important invention during the early stages of U.S. industrialization came from individuals with only very limited formal schooling, raises questions about what sorts of technical or scientific knowledge were really required during that era to advance make a significant discovery, and how technologically creative individuals accumulated that knowledge. Job experience, especially in apprentice-like positions, seems to have been adequate for learning about the frontiers of technology prior to the Second Industrial Revolution, but in both countries great inventors born after 1860 depended on educations at university in technical fields. The shift in academic credentials was, of course, more abrupt in the U.S., and focuses attention on what changed. In other work (Khan and Sokoloff 2004) we have shown that it occurred at roughly the same time across all of the major industrial sectors. It may be that scientific advances had implications for all fields of technology, but the growing importance of academic credentials for securing long-term support of programs of inventive activity could also help account for the change (Lamoreaux and Sokoloff 2005).
Finally, our examination of which of the British great inventors received prizes or honors for their discoveries provides little or no evidence that this approach toward encouraging private investment in inventive activity was effective. On the contrary, the findings that some of the most decisive determinants for whether the inventor received a prize were which university he had graduated from and where he lived, support the view that the inordinate role of politics and/or social connections in selecting recipients tend to undermine the efficacy of the incentives offered under such schemes.
TABLE 1
SOCIAL BACKGROUNDS OF GREAT INVENTORS IN BRITAIN AND IN THE U.S.:
BY BIRTH COHORTS, 1700 TO 1910

<table>
<thead>
<tr>
<th>Birth Cohorts</th>
<th>Occupation of Father</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmer or Ag</td>
</tr>
<tr>
<td></td>
<td>row (%)</td>
</tr>
<tr>
<td>Britain, Distribution of Inventors</td>
<td></td>
</tr>
<tr>
<td>1709-1780</td>
<td>10.0%</td>
</tr>
<tr>
<td>1781-1820</td>
<td>7.8</td>
</tr>
<tr>
<td>1821-1845</td>
<td>8.6</td>
</tr>
<tr>
<td>1846-1870</td>
<td>7.3</td>
</tr>
<tr>
<td>1871-1910*</td>
<td>5.0</td>
</tr>
<tr>
<td>United States, Distribution of Inventors Weighted by Patents</td>
<td></td>
</tr>
<tr>
<td>1739-1794</td>
<td>40.5</td>
</tr>
<tr>
<td>1795-1819</td>
<td>37.4</td>
</tr>
<tr>
<td>1820-1845</td>
<td>39.0</td>
</tr>
<tr>
<td>1846-1865</td>
<td>11.0</td>
</tr>
<tr>
<td>1866-1885</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Notes and Sources: These estimates were computed for all of the great inventors included in the U.S. and British samples, where we had information about the father’s occupation. See the text for more information about the samples. Because many of the British great inventors did not obtain patents, we have reported the distribution of great inventors for Britain. However, we have reported the distribution of great inventors weighted by patents for the U.S., because only a small number (less than 5 percent) of the great inventors there did not obtain patents. As we had some information on British great inventors born up to 1906 (identified using the same procedures as those in the sample for Britain), we computed our estimates for the 1871-1910 cohort with these additional observations so as to increase our sample size for that cohort.
TABLE 2

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

<table>
<thead>
<tr>
<th>Birth Cohort</th>
<th>Primary</th>
<th>Second.</th>
<th>College</th>
<th>Eng/NatSci.</th>
<th>Tot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1739-1794 (row %)</td>
<td>69.5</td>
<td>6.8</td>
<td>12.5</td>
<td>11.3</td>
<td>400</td>
</tr>
<tr>
<td>avg. career patents</td>
<td>5.6</td>
<td>3.8</td>
<td>6.5</td>
<td>5.2</td>
<td>75</td>
</tr>
<tr>
<td>sell/license (col. %)</td>
<td>54.9</td>
<td>11.1</td>
<td>84.0</td>
<td>17.7</td>
<td>51.4%</td>
</tr>
<tr>
<td>prop/direct (col. %)</td>
<td>36.5</td>
<td>74.1</td>
<td>2.0</td>
<td>44.7</td>
<td>35.6%</td>
</tr>
<tr>
<td>employee (col. %)</td>
<td>6.2</td>
<td>7.4</td>
<td>--</td>
<td>--</td>
<td>4.8%</td>
</tr>
<tr>
<td>1795-1819 (row %)</td>
<td>59.1</td>
<td>19.3</td>
<td>5.4</td>
<td>16.2</td>
<td>709</td>
</tr>
<tr>
<td>avg. career patents</td>
<td>20.0</td>
<td>14.4</td>
<td>17.3</td>
<td>12.1</td>
<td>80</td>
</tr>
<tr>
<td>sell/license (col. %)</td>
<td>58.2</td>
<td>81.0</td>
<td>42.1</td>
<td>60.4</td>
<td>62.1%</td>
</tr>
<tr>
<td>prop/direct (col. %)</td>
<td>33.2</td>
<td>10.2</td>
<td>47.4</td>
<td>24.3</td>
<td>28.1%</td>
</tr>
<tr>
<td>employee (col. %)</td>
<td>8.4</td>
<td>8.8</td>
<td>--</td>
<td>13.5</td>
<td>8.8%</td>
</tr>
<tr>
<td>1820-1845 (row %)</td>
<td>39.2</td>
<td>34.7</td>
<td>16.3</td>
<td>9.7</td>
<td>1221</td>
</tr>
<tr>
<td>avg. career patents</td>
<td>41.8</td>
<td>44.0</td>
<td>29.4</td>
<td>23.7</td>
<td>145</td>
</tr>
<tr>
<td>sell/license (col. %)</td>
<td>50.7</td>
<td>31.8</td>
<td>37.4</td>
<td>72.8</td>
<td>44.0%</td>
</tr>
<tr>
<td>prop/direct (col. %)</td>
<td>42.3</td>
<td>55.2</td>
<td>47.7</td>
<td>19.3</td>
<td>45.5%</td>
</tr>
<tr>
<td>employee (col. %)</td>
<td>7.7</td>
<td>13.0</td>
<td>14.9</td>
<td>7.0</td>
<td>10.2%</td>
</tr>
<tr>
<td>1846-1865 (row %)</td>
<td>22.2</td>
<td>24.5</td>
<td>20.9</td>
<td>32.4</td>
<td>1438</td>
</tr>
<tr>
<td>avg. career patents</td>
<td>158.3</td>
<td>73.6</td>
<td>78.6</td>
<td>55.3</td>
<td>80</td>
</tr>
<tr>
<td>sell/license (col. %)</td>
<td>94.5</td>
<td>68.5</td>
<td>46.2</td>
<td>57.1</td>
<td>66.0%</td>
</tr>
<tr>
<td>prop/direct (col. %)</td>
<td>5.5</td>
<td>18.6</td>
<td>52.8</td>
<td>16.9</td>
<td>22.6%</td>
</tr>
<tr>
<td>employee (col. %)</td>
<td>--</td>
<td>12.9</td>
<td>--</td>
<td>23.6</td>
<td>10.4%</td>
</tr>
<tr>
<td>1866-1885 (row %)</td>
<td>0.2</td>
<td>17.9</td>
<td>21.4</td>
<td>60.5</td>
<td>574</td>
</tr>
<tr>
<td>avg. career patents</td>
<td>--</td>
<td>144.5</td>
<td>53.6</td>
<td>155.7</td>
<td>26</td>
</tr>
<tr>
<td>sell/license (col. %)</td>
<td>--</td>
<td>1.0</td>
<td>46.3</td>
<td>40.1</td>
<td>34.3%</td>
</tr>
<tr>
<td>prop/direct (col. %)</td>
<td>100.0</td>
<td>98.1</td>
<td>49.6</td>
<td>18.7</td>
<td>39.7%</td>
</tr>
<tr>
<td>employee (col. %)</td>
<td>--</td>
<td>1.0</td>
<td>4.1</td>
<td>41.2</td>
<td>26.0%</td>
</tr>
</tbody>
</table>
Notes and Sources Table 2: See the text. The table reports the distribution of U.S. 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>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 1800</td>
<td>0.32</td>
<td>0.34</td>
<td>0.34</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>(8.97)***</td>
<td>(7.39)***</td>
<td>(6.51)**</td>
<td>(8.56)***</td>
</tr>
<tr>
<td>1800-1819</td>
<td>0.52</td>
<td>0.60</td>
<td>0.53</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>(3.32)*</td>
<td>(1.81)</td>
<td>(2.49)</td>
<td>(3.11)</td>
</tr>
<tr>
<td>1820-1839</td>
<td>0.38</td>
<td>0.41</td>
<td>0.36</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>(9.16)***</td>
<td>(7.30)***</td>
<td>(7.78)***</td>
<td>(11.54)***</td>
</tr>
<tr>
<td>1840-1849</td>
<td>0.52</td>
<td>0.54</td>
<td>0.60</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>(2.56)</td>
<td>(2.02)</td>
<td>(1.18)</td>
<td>(1.42)</td>
</tr>
<tr>
<td>1850-1859</td>
<td>0.51</td>
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<td>446.92***</td>
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TABLE 3
DETERMINANTS OF LIKELIHOOD OF BRITISH GREAT INVENTOR RECEIVING AT LEAST ONE PRIZE

Maximum Likelihood Estimates of Odds Ratio from Logistic Regression Model
Dependent Variable: Probability of Receiving Prize
Notes and Sources: The data draw on biographical information on British great inventors. Prizes consist of nonpatent awards including medals and ex post or ex ante cash grants. Total patents were determined by a search for all patents granted to the inventor through 1890, and coinvention was counted as one patent. Publications indicate articles in specialized journals and nonfiction books published. London and the Home Counties include Berkshire, Middlesex, Sussex, Essex, Kent, Oxford, Bedfordshire and Hertfordshire. Elite education refers to education at Cambridge, Oxford, Durham, the Royal Colleges, or graduate education in Germany. Science education includes college training in mathematics, sciences, or medicine, whereas Technical education comprises post-secondary education in engineering or metallurgy. Numbers in parentheses are Wald Chi-squared statistics.
FIGURE 1

PATENTING BY BRITISH GREAT INVENTORS AND ALL PATENTEES, 1790-1890

Notes and Sources: See text for sample of great inventors. Patent data before 1852 are from Bennett Woodcroft, *Chronological Index*; patents after 1851 are from the Annual Reports of the Commissioners of Patents.
FIGURE 2

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

FIGURE 3

DISTRIBUTION OF BRITISH GREAT INVENTORS BY LEVEL OF EDUCATION AND BIRTH COHORT

Notes and Sources: See text.
FIGURE 4

BRITISH AND U.S. GREAT INVENTORS WHO ATTENDED COLLEGE
BY OCCUPATIONAL CLASS OF FATHER
PRE-1820 AND 1820-1885 BIRTH COHORTS

Notes and Sources: See text.
FIGURE 5

EDUCATIONAL ATTAINMENT OF BRITISH AND U.S. GREAT INVENTORS
PROPORTIONS WITH ONLY PRIMARY SCHOOLING AND WITH TECHNICAL UNIVERSITY DEGREES

BY BIRTH COHORT

[Graph showing educational attainment over birth cohorts for British and U.S. inventors with only primary schooling and technical university degrees.]

Notes and Sources: See text.
BABBAGE


