Volume Title: Understanding Long-Run Economic Growth: Geography, Institutions, and the Knowledge Economy

Volume Author/Editor: Dora L. Costa and Naomi R. Lamoreaux

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-11634-4

Volume URL: http://www.nber.org/books/cost10-1

Conference Date: November 7-8, 2008

Publication Date: August 2011

Chapter Title: Premium Inventions: Patents and Prizes as Incentive Mechanisms in Britain and the United States, 1750-1930

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Chapter URL: http://www.nber.org/chapters/c12000

Chapter pages in book: (p. 205 - 234)

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Premium Inventions
Patents and Prizes as Incentive Mechanisms in Britain and the United States, 1750–1930

B. Zorina Khan

7.1 Introduction

Technological advances make a critical contribution to the wealth and well-being of nations, so it is not surprising that its analysis and study has long attracted the notice of scholars and policymakers. Kenneth Sokoloff's research portfolio includes a number of significant papers demonstrating that the rate and direction of inventive activity and innovation were endogenous. In particular, both important and incremental inventions responded to incentives, and this was especially true of patent policies that promoted a decentralized market-orientation and offered opportunities for a broad spectrum of the population to benefit from their technological creativity. Sokoloff's pioneering 1988 paper showed that improvements in market access led to a greater proportionate response among rural residents who were new to invention. Further evidence on the identities of nineteenth-century patentees suggested that the specific design of the patent system played a substantial role in inducing relatively ordinary individuals to reorient their efforts toward exploiting market opportunities (Sokoloff and Khan 1990; Khan and Sokoloff 1998). Studies of the great inventors (Khan and Sokoloff 1993; Khan 2005) revealed that technologically and economically

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The great inventors project was initially coauthored with Kenneth L. Sokoloff and funded by a grant from the National Science Foundation. I am grateful for comments from Greg Clark, Stanley Engerman, Naomi Lamoreaux, Peter Lindert, Joel Mokyr, Manuel Tratjenberg, and participants at the UCLA/NBER conference to honor Kenneth Sokoloff. Thanks for excellent research assistance are due to Brian Amagai, Nathaniel Herz, Brittney Langevin, Storey Morrison, Birgitta Polson, Sherry Richardson, Christine Rutan, Peter Smith, and Anne Tolsma. Liability for errors is limited to the author.

important contributions exhibited similar patterns to those of less eminent inventors. Moreover, extensive markets in invention facilitated the appropriation of benefits, especially for inventors who were not well-endowed in terms of formal schooling and financial capital (Lamoreaux and Sokoloff 1996; Khan and Sokoloff 2004). This was not to say that the U.S. patent system and the related legal and market institutions were in any way optimal, but rather that they were appropriate for the circumstances of a newly-developing society and sufficiently flexible to respond to the evolution of economic and social needs.

A number of economists would agree with the view that strong protection of intellectual property rights induced rapid rates of technological and cultural progress during the early industrial period. Indeed, North and Thomas (1976) went as far as suggesting that the patent system was a crucial reason why Britain was the first country in the world to industrialize. A recent paper (Acemoglu, Bimpikis, and Ozdaglar 2008) proposes that patents may facilitate experimentation and diffusion to a greater extent than such alternatives as subsidies. Nevertheless, the historical record is still contested, and debates continue today regarding the design of appropriate mechanisms to encourage potential inventors, innovators, and investors to contribute to expansions in technological knowledge and economic development. Skepticism has increased of late about the efficacy of state grants of property rights in patents and in copyright protection as incentives for increasing creativity and invention. In a reprise of the nineteenth century, extremists today refer to patent systems as "an unnecessary evil," creating "costly and dangerous" intellectual monopolies that should be eliminated (Boldrin and Levine 2008). Among users of intellectual products the open-source movement advocates free access and the elimination of state-mandated rights of exclusion. At the same time, a growing roster of theorists who have been persuaded by models of prizes and subsidies have begun to lobby for these nonmarket-oriented policies as complements or superior alternatives to intellectual property rights. Economic historians who reach similar conclusions tend to extrapolate from the European experience with technological institutions (Clark 2003; Mokyr 1991). As such, it seems timely and relevant to engage in a more systematic comparison of the record of patents and prizes as incentive mechanisms for generating important technological innovation in Europe and America.

This chapter therefore explores the performance of alternative social schemes for promoting inventive activity in Britain and the United States. The evidence suggests that the efficacy of any set of rules and standards will depend on the specific nature of their implementation and on the metasocial context. The early American patent system provided an impressive route to rapid technological progress and economic development, in part because of the supportive network of effective legal, educational, and commercial institutions. In direct contrast, European intellectual property systems imposed constraints and rules that resulted in patterns that ultimately reflected the oligarchic nature of their social and political institutions. These variations in outcome indicate that policies cannot be selected based entirely on abstract conceptualization from models that are not calibrated to determine their sensitivity to institutional design. In particular, mathematical models fail to incorporate one of the most significant differences between patent systems and prizes: their relationship to, and implications for, participation in markets in inventions.

History provides a natural experiment for studying the evolution and effects of patent institutions and prizes. The prevailing view of the leading countries in Europe maintained that only a very narrow group of the population was capable of truly important contributions to technological knowledge. The British patent system was representative in favoring high transactions and monetary costs in order to confine access to a select few. Advocates well understood that patent systems with these sorts of restrictive features would mean that only a limited selection of inventions and inventors would receive patent protection, but the objectives and their outcomes were routinely defended. Moreover, in such countries as England and France prizes were frequently offered as inducements and as rewards for socially-valued contributions. For, the argument went, members of the special class of geniuses would respond more to honors and prizes rather than to mere material incentives, or else they would find it easy to raise the large amounts of funding needed for investments in exclusive rights to inventions. The U.S. institutions, on the other hand, reflected the democratic orientation of the new Republic, in the belief that broad access to property rights and economic opportunities more generally, mediated through the market mechanism, would allow society to better realize its potential. Consequently, in the United States prizes were not as prevalent as in Europe and, indeed, the most prominent of these honorific awards were introduced in the United States at the instigation of foreigners.

This chapter compares the evidence from patent institutions and the bestowal of prizes and their implications for inventors and inventions at the forefront of technological discovery during the early industrial era. The analysis in this chapter draws on samples of so-called "great inventors" from Britain and the United States in the eighteenth and nineteenth centuries. I discuss the extent to which the differences in patent systems across countries were manifested in the award of prizes, and examine the factors that influenced the patterns of patenting and prizes. Given the prevailing orientation of its socioeconomic institutions, it is perhaps not unexpected that the results for England suggest that both patent grants and prizes were primarily associated with recipients from privileged backgrounds. By way of contrast, among the American great inventors, the grant of prizes seemed related more to the nature of the technology rather than the identity of their recipients. Nevertheless, in the United States as well the conferral of prizes was neither as systematic nor as market-oriented as the patterns associated with patents.

7.2 Patent Systems in the Early Industrializers

The grant of exclusive property rights vested in patents developed from medieval guild practices in Europe, and England and France were early leaders in the grant of royal privileges that led to monopolies. According to the 1624 Statute of Monopolies, British patents were granted "by grace of the Crown" and were subject to any restrictions that the government cared to impose.[1] Patents were granted for fourteen years to applicants, including the importers of inventions that had been created abroad, and employers who wished to claim property rights in their workers' inventions. The fees for a full-term patent covering England, Scotland, and Wales amounted to over ten times annual per capita income, until well into the nineteenth century.[2] 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 and to creators of incremental inventions. In general, the 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 be created by 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.

These constraints restricted the use of the patent system to inventions of high value, and favored the elite class of those with wealth, political connections, or exceptional technical and scientific qualifications, whereas they deliberately generated disincentives for inventors from humble backgrounds. Indeed, in the Parliamentary debates regarding the patent system, some

1. 21 Jac. I. C. 3, 1623, Sec. 6. For the history of the British patent system, see MacLeod (1988) and Dutton (1984).

2. Patent fees for England alone amounted to £100 to £120 ($585), or approximately four times per capita income in 1860. The fee for a patent that also covered Scotland and Ireland could cost as much as £350 pounds ($1,680). Adding a coinventor was likely to increase the costs by another £24. Patents could be extended only by a private Act of Parliament, which required political influence, and extensions could cost as much as £700. The complicated administrative procedures that inventors had to follow added further to the costs: patent applications for England alone had to pass through seven offices, from the home secretary to the lord chancellor, and twice required the signature of the sovereign. Coverage of Scotland and Ireland required that the applicant negotiate another five offices in each country. The cumbersome process of patent applications afforded ample material for satire, but obviously imposed severe constraints on the ordinary inventor who wished to obtain protection for his discovery. These features testify to the much higher monetary and transactions costs, in both absolute and relative terms, of obtaining property rights to inventions in England.

witnesses regarded this restrictiveness by class as one of the chief *merits* of higher fees, since they did not wish patent applications to be cluttered with trivial improvements by the "working class."[3] The Comptroller General of Patents even declared that most inventions induced by low fees were likely to be for "useless and speculative patents; in many instances taken merely for advertising purposes."[4] Patent fees provided an important source of revenues for the Crown and its employees, and created a class of administrators who had strong incentives to block proposed reforms.

Other obstacles in the market for inventions related to policies toward trade in intellectual property rights such as patent assignments. Ever vigilant to protect an unsuspecting public from fraudulent financial schemes on the scale of the South Sea Bubble, ownership of patent rights was limited to five investors (later extended to twelve). Nevertheless, the law did not offer any relief to the purchaser of an invalid or worthless patent, so potential purchasers were well advised to engage in extensive searches before entering into contracts. When coupled with the lack of assurance inherent in a registration system and the scarcity of relevant information, the purchase of a British patent right involved a substantive amount of risk and high transactions costs—all indicative of a speculative instrument. Moreover, the state could expropriate a patentee's invention without compensation or consent, although in some cases the patentee was paid a royalty. In 1816, Sir William Congreve was allowed to violate a legal injunction that prevented him from manufacturing gunpowder barrels without the permission of the patentee, on the grounds that the infringement was in the public service on behalf of the ordnance office of the British Government.[5] It is therefore not surprising that the market for assignments and licences seems to have been quite limited.

By the second half of the eighteenth century, nationwide lobbies of manufacturers and patentees were expressing dissatisfaction with the operation of the British patent system. However, it was not until the middle of the nineteenth century that their concerns and requests for reforms were formally addressed. The creativity and efficiency of the U.S. inventions on display at the Crystal Palace Exhibition of 1851 deeply impressed Europeans, and many observers credited this favorable achievement in part to the innovative American 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. Before 1852

3. Thus, in the 1829 Report of the British Committee on the Patent System, one of the questions was, "Do not you think that if it became a habit among that class of people to secure patent rights for those small discoveries at low rates, it would be very inconvenient?" (The answer was in the affirmative.)

4. Great Britain Patent Office (1858), p. 5.

5. Walker v. Congreve, 1 Carp. Pat. Cas. 356.

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.

Reforms were limited and hesitant, in part because of other institutional obstacles. The system remained one based on registration rather than examination through the end of the nineteenth century, and this absence of a centralized examination system likely had important consequences. 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 financing. Moreover, a patent taken to full term remained just as expensive as before and it was not until the 1880s that the total cost was significantly lowered. Still, as figure 7.1 indicates, when Britain changed the features of its patent system in line with the U.S. rules, British patentees—ordinary and more eminent inventors alike—did respond by increasing their investments in patentable property. A striking feature of the second part of this figure is that the patterns for scientist-inventors, generally held to be motivated by nonmaterial factors, were also responsive to the incentives provided by the changes in institutional design.

Sir Henry Sumner Maine regarded it as self-evident that "if for four centuries there had been a very widely extended franchise and a very large electoral body in this country [Britain]. . . . The threshing machine, the power loom, the spinning jenny, and possibly the steam-engine, would have been prohibited," and "all that has made England famous, and all that has made England wealthy, has been the work of minorities, sometimes very small ones . . . the gradual establishment of the masses in power is of the blackest omen for all legislation founded on scientific opinion."[6] However, even as stringent a critic of democratic ideals as Maine conceded that the federal grant of patent rights was one of the "provisions of the Constitution of the United States which have most influenced the destinies of the American people," and was moreover responsible for the finding that the United States in 1885 was "the first in the world for the number and ingenuity of the inventors by which they have promoted the useful arts."[7]

The framers of the U.S. Constitution and statutes were certainly familiar with, and influenced by, the European experience with technological incentives (Khan 2009). It is telling that they made important departures in the ways in which property rights in technology were defined and awarded, and nearly all of their alterations can be viewed as strengthening and extending inducements and opportunities for inventive activity by classes of the population that would not have enjoyed them under traditional intellectual property institutions. From what record of their thinking survives, the framers were intent on crafting a new type of patent system that would promote

6. Sir Henry Sumner Maine (1976 reprint of 1885, 112).
7. Sir Henry Sumner Maine (1976 reprint of 1885, 241–42).

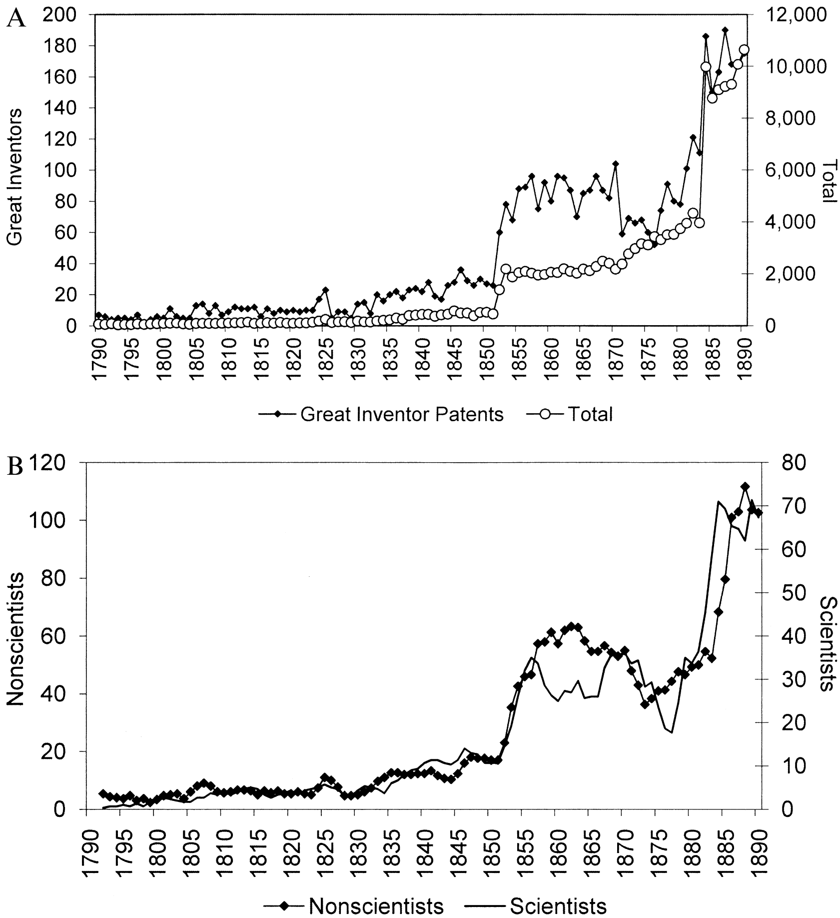

Fig. 7.1 Patenting in Britain, 1790–1890: *A*, Patenting by British great inventors and all patentees, 1790–1890; *B*, Great inventor patents by scientific orientation (three-year moving average, 1790–1890)

Notes: 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. Total patents filed before 1852 comprise patent applications and patent grants after 1851. *Scientists* include great inventors who were listed in a dictionary of scientific biography, those who received college training in medicine, mathematics, or the natural sciences, and Fellows of the Royal Society.

learning, technological creativity, 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 new technology, primarily through the medium of 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.[8] 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 enhanced 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, for within a few decades the federal judiciary evolved rules and procedures to enforce the rights of patentees and their assignees. The key players in the American legal system clearly considered the protection of the property right in new technological knowledge to be of vital importance for the promotion of progress in "the useful arts."

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 scrutinized by technically trained examiners to ensure that the 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 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 a patent examination system such as the one the U.S. pioneered.

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

8. 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.

analyses based on patent counts were flawed by the inability to distinguish between important and trivial inventions, but our study of the behavior of 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 entrepreneurial and inventive activity were also heavily concentrated in geographic areas with low-cost transportation access to markets.[9] 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 provide incentives that influenced the rate and/or direction of inventive activity.

Another indication that the design of a patent system matters is apparent in the contrast between the United States and Britain in the volume of trade in patented technologies. It was not coincidental that the U.S. system was extraordinarily favorable to trade in patent rights. From the special provision made in the 1793 law for keeping a public registry of all assignments onward, it is clear that the framers of the system expected and desired an extensive market in patents to develop. It was well understood that the patent system enhanced potential private and social returns to invention all the more, by defining and extending broad access to tradable assets in technological knowledge to a wide spectrum of the population. A market-orientation enabled patentees to extract income (or raise capital) from their ideas by selling them to a party better positioned for commercial exploitation, and thereby encouraging a division of labor that helped creative individuals specialize in their comparative advantage. The U.S. system extended the protection of property rights to a much broader range of inventions than obtained in Britain or elsewhere in Europe (largely through the lower costs and diffusion of information) and, 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. As seen in figure 7.2, trade in patents was indeed much more extensive—even on a per patent basis—in the United States than in Britain. The markedly higher ratio of assignments to patents displayed for the United States is all the more striking, both because the British numbers are biased upward by the inclusion of licenses, and because the higher expense of obtaining a patent in Britain should, at least in principle, have led to patents of higher average quality. By the mid-1840s,

9. 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 expected returns played a major role in the processes generating inventions both big and small.

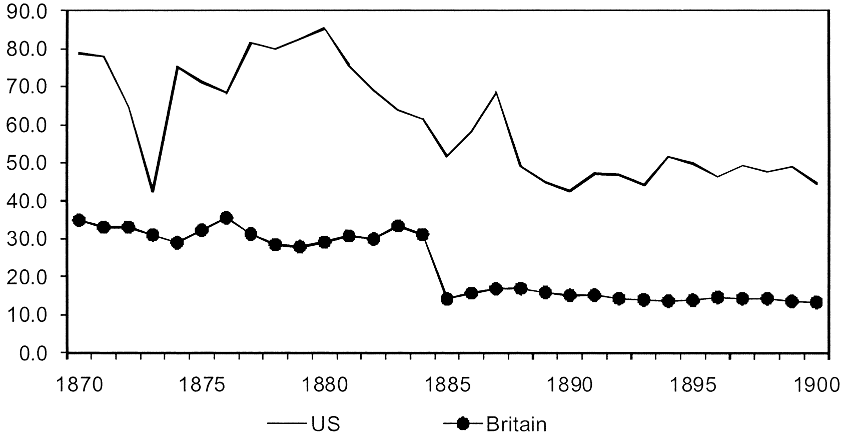

Fig. 7.2 The ratio of all assignments to patents in the United States as compared to the ratio of all assignments and licenses to patents in Britain, 1870 to 1900

Sources: U.S. Patent Office, Annual Report of the Commissioner of Patents. Washington, DC: GPO, 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: HMSO., various years.

trade in U.S. patents (and patenting) was booming, and growing legions of patent agents or lawyers had materialized 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.[10] In short, the institutional design of the American system created incentives that were more conducive to the development of a market in technology than was the costly registration system in Britain, and this created incentives for specialization and commercialization that proved especially beneficial to inventors with more creativity than capital.

7.3 Great Inventors and Technological Innovation

Kenneth Sokoloff and I compared the patterns of inventive activity for ordinary patentees and for great inventors in the United States, and also investigated the impact of the structure of intellectual property institutions on their behavior and socioeconomic standing. The data set used in this chapter is more extensive than in our previous publications: it includes a

10. Patent agents and lawyers became increasingly specialized and were drawn into activities such as the provision of advice to inventors about the prospects for various lines of inventive activity, and the matching not only of buyers with sellers of patents but also of inventors with venture capital. As the extent of the market for technology expanded over the course of the nineteenth century, creative individuals with a comparative advantage in technology appear to have increasingly specialized in inventive activity. This tendency was likely reinforced by the increasing importance to inventors of specialized technical knowledge as technology became

sample of British great inventors who contributed to technological advances in the early industrial era, in addition to the important inventors who were active in the United States during the long nineteenth century. The U.S. sample consists primarily of all the individuals born before 1886 and listed in the *Dictionary of American Biography* (DAB) on the strengths of their careers as inventors.[11] For each of the U.S. inventors the sample comprises 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 career length, and means (if any) of realizing a return on inventions, total numbers of patents ever received, and, for patentees, the years of first and last patent. Also collated were the individual records of a proportion of the patents (4,500 out of 16,900) they were awarded over their careers (approximately 97 percent received at least one). These individual patent records provide a description of the invention (classified by industry of final use), the residence of the inventor at the date of the patent award, as well as 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. In addition, the sample includes information on prizes that these inventors received.

The parallel sample of great inventors from Britain incorporates information on 435 inventors who were credited with at least one invention between 1790 and 1930. The British sample was compiled from a broader series of biographical dictionaries, including the *Oxford Dictionary of National Biography* (DNB) (Goldman 2005), and the *Biographical Dictionary of the History of Technology* (BD) (Day and McNeil 1996), among others. The objective was to assemble 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 examined. The DNB's objective was somewhat different and more diffuse, and their selection criteria were less aligned with variables that might conduce to economic or technological significance (and also diverged from the classification of inventions in the DAB). Such inconsistent terminology in the description of occupations and basis for inclusion in the DNB biographies made it necessary to refer

more complex. For evidence and more discussion, see Lamoreaux and Sokoloff (1996) and Khan (2005).

11. A small number of inventors 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), I examined whether the number of modern patent citations to the great inventors varied with their characteristics (such as residence), and found that the only significant correlation was with the year of the invention (the later the year, the more likely it was to be cited). Also reassuring was that roughly 40 percent of the U.S. great inventors were cited at least once since the late 1970s.

to a larger number of other historical dictionaries, and also required more cross-checking to compile the sample of great inventors in Britain than for the U.S. counterpart.[12] The information from the DNB and BD volumes was supplemented with other biographical compilations, and numerous books that were based on the life of a specific inventor.[13] Although a few of the entries in any such sample would undoubtedly be debatable, this triangulation of sources minimizes the possibility of egregious error. In addition to the standard variables, it was also possible to collect general information on the prizes and other sorts of official recognition the British great inventors received, including membership in the Royal Society. In short, biographical coverage of the resulting records for the British great inventors is quite comparable to the United States sample.

Even a casual perusal of these data indicates significant contrasts in the characteristics of British and American great inventors, and in the nature of important technological contributions in the two countries. The American sample demonstrates a higher propensity to patent, and greater numbers of average patents per inventor. Top U.S. patentees include Thomas Edison (1,093 patents), Carleton Ellis (753 patents), Elihu Thomson (696), Henry A. Wood (440), Walter Turner (343), and George Westinghouse (306), with numerous other inventors who filed over 100 patents. Among the British inventors, although Sherard Cowper-Coles stands out with a portfolio of some 900 patents, and inventors such as Sir Henry Bessemer, Samuel Lister, and Robert Mushet were also prolific patentees, the ranks of the numbers of patents per person rapidly decline. George Stephenson, Henry Fourdrinier, and Henry Shrapnel each barely mustered a half-dozen patented inventions, and fully forty-seven of the British patentees failed to obtain patent protection for their discoveries (compared to thirteen of the American inventors). American great inventors contributed to technologies in a wide range of industries that included varying degrees of capital intensity, engaged in more experimentation, and were quick to switch to emerging and riskier fields of invention. British inventors, however, were heavily specialized in a narrow range of already leading capital-intensive industries such as textiles, heavy metals, engines, and machinery.

The comparison presented in table 7.1 suggests that throughout most of

12. For instance, the DNB 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 McNeil (1990, 113).

13. Approximately 15 percent of the sample from these alternative sources was missing altogether from the DNB.

Table 7.1 **Social backgrounds of great inventors in Britain and the United States: By birth cohort, 1700 to 1910**

	Occupation of father					
Birth Cohorts	Farmer or agri. row (%)	Professional or elite row (%)	Manufacturer or skilled worker row (%)	Other white collar row (%)	Unskilled worker or miscellaneous row (%)	*n*
			Britain, distribution of inventors			
1709–1780	10.0	45.7	21.4	10.0	12.9	70
1781–1820	7.8	37.9	38.8	11.2	4.3	116
1821–1845	8.6	42.9	35.7	4.3	8.6	70
1846–1870	7.3	45.5	21.8	18.2	7.3	55
1871–1910	5.0	57.5	12.5	7.5	17.5	40
			United States, distribution of inventors weighted by patents			
1739–1794	40.5	9.3	22.7	12.6	11.2	259
1795–1819	37.4	19.8	27.9	12.8	2.0	494
1820–1845	39.0	18.7	32.1	7.0	3.2	918
1846–1865	11.0	28.1	31.8	23.3	7.7	1,115
1866–1885	0.2	54.9	8.2	36.7	—	463

Notes: These estimates were computed for all of the great inventors included in the U.S. and British samples, where information about the father's occupation was available. See the text for more information about the samples. Because many of the British great inventors did not obtain patents, the distribution of great inventors for Britain is reported. However, the distribution of great inventors weighted by patents is provided for the United States, because only a small number (less than 5 percent) of the great inventors there did not obtain patents. For tables 7.1 through 7.4, a dashed cell implies there is no entry.

the nineteenth century the great inventors in the United States were 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 United States 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 that 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 does not seem to be attributable to a shift in the social origins of British great inventors, but rather to an increased proportion of their counterparts in the United States whose fathers were of elite, professional, or other white-collar occupations. This reflects in part the growing importance of a high level of formal schooling for becoming a productive inventor, and the pattern that children of such fathers were more likely to attend institutions of higher learning than children from different backgrounds.

Indeed, another way of gauging the socioeconomic class of the great inventors is to utilize the information on the formal schooling they received. For most of the eighteenth and nineteenth centuries, especially for Europe, 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 nineteenth 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. Table 7.2 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.[14] So modest were the educational backgrounds of these first generations of great U.S. inventors, that 70 percent of those born during 1739 to 1794 had at best a primary edu-

14. Primary education comprises those who spent no time in school to those who attended school until about age twelve. Secondary schooling indicates those who spent any years in an academy or who attended school after the age of twelve (but did not attend a college or seminary). Inventors who attended college were either counted in the college category, or—if they were academically trained in engineering, medicine, or a natural science—in the engineering/natural science group.

Table 7.2 **Distribution of U.S. 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**

	Level of education				
Birth cohort	Primary	Second	College	Eng/natsci.	Total
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	1,221
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	1,438
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: See the text.

cation, 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 nineteenth century, these numbers unambiguously indicate that people of rather humble backgrounds were capable of making important contributions to technological knowledge.

The evidence suggests that these features and the market-orientation 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 7.2, 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 the rights to their inventive property. Moreover, it was just those groups that one would expect to be most concerned to trade their intellectual property that

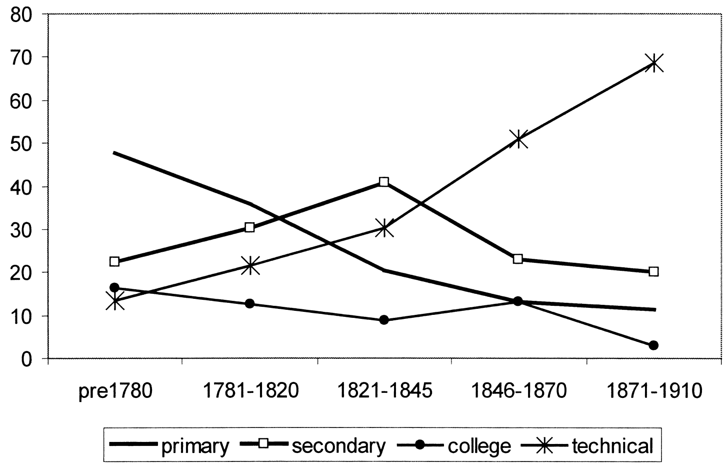

Fig. 7.3 Distribution of British great inventors, by level of education and birth cohort
Note: See text.

were indeed the most actively engaged in marketing their inventions. Specifically, 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 nontechnical field were generally the least likely to follow that strategy. Overall, the reliance on sales and licensing was quite high among the first 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.

Consistent with what one 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. After the change in the laws toward the American model, an increasing proportion of these eminent British inventors went on to obtain at least one patent over their career. Britain lagged the United States considerably in literacy and other gauges of schooling amongst the general population (thus, biasing the results against the case being made here). Nevertheless, as figure 7.3 indicates, individuals with low levels of schooling were far less well represented among the British great inventors, and those with university degrees in technical fields such as engineering, natural sciences, or medicine were far more represented than they were in the U.S. sample. Primary school education accounted for roughly 40 percent of the patents that were granted to the U.S. cohort

Fig. 7.4 British and U.S. great inventors who attended college, by occupational class of father and birth cohort
Note: See text.

born between 1820 and 1845, while those with university education 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 evidence in figure 7.4 on the occupations of the fathers of the great inventors who attended university likewise signals that the British universities recruited their students from far more privileged backgrounds than institutions of higher education in the United States.

Circumstances changed over time with the evolution of technology. Knowledge of science clearly became increasingly important, particularly in the late nineteenth century with the beginning of the Second Industrial Revolution (Khan 2008). Although this development can be overemphasized, such systematic knowledge inputs made significant contributions at the technological frontier and perhaps occurred in the context of R&D programs. For instance, individuals with technical degrees rapidly began to dominate among the later birth cohorts of great inventors in both countries (figure 7.5). Although there is substantial convergence in the distributions of great inventors by formal schooling during this period, this may overstate the extent to which the social origins of the inventors likewise converged. As reported earlier, it seems the great inventors in Britain who received degrees at universities were continually drawn overwhelmingly from extremely privileged backgrounds.[15] The U.S. educational institutions may have evolved

15. See also Khan (2008): 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

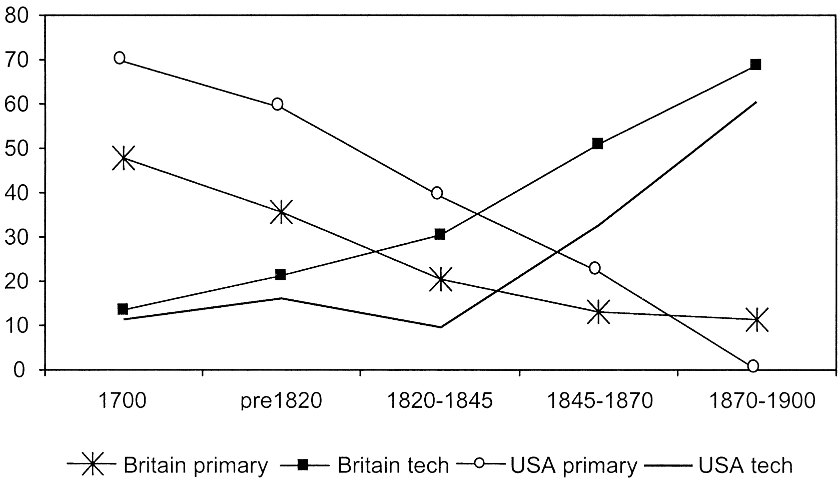

Fig. 7.5 Educational attainment of British and U.S. great inventors, by birth cohort

Note: See text.

more readily to support broader access to the increasingly valuable training in technical fields than did those in Britain. Land-grant state universities began expanding rapidly in the United States during the late-nineteenth century, and these institutions of higher learning are recognized both for offering open access as well as for having a disproportionate number of programs in the natural sciences and in engineering. Britain was much slower in extending entry 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 United States and Britain became more similar, the contrasts in the social origins of those active at invention may have persisted because of other institutional differences.

7.4 Prizes in Britain and America

Observers commonly propose that scientists are primarily motivated by the recognition of their peers, and that solutions to previously intractable

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.

problems yield an innate satisfaction. The implication is that supply elasticities with respect to economic incentives are rather low and that honors might be more appropriate than material gains for eliciting or rewarding contributions at the frontiers of knowledge. In recent years, economists have paid increasing attention to prizes as alternatives to patents as a means of encouraging creativity and innovation without incurring the inefficiency of 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 temporary monopoly associated with 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 in circumstances where awards can be adjusted ex post. Shavell and van Ypersele (2001) argued that subsidies were likely the most effective means of calibrating rewards for innovations according to social value, whereas 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 could then engage in patent buyouts of high-valued discoveries and turn them over to the public domain. The theoretical and practical problems with prizes are well recognized, however, and they include challenges 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 that might accrue from sequential innovations). Even if these issues 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 based on isolated historical events. Proponents of patent buyouts, the hybrid patent-prize model, point to the example of the daguerrotype in France, where the state purchased the patent and made it available to the public. Other popular examples of prizes are drawn from the aviation industry in the early twentieth century, most notably the Orteig prize that Charles Lindbergh secured in 1927 for the first transatlantic flight. Ironically, the example that is most frequently cited in favor of prizes, the problem of determining longitude at sea, and the experience of the humble artisan John Harrison with the Board of Longitude, instead demonstrates the disadvantages of administered award systems.[16] More systematic studies of prizes include Petra Moser's (2005) work on the Great Exhibition of 1851, and Brunt, Lerner,

16. 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

and Nicholas, (2008) who conclude that prizes offered by the Royal Agricultural Society of England comprised a "powerful mechanism" in inducing technological innovation. Nevertheless, closer inspection of the British and French historical records gives ample reason to question the efficacy of prizes during this period, especially in the case of inventors who were not politically astute or who were more likely to have been drawn from the "lower classes."[17]

In Europe, an extensive array of prizes were conferred on "deserving" inventors, such as the premium offered for margarine and food preservation, and the sums directed toward the process to make soda from sodium chloride.[18] European inventors or introducers of inventions could benefit from the award of pensions that sometimes extended to spouses and offspring, loans (some interest-free), lump-sum grants, bounties or subsidies for production, exemptions from taxes, cash, and more honorary items such as titles or medals. The biographies of the British great inventors include information about honors and awards they earned. Altogether, 171 of the inventors in the sample (close to 40 percent) 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). Unlike patents, it is impossible to trace and compile comprehensive counts of prizes that inventors received over their careers, but the omissions seem to be random. Although they are not as detailed or complete as one would like, these data still allow us to obtain insights into the advantages and drawbacks of patents and alternative incentive/reward mechanisms in the case of technologically important discoveries.

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

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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.

17. In 1775 the French government and the Académie des Sciences offered a prize of 2,400 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 £16,500 pounds for his telegraph but they only gave him £2,000 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."

18. 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.

reduce growth (Murphy, Shleifer, and Vishny 1991). If potential inventors are aware that prize winners will be drawn from the more privileged classes, such awards are less likely to induce the more humble inventors to make contributions to new technologies. Table 7.3 presents ordinary least squares (OLS) regressions where the dependent variable is the likelihood that a British great inventor is the recipient of at least one prize (the analysis here does not distinguish between different types of awards).[19] The results highlight the potential inefficiencies of administered awards, which were highly susceptible to the possibility of bias, personal prejudices, or even corruption. The grants of prizes to British great inventors seem to have been primarily connected to elite status itself rather than to factors that might have enhanced productivity.[20] The most significant variable affecting the possession of a prize was an elite or Oxbridge education, which substantially increased the odds of getting an award, despite the traditional hostility of such institutions to pragmatic or scientific pursuits.[21] It is worth noting the contrast with specialized education in science and engineering, patentee status, and employment in science or technology, which had little or no impact on the probability of getting a prize. Instead, such accolades were more 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 substantial dues.

An interesting facet of the relationship between privilege, science, and technological achievement in Britain is reflected in the experience of the ninety great inventors who were also Fellows of the Royal Society.[22] The

19. Ideally, one would like to distinguish between different categories of awards, especially between those that were bestowed as an ex post reward for career achievements and those that were offered as ex ante inducements. One would also wish to allow for variation in their objectives, value, timing, and frequency. However, the biographical information is unfortunately not sufficiently detailed to allow such disaggregation.

20. Samuel Sidney (1861) thought that "the prize system has invariably broken down" (375), and "[t]he theory that prizes encourage humble merit is only a theory, for experience shows that in a series of yearly contests wealth wins, as it must be when hundreds of pounds must be expended to win ten" (376).

21. See Roy Macleod and Russell Moseley (1980). As late as 1880 only 4 percent of Cambridge undergraduates read for the NSTs (Natural Science Tripos) 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.

22. The variable indicates whether the inventor was inducted into the Royal Society at any point in his lifetime. Although the society was associated with some of the foremost advances in science, many of the projects the Royal Society funded were absurd or impractical. James Bischoff (1842) notes that the Society distributed £544 12s in premiums "for improving several machines used in manufacturers, vis. The comb-pot, cards for wool and cotton, stocking frame, loom, machines for winding and doubling, and spinning wheels. None of these inventions of spinning machines, however, succeeded."

Table 7.3 Likelihood of British great inventor receiving prize (OLS linear probability), dependent variable: Probability of receiving prize

	(1)	(2)	(3)	(4)
Intercept	0.43	0.40	0.38	0.29
	(9.75)***	(6.23)***	(5.90)***	(1.83)
Time period				
Before 1800	–0.22	–0.22	–0.23	–0.17
	(2.88)***	(2.62)***	(2.77)***	(1.93)*
1800–1819	–0.12	–0.13	–0.13	–0.09
	(1.59)***	(1.51)	(1.54)	(1.07)
1820–1839	–0.18	–0.20	–0.23	–0.19
	(2.68)***	(2.63)***	(3.11)***	(2.58)***
1840–1849	–0.12	–0.08	–0.10	–0.06
	(1.31)	(0.84)	(1.03)	(0.60)
1850–1859	–0.11	–0.07	–0.10	–0.09
	(1.43)	(0.83)	(1.13)	(0.95)
1860–1869	0.02	–0.03	–0.01	–0.03
	(0.19)	(0.31)	(0.11)	(0.28)
Education				
Elite schooling	0.33	0.30	0.21	0.20
	(5.24)***	(4.06)***	(2.88)***	(2.63)***
Science degree	—	0.02	–0.04	–0.02
		(0.28)	(0.63)	(0.22)
Technical degree	—	0.03	0.00	0.01
		(0.33)	(0.00)	(0.08)
Residence				
London and home counties	—	0.16	0.12	0.13
		(3.27)***	(2.50)***	(2.64)***
Patentee	—	–0.04	–0.06	–0.11
		(0.64)	(0.97)	(1.81)
Fellow of Royal Society	—	—	0.15	0.15
			(2.43)***	(2.23)***
Publications	—	—	0.16	0.16
			(3.04)***	(3.02)***
Employment				
Scientific	—	—	—	0.06
				(0.37)
Professional	—	—	—	–0.01
				(0.05)
Engineering	—	—	—	–0.00
				(0.02)
Manufacturing	—	—	—	0.06
				(0.40)
Inventive Career	—	—	—	0.003
				(2.19)*
	$N = 435$	$N = 394$	$N = 390$	$N = 385$
	$R^2 = 0.09$	$R^2 = 0.11$	$R^2 = 0.15$	$R^2 = 0.16$

Notes: T-statistics are in parentheses. Prizes consist of all nonpatent awards including medals and ex-post or ex-ante cash grants. Patentee is a dummy variable that indicates whether the inventor had ever received a patent through 1890, and coinvention was counted as one patent. Publications comprise a count of articles in professional journals and nonfiction books. 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 postsecondary education in engineering or metallurgy. Career length is measured as the period between the first and last invention plus one year.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level

likelihood that an inventor had received prizes and medals was higher for scientific men who had gained recognition as famous scientists or Fellows of 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 Sir William Grove and Charles Babbage. 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. Grove, a great inventor and member of the Royal Society, was only one of the many contemporary observers who "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."[23] The bias in the award of technological premiums was widespread and was not merely limited to privileges for members of the Royal Society. William Sturgeon, an electricity pioneer who was the son of a Lancashire shoemaker, was ignored by the scientific elites because of his social 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 £2,000 and Stephenson the relatively paltry sum of 100 guineas." The growing disillusionment in Europe with the prize system as an incentive mechanism for generating innovation—and its subsequent decline in the twentieth century—are consistent with the coefficients on the time trend over the course of the nineteenth century.

In the United States the statutes from the earliest years of the Republic 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. Notable Americans such as Benjamin Franklin and Alexander Hamilton advocated the award of prizes and subsidies for invention and innovation but, despite their support, the premium system in the United States has always been sporadic and limited in scope. For instance, the New York Society for Promoting Arts, Agriculture, and Economy, founded in 1764, offered £600 in premiums for innovations in spinning flax, manufactures, and agricultural products, but was dissolved only a decade later. The state of New York provided premiums in 1808 for textile goods but similarly ceased after a few years, whereas the Pennsylvania Society for the Encouragement of Manufactures and the Useful Arts occasionally offered gold medals and cash disbursements. Little success met the proposals that 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. In general, the granting of premiums was far more prevalent in agriculture rather than

23. Gillespie (1980, vol. 5, 559).

in manufacturing, possibly because many agricultural innovations were not patentable.

Annual fairs for a variety of agricultural and mechanical exhibits were organized by the American Institute of New York (founded in 1828), and the Massachusetts Charitable Mechanic Association (founded in 1795 but with an inaugural exhibition in 1837), whereas numerous state fairs of varying scale sporadically raised funds to reward the best improvements in diverse categories among the exhibits.[24] The occasional exhibitions of the Franklin Institute, founded in 1824 to promote mechanics and manufactures, comprised the most significant of such prizes for technological innovations, but these had largely ceased by the middle of the nineteenth century. Prizes in the form of medals and diplomas were similarly featured at international and national exhibitions, notably the Crystal Palace Exhibition in London in 1851; the Paris expositions of 1855, 1867, and 1889; the Centennial Exhibition of 1876 in Philadelphia; and the World's Columbian Exposition of 1893 in Chicago.

Individual benefactors also offered prizes for advances in American technology. The most prominent awards included the medals funded by Elliott Cresson's 1848 endowment, the Longstreth Medal in 1890, and the John Scott Medal and premium. The latter was funded by a legacy from a London pharmacist, who bequeathed $4,000 in 1815 to the corporation (city) of Philadelphia for "premiums to ingenious men or women who make useful inventions." Noted recipients of the Scott Medal included George Westinghouse, Nikola Tesla, and Thomas Edison, but some contend the award was administered with "generally low standards and a certain narrowness" (Fox 1968, 416). Other prizes were designed to address specific problems, such as "Ray Premiums" offered by F. M. Ray for innovations "to improve the conveniences and safety of railroad travel." Nevertheless, more extensive proposals to enhance the premium system failed to persuade, because it was argued that the process of rapid technological change was most likely to be attained through decentralized decision making by inventors themselves, impersonal filtering of value by the market, and through legal enforcement by judges confronting individual conflicts on a case-by-case basis. The general conclusion is that Americans tended to be far more skeptical about premiums as incentives for invention than their European counterparts.[25]

24. In 1841 New York state authorized $8,000 annually to promote agriculture and domestic manufactures, allocated through individual counties. Other states followed the same model, including Ohio (1846), Michigan and New Hampshire (1849), Indiana and Wisconsin (1851), Massachusetts and Connecticut in 1852, Maine (1856), Iowa (1857).

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." The editors of *Scientific American* were critical of the proposal and pointed out that "[t]he 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

Of the great inventors in the United States, 30 percent received prizes, mainly awards from the Franklin Institute, medals from exhibitions, and overseas honors. Amasa Marks and Thaddeus Fairbanks, assiduous exhibitors, won over thirty medals for prosthetics and improvements to scales, respectively. Contributors to electricity innovations such as Elihu Thomson, Thomas Edison, and George Westinghouse were overwhelmed with numerous medals, tributes, and titles. Edison was made a Chevalier of the French Legion of Honor, the Royal Society of Arts in London bestowed the Albert Medal for his career achievements, and Congress presented him with a gold medal in recognition of his "development and application of inventions that have revolutionized civilization in the last century." The inventors of military implements, in particular, were accorded favors both in the United States and throughout the rest of the world: Samuel Colt received a Telford Medal, Hiram Maxim was knighted in England, and by order of the King of Belgium John M. Browning was created a Chevalier de l'Ordre de Léopold for his improvements to armaments.

The first regression in table 7.4 shows the factors influencing the probability that an American great inventor would obtain a prize. It is striking that the regression has very little explanatory power, with an adjusted *R*-square of only 7 percent, suggesting that the conferral of prizes was largely unsystematic. Individual variables that one might expect would signal the potential for higher economic or technical productivity—schooling, science and technology training, industry—are not significantly different from zero. Location is not influential, neither is birth cohort or prolific patenting. However, in regressions of prizes that great inventors received at industrial exhibitions (not reported here), a higher likelihood of winning prizes tended to be associated with higher number of patents, perhaps because judges used patent records as a signal of greater merit or because multiple patentees who were adept at commercialization also sought to be eligible for prize contests at exhibitions to better market their discoveries. Finally, in all types of prizes, contemporary citations to the inventor's innovations increased the probability of receiving an award, indicating that prizes were in part given because judges were persuaded by the currency of "the next new thing."[26] As the coefficient on long-term citations shows, inventors who made contributions to more lasting technological innovations were not so distinguished.

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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" (*Scientific American* 54 [April, 1886]: 208).

26. Sidney Smith (1861–1862) referred to the "number of colourable alterations and improvements, devised to satisfy the passion for 'something new,' which is the peculiar failing of amateur judges" (376).

Table 7.4 Determinants of prizes and career patents among U.S. great inventors

Dependent variable	(1) Prob. of prize		(2) Log of total patents	
Intercept	0.142	(0.90)	1.516	(6.72)***
Birth Cohort				
1820s and 1830s	0.094	(0.91)	0.021	(0.13)
1840s	0.010	(0.08)	0.034	(0.19)
1850s	0.106	(0.98)	0.219	(1.29)
Region				
Northern New England	0.083	(0.77)	0.217	(1.27)
Southern New England	–0.152	(1.72)	0.111	(0.80)
Middle West	–0.049	(0.49)	0.035	(0.23)
West	–0.001	(0.00)	0.301	(0.56)
South	–0.093	(0.58)	–0.217	(0.87)
Education				
Secondary school	–0.022	(0.24)	0.189	(1.33)
College	–0.007	(0.09)	0.095	(0.77)
Science	0.002	(0.02)	–0.186	(1.03)
Engineering	–0.055	(0.48)	0.065	(0.36)
Citations (index of technical value)				
Contemporary citations	0.010	(2.69)***	0.020	(3.53)***
Long-term citations	0.006	(1.21)	0.038	(5.65)***
Industry				
Construction and engineering	0.054	(0.46)	–0.069	(0.37)
Electrical and communications	0.164	(1.39)	0.329	(1.77)
Heavy industry	0.041	(0.49)	0.227	(1.71)
Light manufacturing	0.126	(1.15)	0.073	(0.42)
Transportation	–0.028	(0.29)	0.061	(0.41)
Patenting				
Log (total patents)	–0.034	(0.77)	—	—
Patent litigation	–0.001	(0.16)	–0.008	(0.72)
Percent of patents sold	0.002	(1.51)	0.007	(4.70)***
Inventive career	0.003	(1.12)	0.036	(4.70)***
Prize dummy	—	—	–0.085	(0.77)
	$R^2 = 0.1605$		$R^2 = 0.67$	
	Adj $R^2 = 0.0677$		Adj $R^2 = 0.63$	
	$N = 231$		$N = 231$	

Notes: These OLS regressions are estimated over a sample of great inventors from the United States from the birth cohorts of the 1820s through 1885. T-statistics are in parentheses. See notes to other tables. Contemporary citations refer to patent citations by other inventors of the same period to the great inventor's work, whereas "long-term citations" refer to citations that were made to the great inventor's work by modern-day patentees (between 1975 and the present). Patent litigation indicates the total number of lawsuits in which the great inventor was involved either as a plaintiff or a defendant. Percent of patents sold (assigned) is an index of commercial success. Career length is measured as the period between the first and last invention plus one year.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

By contrast, the second regression assesses the determinants of variation in the total number of patents that the great inventors received (only three in this sample were not patentees). Patent grants appear to have been more systematic, for two-thirds of their overall variation can be explained by the included variables. Patents were positively associated with higher numbers of both contemporary and long-term citations. Thus, a greater propensity to invest in patented inventions was indicative of contributions to technology that were not only important in their own time but also still matter to technical progress today.

7.5 Conclusion

Institutions such as property rights comprise rules and standards that create incentives and constraints that influence behavior. This chapter uses parallel data sets of great inventors from Britain and the United States to explore the nature and consequences of different institutions for generating technological progress. At least three results stand out. First, the inventors in the United States were drawn from a much broader spectrum of the population than were their counterparts in Britain, consistent with the view that the more restrictive provision of property rights in new technological knowledge under the British patent system did matter for who was involved in inventive activity. Although other differences in institutions and economy-wide circumstances undoubtedly contributed to this pattern, it is striking that so much of the important invention in the United States was carried out by individuals from humble backgrounds until very late in the nineteenth century. For these inventors, the patent system and the related market for property rights in invention were critical to their expected and actual ability to appropriate returns from their efforts.

Second, the analysis of the prizes that the great inventors were accorded for their discoveries highlights the potential for "capture" whereby select groups of prize givers bestow prizes on members from their own background, independently of merit. In Britain the most decisive determinants for whether the inventor received a prize were which particular university he had graduated from and membership in the Royal Society of Arts, characteristics that seem to have been somewhat uncorrelated with technological productivity. Thus, rather than being calibrated to the value of the inventor's contributions, prizes to British inventors appear to have been largely determined by noneconomic considerations. If petty politics and social connections were perceived to have played a major role in selecting recipients, this likely undermined the efficacy of such incentives in eliciting efforts by creative individuals without the requisite links or influence. And here it is worth repeating that inventors from undistinguished backgrounds were indeed capable of making discoveries at the frontiers of technology, as the record of the great inventors in the United States amply demonstrates.

Finally, apart from such factors, the determination of prizes seems to have been largely idiosyncratic and difficult to predict, both in Britain and in the United States. In the American case, the only systematic factor influencing their award was whether the innovator operated in the newest technology field, as opposed to discoveries that had lasting technical value. The contrast with patenting is quite marked, especially given that the grant of property rights in patented inventions was related more to the nature of the technology than to the personal characteristics of the inventors. If inventors respond to expected benefits, the implication is that prizes may have been less effective as inducements for investments in inventive activity than other alternative mechanisms. It is therefore not surprising that technological prizes declined in popularity over the course of the nineteenth century. The French Academy of Sciences ultimately switched from a system of prestigious prizes toward more dispersed funding of projects for younger researchers (Crosland and Galvez 1989). Similarly, by 1900 the Council of the Royal Society decided to change its emphasis from the allocation of medals to the financing of research.[27]

These results support the view of those economists who argue that institutions matter, but they also function within a political and economic context that can dramatically influence outcomes. In the context of institutional mechanisms to promote the progress of useful arts, society is likely to benefit most when rewards are tailored to objective technological contributions rather than to the identities of the inventors. Markets for patented inventions in the period of early industrialization in the United States were effective in mobilizing the efforts of creative men and women from all social classes and backgrounds. By contrast, British patent institutions were designed to elicit contributions from only a select class, thus providing fewer incentives for incremental inventions or for the efforts of more humble inventors. The experience of the great inventors in both Britain and America suggests that the institutional structure of prize systems should be calibrated to be more predictable and correlated with productivity, with specific measures to avoid the potential for capture and corruption to which their administration is susceptible. For, as Thomas Jefferson long ago pointed out, perhaps one of the most crucial elements of achieving growth is to ensure that institutions are sufficiently open and flexible to respond to the needs of the developing society.

27. 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." See MacLeod (1971, 105).

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