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INVENTING PRIZES:
A HISTORICAL PERSPECTIVE ON INNOVATION AWARDS AND TECHNOLOGY POLICY

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ABSTRACT

Prizes for innovations are currently experiencing a renaissance, following their marked decline during the nineteenth century. However, Daguerre's "patent buyout," the longitude prize, inducement prizes for butter substitutes and billiard balls, the activities of the Royal Society of Arts and other "encouragement" institutions, all comprise historically inaccurate and potentially misleading case studies. Daguerre, for instance, never obtained a patent in France and, instead, lobbied for government support in a classic example of rent-seeking. This paper surveys empirical research using more representative samples drawn from Britain, France, and the United States, including "great inventors" and their ordinary counterparts, and prizes at industrial exhibitions. The results suggest that administered systems of rewards to innovators suffered from a number of disadvantages in design and practice, some of which might be inherent to their non-market orientation. These findings in part explain why innovation prizes lost favour as a technology policy instrument in both the United States and Europe in the period of industrialization and economic growth.

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"Everybody has won and all must have prizes."
---*Alice in Wonderland*, Chapter III.

Technological progress has been characterized as a "lever or riches" that has been responsible for a significant fraction of human welfare in the past three centuries.[1] In such areas as innovations in pharmaceuticals and healthcare, the stakes can be as fundamental as the difference between large financial gains or losses for firms, and life or death for consumers. It is therefore not surprising that policy debates surrounding inventions and innovations have frequently been controversial. Policy makers of the past explored the full range of options that were available for promoting ingenuity, including patents, prizes, subsidies, bounties, trade secrecy protection, cartelization and the protection of monopolies, as well as specialized institutions dedicated to administering inducements for innovation. What is, perhaps, surprising, is the extent of historical myopia that manifests itself in the policy debates of the twenty-first century. Proponents of different policies today tend to make selected and often inaccurate reference to history, without a full assessment of all the relevant costs and benefits, a practice that creates the potential for suboptimal rules and standards.

In the nineteenth century, President Abraham Lincoln, a patentee himself, was convinced that economic and business prosperity depended on strong property rights in patents. In 2014, the President of the United States included patent policy in his State of the Union address, but from a critical perspective that called for major reforms in longstanding rules and standards regarding such intellectual property rights. Nobel Prize winners in economic theory have contended that "probably the best solution would be to maintain the patent system on drugs and a

[1] For excellent overviews, see Joel Mokyr, The Lever of Riches: Technological Creativity and Economic Progress. New York: Oxford University Press, 1990. Mokyr has also produced a number of other thought-provoking works on related issues, including The Gifts of Athena: Historical Origins of the Knowledge Economy, Princeton, N.J.: Princeton University Press, 2002; and Joel Mokyr, The Enlightened Economy: An Economic History of Britain, 1700-1850. New Haven, CT: Yale University Press, 2009.

few other products that are expensive to innovate and cheap to copy, and eliminate patents on everything else."[2] Others, however, are more concerned about the negative effects of pharmaceutical patents on the provision of drugs and access to medical care.[3] According to some extremists, it is time to abolish the entire intellectual property system, which they regard as an "unnecessary evil" and an unwarranted monopoly.[4]

By way of contrast, both academics and American policy makers today are increasingly enthusiastic about prizes. The White House urges that "history should be our guide" and "the Federal Government should… use high-risk, high-reward policy tools such as prizes and challenges to solve tough problems."[5] The federal government has begun to finance prizes as a means of generating new ideas and products, claiming that prizes "have a good track record of spurring innovation."[6] Numerous businesses have also offered large privately-funded prizes for objectives that range from specific targets to solutions for more general problems.[7] Many

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[2] See http://www.becker-posner-blog.com/2012/09/reforming-the-patent-system-toward-a-minimalist-system-becker.html. Joseph Stiglitz, another Nobel Prize winner, takes a similar position in "Scrooge and intellectual property rights," BMJ 333.7582 (2006): 1279-1280.

[3] William W. Fisher III and Talha Syed, Infection: The Health Crisis in the Developing World and What We Should Do About It, Stanford University Press (forthcoming); Michael Kremer and Rachel Glennerster, Strong Medicine: Creating Incentives for Pharmaceutical Research on Neglected Diseases, Princeton, NJ: Princeton University Press, 2004.

[4] Michele Boldrin and David K. Levine, Against Intellectual Monopoly, a work that is copyrighted, New York: Cambridge University Press, 2008. See also Fritz Machlup and Edith Penrose, "The Patent Controversy in the Nineteenth Century," Journal of Economic History, 10 (1) 1950: 1-29.

[5] A Strategy for American Innovation, 2009, https://www.whitehouse.gov/administration/eop/nec/StrategyforAmericanInnovation.

[6] See "Implementation of Federal Prize Authority: Progress Report, A Report from the Office of Science and Technology Policy In Response to the Requirements of the America COMPETES Reauthorization Act of 2010," Office of Science and Technology Policy, March 2012, http://www.whitehouse.gov/sites/default/files/microsites/ostp/competes_report_on_prizes_final.pdf. The America COMPETES Reauthorization Act of 2010 granted all Federal agencies the authority to administer prize competitions to increase innovation.

[7] Netflix, for example, offered one million dollars in 2006 for an algorithm to improve its predictive capacity. The competition attracted some 27,000 entrants and the prize was awarded in 2009 to a team that achieved the specified target. The (excessive?) number of entrants may mirror problems that also occur in "patent races" (Michael Baye and Heidrun C. Hoppe, "The strategic equivalence of rent-seeking, innovation, and patent-race games," Games and Economic Behavior, 44 (2) 2003: 217-226.) The publicity was undoubtedly valuable for Netflix, but the firm later reported that the benefits it derived from the prize-winning code were limited because "the additional accuracy gains that we measured did not seem to justify the engineering effort needed to bring them into a production environment." This owed in part to a changed market environment, for which the findings from the competition

economists lobby for these nonmarket-oriented policies as complements or superior alternatives to intellectual property rights.[8] The rationale for promoting innovation prizes ranges from attractive properties of theoretical economic models to unexamined case studies, and these debates would benefit from more empirical analysis and information drawn from the actual historical record.

This survey considers the nature and consequences of alternative technology policy instruments in the United States, Britain and France during the early industrial period. The paper reviews the use and misuse of case studies regarding several prominent innovation awards, assesses the experience of prestigious prize-granting institutions, and presents the results from systematic empirical research on historical innovation prizes. The first section revisits the record for several popular case studies that have figured prominently as representative of the historical experience for inducement awards and related policy initiatives. The second section discusses the salient details regarding the award of prizes by the Royal Society of Arts in England, and the Society for the Encouragement of National Industry in France. The final section outlines the results from large-scale empirical studies based on several different samples of prizes, including awards to great inventors, and prize grants at industrial exhibitions in the nineteenth century. These findings have implications for effective innovation policies, but the paper does not attempt to project schemes for the design of an optimal inducement mechanism.

I. PRIZES IN PRACTICE

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were less relevant. See Xavier Amatriain and Justin Basilico, "Netflix Recommendations: Beyond the 5 stars (Part 1)," available on the firm's website at http://techblog.netflix.com/2012/04/netflix-recommendations-beyond-5-stars.html.

[8] Joseph Stiglitz, "Give prizes not patents," New Scientist, 16 September 2006, p. 21.

A substantial amount of theoretical economic research addresses the question of innovation prizes.[9] Theorists primarily distinguish between ex ante inducement awards, ex post prizes such as rewards to the winners of competitions, targeted prizes that relate to a specific and well-defined problem, and prizes for nonspecific achievements such as lifetime-career awards, while more expansive definitions include research grants that subsidize inputs into technology, and procurement contracts. The analysis at times contrasts intellectual property rights and alternative arrangements as mutually exclusive, whereas other approaches assume their complementary existence.[10] Both technological discovery and the transformation of an invention into a commercially useful innovation are stochastic and dynamic processes that are inherently difficult to predict, so it is important to understand the fundamental role of information, valuation, and incentives in policy alternatives. For instance, in a pioneering article, Brian Wright concludes that the choice between intellectual property and other mechanisms will depend on the degree of informational asymmetry between inventors and prize-granting agencies; if value and cost cannot be accurately determined by grantors, patents would tend to dominate other prospective incentive measures.[11] What has been markedly missing from such valuable discussions, however, is direct attention to the pragmatic details of how innovation prizes have worked in practice, the political economy of administered institutions, and the deadweight losses that may result from associated sources of inefficiency.

The most popular and influential example of an inducement prize is the significant sum that was offered for an accurate means of gauging longitude at sea, so it is worth re-examining

[9] An excellent overview is available in Suzanne Scotchmer, Innovation and Incentives, Cambridge: MIT Press, 2004. See also Benjamin N. Roin, "Intellectual Property versus Prizes: Reframing the Debate," University of Chicago Law Review, vol. 81, 2014: 999-1078.

[10] See, for instance, Bronwyn Hall et al., "The choice between formal and informal intellectual property: a review," Journal of Economic Literature 52 (2) 2014: 375-423; Michael Kremer and Heidi Williams, "Incentivizing innovation: Adding to the tool kit," Innovation Policy and the Economy, Vol. 10 (2010): 1-17.

[11] Brian Wright, "The Economics of Invention Incentives: Patents, Prizes and Research Contracts," American Economic Review, 73 (4) 1983: 691-707.

this case study.[12] Specialists with a detailed knowledge of this case tend to be somewhat skeptical about the effectiveness of the Longitude prize, which nobody ever officially won.[13] John Harrison (1693-1776), a poor uneducated clockmaker, encountered numerous obstacles in his dealings with the Board that administered the prize, including competition from some who were also attempting to win the award on their own account.[14] A full 47 years elapsed before Harrison actually received compensation from another source than the Longitude Board. It is possible that the information about the winning technology generated spillovers that benefited the industry, but the incentives were quite different for the losers, who bore the risk of revealing their inventive ideas without obtaining a return. The astronomer Samuel Molyneux was appointed to examine the work of another participant in the race, Zachariah Williams, and

[12] The British Parliament passed a bill in July 1714 "for providing a public reward for such person or persons as shall discover the longitude at sea." The bill offered "10,000 pounds if the method were accurate to within 1 degree, or 60 nautical miles; 15,000 pounds if the method were accurate to within 2/3 degree, or 40 nautical miles; 20,000 pounds if the method were accurate to within ½ degree, or 30 nautical miles." The panel of judges comprised 22 commissioners, including the astronomer royal, the Speaker of the House of Commons, and the lords of Admiralty. See the records at Papers of the Board of Longitude RGO 14/1, available at http://cudl.lib.cam.ac.uk/view/MS-RGO-00014-00001/19. A modern version of this prize, Longitude 2014 (https://longitudeprize.org) notes that "Bacteria are evolving to become resistant to the antibiotics we have successfully used for decades to treat infections. Longitude Prize is looking to help tackle the problem with a £10 million prize fund for a diagnostic tool that can rule out antibiotic use or help identify an effective antibiotic to treat a patient." At the same time, other grantors are offering equally large sums for similar solutions. For instance, the Department of Health and Human Services plans that "A prize of up to $20 million will be awarded to the first group(s) to develop a rapid, point-of-care diagnostic test to be used by health care providers to identify highly resistant bacterial infections" (nih.gov website). See also Jon White, "Why it's time to resurrect a centuries-old prize," New Scientist, Volume 222, Issue 2970, 24 May 2014, p. 29; and M. Diane Burton and Tom Nicholas, "Patents and the Search for Longitude," unpublished working paper, July 2015.

[13] David Landes, Revolution in Time, Cambridge: Belknap, Harvard University Press, 1983. For a popular account that also highlights the inefficiencies and biases associated with the administration of this prize, see Dava Sobel, Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time, New York: Penguin Press, 1996.

[14] As shown in the empirical section, the social standing of inventors affected the likelihood of prize awards. For instance, the uneducated George Stephenson and the well-connected Sir Humphry Davy both resolved the problem of an effective safety lamp. According to the Dictionary of National Biography, Davy received public accolades and a testimonial of £2000, whereas Stephenson was given the "paltry" sum of 100 guineas.

Williams claimed that Molyneux stole his design. Williams understandably became so secretive about his methods that it was difficult to accurately assess his contributions.[15]

The positive assessment of the role of prizes in generating a solution to longstanding problems at times risks faulty logic involving post hoc ergo propter hoc fallacies. David Landes points out that, while it is true that the British prize was associated with numerous attempts to resolve the problem, the issue had been known and researched for more than a century prior to the passage of the Longitude Bill in 1714. Enormous sums had been offered throughout Europe for the discovery of a means of measuring longitude, long before the British introduced their own prize, and those had all failed to produce a positive outcome. Despite the outlay of significant resources towards assessing and aiding applicants, Spain, Venice and Holland had eventually given up, because "necessity may be the mother of invention, especially if backed by money, but there is no substitute for the kind of environment that generates novelty."[16] Markets may have failed because of spillovers that could not be privately captured, but it is also possible that, even in the absence of state-sponsored prizes, another substitute would have been developed, because of the significant profits that awaited anyone who resolved the problem.

In Europe, an extensive array of targeted prizes were conferred on inventors who directed their efforts to specific discoveries, such as the premium offered for margarine and food preservation, and the sums directed toward the process to make soda from sodium chloride.[17] In a related example, the French Academy of Sciences in 1775 offered a cash prize for the

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[15] Albert J. Kuhn, "Dr. Johnson, Zachariah Williams, and the Eighteenth-Century Search for the Longitude," Modern Philology, Vol. 82, No. 1 (Aug., 1984): 40-52.

[16] David Landes, "The Creation of Knowledge and Technique: Today's Task and Yesterday's Experience," Daedalus, Vol. 109, No. 1, (Winter, 1980): 111-120, p. 114. Similar examples appear in the archives of the Royal Society of Arts in London, where committees concluded that prizes, claimed fifty years or more after their initial introduction, had functioned as successful inducements.

[17] Liam Brunt, Josh Lerner, and Tom Nicholas, "Inducement prizes and innovation," Journal of Industrial Economics 60, no. 4 (2012): 657-696, study the awards of the Royal Agricultural Society in England and conclude that such prizes promoted technological progress and competition.

discovery of a process to create sodium carbonate from the cheaper sodium chloride.[18] Nicolas Leblanc succeeded in finding a viable manufacturing solution, but he never received the prize and his factory was expropriated by the revolutionary government. From one perspective, such prizes succeeded if, despite the failure of Harrison or Leblanc to win the award, the offers did induce inventors to turn to the issue that was in need of a resolution. However, even if unawarded prizes provided an effective one-period inducement, this argument fails to take into account the deterrent effect owing to a fall in the credibility of the granting agency or mechanism. That is, the process of invention is a repeated game and, when a prize is not bestowed even though the conditions are satisfied, this occurrence reduces the perceived probability of future awards and thus the expected benefits of prizes.[19]

Other prominent examples of such innovation prizes reveal additional complexities, including the potential for overcompensation of some inventors through multiple overlapping awards. Premiums from the state did not preclude inventors from also pursuing profits through other means, including patent protection. For instance, Napoleon III offered a monetary prize for the invention of a cheap substitute for butter that may have 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, and for the use of such fats in candles and soap. Mège not only won the prize money, 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

[18] Charles C. Gillispie. "The Discovery of the Leblanc Process." Isis. 48 (June 1957): 152-170.

[19] The key point is that systematic awards take place in the context of a repeated game. If this were not the case, it would be rational for governments or private institutions to costlessly benefit, by continually announcing an array of spectacular prizes for inventions, and to subsequently refuse to make the award once the solution was discovered. For a French example, see the prize of one million francs which Napoleon offered in 1810 for the inventor of an effective flax-spinning machine. Philippe Girard succeeded in making such a machine but never received the award, although his heirs were later given a small pension after his death. Gabriel Desclosières,Vie et inventions de Philippe de Girard, inventeur de la filature mécanique du lin (2e éd.), Paris: A. Pigoreau, 1881.

the United States. He sold the patent rights in Holland and the United States, to assignees who made the improvements that transformed the patented product into a commercially-viable good. In the absence of these follow-on patent rights, it is not clear that Mège himself would have had the incentive to invest in efforts to turn the discovery into a better product.[20]

The experience of the patentee John Wesley Hyatt is also often cited as an example of an inducement prize that was administered by a private company.[21] The billiard table producers Phelan and Collender had offered a prize of $10,000 in 1863 for a material to replace costly and increasingly scarce ivory inputs that were used to make billiard balls.[22] This was not a new area of inquiry, as witnessed by the accomplishments of British inventors Alexander Parkes and Daniel Spill, as well as prior American patents on this subject-matter, but Hyatt sustained an independent patent claim on his contribution.[23] Both Parkes and Spill failed as entrepreneurs, and Hyatt's patented version proved to be successful in the marketplace. The $10,000 prize was never paid out, but it is possible that Hyatt himself chose not to accept it. He established several firms (including the prominent Celluloid Manufacturing Company), which allowed him to obtain benefits from the marketplace, as a multiple patentee and entrepreneur, that were far in excess of the prize money that Phelan and Collender had offered. This example illustrates problems of

[20] To avoid this problem, it is possible to structure the terms of the prize to offer interim awards until the product or process is successfully commercialized.

[21] Hyatt's first patent was obtained in 1861; his first patent for billiard balls was granted in 1865; and he later filed over two hundred patents on a wide variety of inventions.

[22] This New York company was the largest manufacturer of billiards tables in the world, employing over 150 men and significant capital. The firm continually introduced patented innovations, and both Hugh Collender and Michael Phelan were successful multiple patentees. The partners were flamboyant promoters, and it is possible that the prize may have been offered as a means of gaining free publicity. ("These gentlemen are more enterprising than most of the New York manufacturers, and do not hide their light under a bushel. They have made their names so familiar to the public, and their manufactory so well known, that it is impossible to write a comprehensive account of the manufactures of New York without noticing it," according to John Leander Bishop, A History of American Manufactures from 1608 to 1860, Edw. Young, 1864, p. 612.)

[23] A fascinating account of the progress of invention in the industry is given in Celluloid Manuf'g Co. v. American Zylonite Co., CC S.D. NY, 26 F. 692, 1886. See also Tim A Osswald and Sylvana Garcıa-Rodrıguez, "The History of Sustainable Bio-based Polymers," in Sanjay Kumar Sharma et al. (eds), A Handbook of Applied Biopolymer Technology: Synthesis, Degradation and Applications, London: Royal Society of Chemistry, 2011: 1-21. Hyatt obtained a trademark in 1873 on the term "celluloid."

adverse selection (where only "lemons" are awarded the payoff), and also difficulties in arriving at an accurate inducement "price" when part of the benefit to the winner comprises additional gains such as market power.

Scholars who favour "patent buyout" policies typically cite the example of the "Daguerreotype patent," claiming that the French government purchased the rights to a patent whose social value was great, and allowed everyone to have free access to the technology. According to Michael Kremer's account, "In 1839 the French government purchased the Daguerreotype patent and placed it in the public domain. Such patent buyouts could potentially eliminate the monopoly price distortions and incentives for rent-stealing duplicative research created by patents, while increasing incentives for original research."[24] The facts are somewhat different, however. Most noticeably, a search in nineteenth-century patent records reveal that Daguerre never obtained a patent in France at any point in his life for this or any other invention. As such, there was no patent for the French government to buy out, and the case study instead highlights the incentives for unproductive "rent-stealing" that arises when returns can be negotiated through a political process.

In popular histories, Daguerre typically receives sole credit for the discovery of a method of reproducing photographic images. However, work in photography had been in progress for over a century, and arguably the most significant advances up to that date had been made by Joseph-Nicéphore Niépce. Daguerre formed a partnership with Niépce, who died in 1833 and bequeathed his inventive rights to his son. Isidore Niépce agreed that it was advisable for

[24] Michael Kremer, "Patent Buyouts: A Mechanism for Encouraging Innovation," Quarterly Journal of Economics (1998) 113 (4): 1137-1167. The quote is from the abstract of this article. For related buyout theories, see the discussion in Alberto Galasso et al., "Market Outcomes and Dynamic Patent Buyouts," No. w20197. National Bureau of Economic Research, 2014. Michael Kremer, "Creating Markets for New Vaccines. Part II: Design Issues," Innovation Policy and the Economy, Vol. 1 (2000): 73-118, motivates the discussion with the Longitude Prize.

marketing purposes that Daguerre should have the sole attribution rights to the joint work Daguerre had accomplished with Isidore's father.[25] The political economy behind Daguerre's prize of August 1839 was typical of the stratagems and manipulations that French inventors often adopted to get support and payouts from the authorities.[26] Instead of paying the extremely high fees for a patent, and trying to interest licencees or assignees, Daguerre was able to secure the patronage of François Arago, a politician and influential member of the Académie des Sciences, who lobbied strongly on Daguerre's behalf in favour of a government grant. When the inventor turned over to the Ministry of the Interior a packet with the specification and information on the discovery, Arago was involved in the process of examining and verifying their validity on behalf of the French government, in something of a conflict of interest.

In view of the "patent buyout" argument, it is ironic that Daguerre's main plea to the French legislature was that he was unable to apply for a patent to gain benefits from the process: "Unfortunately for the authors of this great discovery, it is impossible for them to commercialize it and thereby obtain compensation for the sacrifices they have endured as a result of their long and hitherto fruitless trials. *Their invention is not susceptible to patent protection* ... It is therefore necessarily the case that this process must belong to everyone or else it must remain unknown."[27] Daguerre thus contended that his idea was an unpatentable trade secret and, once it

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[25] The two seem to have had a falling-out, however, as Isidore later inveighs against Daguerre for "the Machiavellian tendencies which have taken away … the honor for which M. J.-N. Niépce had toiled over a period of twenty years": Historique de la découverte improprement nommée Daguerréotype, précédée d'une notice sur son véritable inventeur M. Joseph-Nicéphore Niépce de Chalon-sur-Saône; par son fils Isidore Niépce, Paris: Astier, 1841 (my translation).

[26] See Liliane Hilaire-Perez, L'Invention technique au siècle des lumières, Paris: Albin Michel, 2000; and B. Zorina Khan, The Democratization of Invention: Patents and Copyrights in American Economic Development, Cambridge: NBER and Cambridge University Press, 2005, Chapter 2.

[27] My translation (and my emphasis) of: "Malheureusement pour les auteurs de cette belle découverte, il leur est impossible d'en faire un objet d'industrie et de s'indemniser des sacrifices que leur ont imposés tant d'essais si long-temps infructueux. Leur invention n'est pas susceptible d'être protégée par un brevet. … il faut donc nécéssairement que ce procédé appartienne à tout le monde ou qu'il reste inconnu." Louis-Jacques-Mandé Daguerre, Historique et description des procédés du daguerréotype et du diorama, Paris: Delloye, 1839, p. 2. The main details in this section are drawn from this original text, which includes official documents for the transaction.

was revealed, the whole world would have free access to his ideas and he would be unable to appropriate any returns. As such, the choice before the legislature was for his secret to die with him and be lost to the world ("il devait se perdre et mourir avec ses inventeurs"), or for the state to buy the information and so benefit the public. An appeal was further cannily made to the essentially mercantilist nature of the French authorities, by hinting that otherwise foreigners might make an offer that Daguerre could not refuse. The measure was quickly approved, and an annual lifetime pension of 10,000 francs was awarded for the discovery.[28]

Daguerre at the same time proceeded to file for a patent in England under the name of Miles Berry (a British patent agent), giving the lie to the notion that the invention was unpatentable, and reneging on the bargain that the French government would buy the discovery on behalf of the entire world.[29] Daguerre and Berry then placed a true patent buyout prospectus before the British government, on the grounds that the inventor was "obliged to ask so large a sum to Individuals for Licences that few can afford to take them."[30] As a result of this alleged failure of the market to recognize the true value of the invention, the inventor wished "to solicit Her Majesty or the Government of England to purchase the said Patent right for the purpose of throwing it open in England for the benefit of the Public and preventing this important Discovery being fettered or limited by individual interest or exertion."[31] Daguerre's British patent buyout

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[28] The request was initially for an upfront award of 200,000 francs, but an annual lifetime payment seemed more politically expedient than such a large lump sum payout. Six thousand francs per annum went to Daguerre, and the remainder to Isidore Niepce, with residual rights of 50 percent of this sum payable during their widows' lifetime. Louis-Jacques-Mandé Daguerre, Historique et description des procédés du daguerréotype et du diorama, Paris: Delloye, 1839.

[29] See patent No. 8194 (August 14, 1839) for "A New or Improved Method of Obtaining the Spontaneous Reproduction of all the Images Received in the Focus of the Camera Obscura." England maintained a registration system, where patentees did not have to be the "first and true inventor" in reality, and it was common for agents like Berry to obtain patents on behalf of foreigners. See also the Court of Common Pleas, Beard v. Egerton et al., May 27, 1846.

[30] This "Memorial" is included in the appendix to R. Derek Wood, "The Daguerreotype Patent, The British Government, and The Royal Society," History of Photography, 4 (1)1980: 53–59.

[31] Wood Appendix, op cit.

proposal was made on March 30, 1840; the government representative politely and tersely declined the opportunity on March 31, 1840, on behalf of Her Majesty's Treasury.

Patent buyouts are often proposed because they would allow ideas to circulate freely and because such access enables cumulative inventions to flourish without the transactions costs and deadweight loss that a monopolistic right of exclusion might impose. The Daguerre-Niépce method did indeed spread quickly, comprising an undoubted advantage of the French policy, but this approach to photographic reproduction was also short-lived and did not become the dominant process in the marketplace. Instead, the English inventor William Fox Talbot patented a technique in 1841 through which photographic prints could be developed from negatives, and it was this approach that ultimately prevailed throughout the nineteenth and twentieth centuries in the pre-digital era.[32] The buyout of the Daguerre process may also have created its own problem of cumulative invention, by putting in the public domain all of the efforts of prior inventors whose work was incorporated in the Daguerreotype, without their permission and without offering them any compensation.[33] Questions also remain about whether the monetary award accurately gauged the true value of the invention, given the availability of (present and imminent) substitutes that were not taken into account in the public accounting; the deadweight loss of taxation and redistributive effects of using public funds to benefit one group in society (photographers); and, ultimately, the incentives that such a policy creates for inefficient rent-seeking and patronage on the part of inventors and their influential connections.[34]

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[32] Talbot's methods were different and independent of Daguerre's and the validity of his patented discovery was upheld in litigation. He was publicly criticized for the price of its use, and chose to appropriate returns through the practice of price discrimination, charging professional photographers higher licence fees than amateurs.

[33] Even if the process had been patented, this would still be true, because French patents were granted via a registration system without any prior examination to determine the incremental contributions that were worthy of exclusive property rights.

[34] The role of such connections was important in European innovation awards, and comprised an additional cost of administered prizes. Even in competitions with open access, worthy applications were at times not rewarded, because the inventors lacked the advantage of patrons to exert their influence in prosecuting the claim on behalf of

II. EARLY PRIZE-GRANTING INSTITUTIONS

As the example of Daguerre highlights, European policies towards inventions and innovations in the eighteenth and nineteenth centuries were based on an extensive but somewhat arbitrary array of rewards and incentives. Inventors or introducers of inventions could benefit from titles, pensions that sometimes extended to spouses and offspring, loans (some interest-free), lump-sum grants, bounties or subsidies for production, exemptions from taxes, and monopoly grants in the form of exclusive privileges.[35] As such, the French and British experience offers a valuable opportunity to analyze the relative benefits and costs of alternative institutions and policy instruments for generating technological innovation. This section focuses on the analysis of innovation inducements offered by two of the primary societies in London and Paris for the encouragement of technological discoveries during the industrial revolution.

A key institution in the granting of prizes, medals, and "encouragements," the Société d'Encouragement pour l'Industrie Nationale (Society to Encourage National Industry or SEIN), was founded in 1801.[36] As the name suggests, its objectives were to promote economic

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the inventor. "Unfortunately the government had no uniform policy for all inventors. Some it aided financially; others it did not. More flagrantly inconsistent was its policy of granting monopolistic rights in many lines to court favorites, so that the greater number enjoying exclusive privileges were not inventors," Shelby T. McCloy, French Inventions of the Eighteenth Century, Lexington: University of Kentucky Press, 1952, p. 171.

[35] The award of technological prizes was administered by ad hoc committees or institutions who varied significantly in the extent to which the application was debated or formally examined, and in the accuracy of their valuations. (As Scientific American recognized, "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." Scientific American, March 1852, vol 7, p. 221.) In 1790, M. Devilliers demonstrated two inventions in Paris: a device to measure longitude and one to purify the town water supply. He claimed a total of 4,200 livres, and offered to donate a quarter of the award to the paupers in the town, and the French Committee on Agriculture and Commerce saw no need for deliberations before granting his request. In other cases, committees engaged in extensive due diligence, and only offered conditional awards that awaited successful outcomes before payouts. See B. Zorina Khan, The Democratization of Invention, op. cit.

[36] Societies such as the Paris Académie des Sciences ostensibly offered prizes for discoveries in pure science, although at times the subject matter included technological issues. See Maurice Crosland, "From Prizes to Grants in the Support of Scientific Research in France in the Nineteenth Century: The Montyon Legacy," Minerva, Vol. 17, No. 3 (Autumn, 1979): 355-380.

development by furthering technological innovation and manufacturing, and specifically to distribute information, assess and fund new inventions, and award prizes.[37] The SEIN is often characterized as a private free-market initiative to promote French industrial competitiveness, but scholars point out that it was initially a state-founded and state-run institution that was created by representatives primarily from such government departments as the Ministry of the Interior.[38] In any event, it is clear that throughout its first century the administrators, committees and members of the SEIN were primarily drawn from the elite circles of politicians, aristocrats, scientists, professors, bankers, and wealthy manufacturers, who were not all necessarily qualified to gauge inventive merit.[39] Juries or committee membership may in part have been offered as an honour, rather than as a means of obtaining the most competent or technically-qualified personnel.

The Society published an annual list of proposed areas, to which it sought to attract applicants for cash prizes, medals, and "encouragements" or other support for projects. The list identified the problem, in specific terms in some cases, and quite broad and vague phrases in others, along with the monetary value of the prize that was at stake. The Jacquard loom for silks, improved turbines by Claude Burdin and his student Benoit Fourneyron, and the naturalization of sugar beets, illustrate the successes of the Society. In 1810 Nicolas-François Appert received a payout of 12,000 francs for his discoveries of improvements in food preservation, although his

[37] Jean-Antoine Chaptal, President of the Society from 1801-1832, proved to be a remarkable force and leader in the movement to support national industry, and was himself an accomplished scientist and industrialist.
[38] The SEIN is typically described as the spontaneous creation of influential individuals and entrepreneurs who wished to support domestic industry, but some researchers refer to this perspective as a "founding myth." See Andrew J. Butrica, "Creating a Past: The Founding of the Société d'Encouragement pour l'Industrie Nationale Yesterday and Today," The Public Historian, 20 (4) 1998: 21-42.
[39] http://cnum.cnam.fr/CGI/fpage.cgi?BSPI.92/823/100/916/61/726 Bulletin for 1893, pp. 813-840 lists the members of the board of directors since the inception. See also Serge Chassagne, "Une Institution Originale de la France Post-Revolutionnaire et Imperiale: La Société D'encouragement pour L'industrie Nationale," Histoire, Économie et Société, 8e Année, No. 2 (2e trimestre 1989): 147-165.

method of employing heated glass bottles was not entirely novel.[40] Appert did not have to turn his rights over to the public; the sole requirement for earning the award was the printing of 200 copies of a short book to describe his methods, and he signed each volume individually, warning potential infringers that he would prosecute them.[41] The Society awarded Appert a silver medal in 1816, followed by a gold medal in 1820, and a lack of coordination across prize-granting societies allowed him to garner cash awards and prizes for the same discovery from several different sources.[42] Administered prize systems implied such negotiations and strategy could increase the inventor's rewards independently of the value of the invention and, consequently, as Liliane Hilaire-Pérez notes, "in France, to invent meant to go into politics."[43]

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[40] The Appert process seems to provide an example of an ex post award, rather the outcome of an inducement. Relevant supporting original documents are included in Nicolas Appert, L'Art de conserver, pendant plusieurs années, toutes les substances animales et végétales, Paris: Patris et Cie, 1810. See also the biography of Appert in Potin, J., Exposition universelle internationale de 1889 à Paris, Rapports du jury international, Classes 70 et 71,1891: 9-14. Salting, boiling, pickling, and freezing had been practiced for centuries as cheap methods of conserving foods, and several scientists had devised a similar process to Appert's. Appert had long been experimenting on the job with ways to improve on the flavor of such preserved foods. He was able to interest English financiers who in 1804 funded his small manufactory in Massy that employed about 30 women, and this work drew the attention of connected officials, as well as the popular press. The Bureau consultatif des arts et manufactures subjected his foods to several tests and testimonies from elite panelists. As might be expected from a former gourmet chef, the samples he offered the panel included delicacies like freshly-picked truffles that had been preserved, cherries, raspberries and cream, that had been put up by hand in bottles in a very labour-intensive process. Clearly, Appert's bottles were not ideal for provisioning an army, and the English method of canning (with American improvements) was more efficient. In France, "Appertized" establishments were small artisanal shops, the price of preserved foods was too expensive for large-scale usage, (French!) soldiers detested the taste of the tinned mass-produced items, cases of massive food poisoning led to wariness, and these goods remained a niche product until the end of the nineteenth century. See Martin Bruegel, "Du temps annuel au temps quotidien: la conserve appertisée à la conquête du marché, 1810-1920," Revue d'histoire moderne et contemporaine, 44 (1) 1997: 40-67. Appert's manufacturing efforts were not financially successful and the state made him an annual pension of 1200 francs to ease his poverty.

[41] "L'auteur s'est conformé a tout ce qu'exige la loi pour assurer sa propriété; il prévient en conséquence qu'il poursuivra les contrefacteurs et débitants d'exemplaires contrefaits…" (This signed warning appeared on the frontispiece of Appert's 1810 book, op. cit.) Appert submitted the copies of this work to the Bureau consultatif des Arts et Manufactures. Similarly, James Douglas, an English engineer, was able to gain the support of influential officials, including Chaptal, which he was able to parlay into a portfolio of benefits, including a large loan from the Conservatoire des arts et métiers, patents for his machines, as well as funds from the Society for the Encouragement of National Industry. Michael P. Fitzsimmons, From Artisan to Worker: Guilds, the French State, and the Organization of Labor, 1776-1821, Cambridge: Cambridge University Press, 2010.

[42] The archival records of both the RSA and the SEIN indicate a significant number of "repeat players." The prevalence of repeat winners, rather than losers who subsequently won, suggests that the patterns were likely not due to learning.

[43] "Invention and the State in 18th-Century France," Technology and Culture, 32 (4) 1991: 911-931.

Table 1 shows the subject-matter for the prizes that were granted during the first half-century of the Society's existence. The percentage distribution by value indicates the relative importance of the awards during this critical period, and suggest the prizes were not wholly aligned with the economic value of innovations for the individual industry. The Society offered valuable support for heavy industry and metals, including forges, locomotives, machine tools, as well as steam engines. However, awards for the domestic cultivation of sugar beets and sugar production accounted for 9.3 percent of prizes, relative to a mere 1.2 percent for locomotives, and it is not clear why sugar should have been viewed as more meritorious than transportation. The ceramics industry obtained a surprising 12.7 percent of funding, and fine arts and music similarly received 11 percent of the prizes and encouragements. The criteria for some grants were associated with inventive novelty and higher productivity, but others were less related to technological excellence, and included justifications that ranged from close imitation of foreign goods, to good workmanship and the beauty of an item, and even the moral character of the applicants.[44] The Bulletin of the Society for 1820 included figures that showed 184,000 francs had been offered as prizes since the founding of the institution, whereas only 41.6 percent of this sum had actually been granted. In some instances, the prize was withdrawn because the problem had already been resolved elsewhere, or because no applicants were deemed to be worthy, which were indicative of effective due diligence. In many other areas, the award remained unclaimed throughout its history because of a lack of entries, indicating nobody had been "induced" by the offer, perhaps because the award was too low or the problem was insoluble or uninteresting. Such failures need to be taken into account, to avoid a selection bias in the assessment of inducement prizes.

[44] These statements are based on a perusal of several thousand pages of handwritten committee reports in the attic of the Society in Paris, France.

In view of current advocacy in favour of prizes for medical discoveries, it is relevant to note that several prizes were offered in nineteenth-century France, and in other countries, for cures, preventive measures, and medical solutions to public health problems such as cholera.[45] The French Academy of Sciences bestowed a prize of 5000 francs on Léon Doyère for his experiments on cholera victims, whereas specialists disparaged his efforts as already known in points, and incorrect in others. The Russian government offered 25,000 roubles for the best treatise on this subject, and made investments in examining 125 entries, none of which was practicable.[46] A well-known and often-cited prize of 100,000 francs, the Bréant award, was offered for a means of curing cholera, or for prevention of the epidemics. The Bréant fund made a minor payout but remained largely intact and unclaimed well into the twentieth century, despite numerous submissions that proved to be largely ineffective or even irrelevant. Clearly, "money left on the table" in this way was not costless, because there was an opportunity cost in terms of more viable or productive alternatives that could have been funded.

The Royal Society for the Encouragement of Arts, Manufactures and Commerce (commonly known as the Royal Society of Arts or the RSA) offers another example where the historical details are not entirely consistent with popular anecdotes. The Royal Society of Arts has been cited as an institution that serves as a model for the adoption of prizes instead of intellectual property rights. For instance, Joseph Stiglitz, a theorist and holder of the Nobel Prize in Economics, proclaims: "the alternative of awarding prizes would be more efficient and more equitable. It would provide strong incentives for research but without the inefficiencies

[45] An example is S. 627 (113th Congress): Medical Innovation Prize Fund Act of March 2013. For an assessment of policy towards medical innovation, see Marlynn Wei, "Should Prizes Replace Patents-A Critique of the Medical Innovation Prize Act of 2005," BUJ Sci. & Tech. L. 13 (2007): 25; and Ernst Berndt et al., "Advance Market Commitments for Vaccines Against Neglected Diseases: Estimating Costs and Effectiveness" Health Economics 16(3) 2007: 491-511.

[46] See S.L. Kotar and J.E. Gessler, Cholera: A Worldwide History, McFarland, 2014.

associated with monopolisation. This is not a new idea – in the UK for instance, the Royal Society of Arts has long advocated the use of prizes. But it is, perhaps, an idea whose time has come."[47]

The RSA was founded in London in 1754, in part to "embolden enterprise," according to its charter. Initially, the Society published annual lists of items for which inducement awards were to be offered, in the form of honorary medals and cash payouts. These prizes were administered by specific committees in the designated categories of Polite Arts, Mechanics, Agriculture, Chemistry, Manufactures, as well as Colonies and Trade. The society achieved some success in calling attention to scarcity in such industrial areas as the production of soda made from salt. In others, such as its treatment of the great inventor John Kay, its record is less than stellar.[48] The Royal Society itself was the target of persistent criticism throughout this period, including scathing assessments by its own disillusioned members, who attributed awards to arbitrary factors such as personal influence, the persistence of one's recommenders, or the self-interest of the institution in making the award. As in France, the mercantilist doctrines that informed the choices of the Royal Society of Arts (RSA) meant that a great deal of effort and funds were directed toward nationalistic attempts to replicate items and inputs that were already being produced more efficiently in foreign countries.

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[47] Joseph Stiglitz, "Give prizes not patents," New Scientist, 16 September 2006, p. 21.

[48] The experience of the famous English textile machine inventor, John Kay, illustrates the asymmetries and risks involved in individual bargains struck with such authorities. Kay settled in France because of state promises of support as well as a monopoly on textile shuttles, and he substantially aided this country's technological competency in the textile industry. The Royal Society in England promised him a generous reward to leave France, and then reneged on the agreement once he was back in London. Kay then contacted Prudaine de Montigny, Conseiller d'Etat in London, to explore the possibility of receiving French financial aid if he again immigrated to Paris. Later that same year, Kay wrote to M. de Brou, Intendant de Rouen, to complain that he was still not receiving the annuity he had been promised. This account is based on correspondence and documents in the French National Archives. See B. Zorina Khan and Kenneth L. Sokoloff, "Institutions and Technological Innovation During Early Economic Growth: Evidence from the Great Inventors of the United States, 1790-1930," in Institutions and Economic Growth, (eds) Theo Eicher and Cecilia Garcia-Penalosa, MIT Press (2006):123-158.

The Royal Society, an early advocate of prizes, did not view them as complementary to patents and, indeed, was initially hostile to the grant of patents. The Rules and Orders of the Society stipulated that prize winners were not permitted to obtain patents for their inventions. This led to an adverse selection effect, because the owners of important discoveries chose to obtain patents and bypassed the RSA, whereas the owners of minor inventions had an incentive to try to claim a prize award that was in excess of the market value of the item.[49] As a result, the annals of the RSA prizes were largely devoted to undistinguished contributions, and the truly significant innovations were to be found in the roster of patentees, rather than in RSA records. For instance, the inventor Samuel Clegg obtained a patent for an important gas-meter in 1815, and the RSA gold medal was instead given for an incremental improvement on Clegg's patent. As one contemporary observer pointed out: "Of the importance of these discoveries the Society is by no means ignorant; but as, in connection with the majority of the industries which grew out of these discoveries, patents were obtained, the Society refused to take cognizance of them, having effectually closed its doors against all patented inventions; the necessary result, as coal, iron, and the steam engine extended their influence, was that the Society lost power and position…."[50]

As was the case for the French SEIN, the archives of the Royal Society of Arts reveal prizes which remained unawarded over the course of decades, as well as other prizes offered for

[49] The most palpable successes of the RSA were typically in subject areas that were unpatentable, such as the 1802 medal and cash award to Henry Greathead's lifeboat, which also received numerous other awards from Parliament, as well as from other institutions. Inventors who competed for nonmonetary awards may have been interested in the prospect of attracting the notice of a patron on one of the committees, or in promoting their claims to the military or the government.

[50] The quote is from an address of the Financial Officer of the Society, Samuel Thomas Davenport, "A Glance of the Past and Present of the Society of Arts, with some suggestions as to the Future," Journal of the Royal Society of Arts, vol 17, 1868: 10-27, p. 22.

problems that had long been resolved or patented.[51] For instance, in 1777 a gold medal was available for a method to measure the degree of sweetness in saccharine substances, that no one ever attempted to resolve.[52] Sir Henry Trueman Wood, a Secretary of the RSA for several decades, points to the inability of the committees to identify or predict the course of economically important new technologies.[53] A large sum was allotted to the provision of an improved supply of fish to markets in London, although the results were not entirely satisfactory in terms of meeting the expectations of the Committee in question. Panels of judges applied idiosyncratic criteria to the assessment of applications and, Wood noted, some of the awards may have been motivated by criteria besides the objective quality of the invention, such as sympathy or friendship. Other chroniclers (including another Secretary) of the RSA conclude that economic advance soon "made obsolete the whole idea of encouraging industrial progress by the award of prizes."[54] Outsiders tended to regard the institution with a more sanguine perspective, but conceded that "Of course it is true that the Society of Arts can take no credit for the development of the iron industry in Britain, or that of the steam-engine, and little for the creation

[51] Sir Henry Trueman Wood, "The Royal Society of Arts VI.—The Premiums. (1754-1851) ," Journal of the Royal Society of Arts, vol. LX January 26 1912: 263-274. The other unattributed examples in this paragraph are drawn from this article. The quoted phrase appears on p. 268.

[52] Wood censures some of the decisions that were motivated by "lamentable ignorance" (p. 210), but looks on the bright side, musing that "while a great many undeserving inventions were rewarded, there are not a great many which were rejected and which afterwards proved themselves of any value" p. 209. Henry Trueman Wood, "The Royal Society of Arts," VI.—The Premiums, Journal of the Royal Society of Arts, Vol. 60 (3086) 1912: 208-216.

[53] See H. T. Wood, A history of the Royal Society of Arts, Murray, London, 1913:
"That in the lists so many familiar names are missing is certainly disappointing. One would like to have found the names of Watt, Hargreaves … amongst those whose inventions were recognized and rewarded by the Society of Arts. But in the early records none of these names appear. Why is this? … A committee which could anticipate the direction in which industry or science would progress would have to be composed of men with prescience beyond their fellows (p. 241)…Another reason which prevented the Society from taking cognizance of many important inventions was the regulation which excluded patented articles (p. 244)." Instead, one notes awards for obsolete spinning wheels, for which "various prizes were offered, and certain small improvements were duly rewarded. None of them, however, were of any great value, and, as we fully recognize now, the efforts of the Society were quite futile, and its energy was entirely misdirected" (p. 260).

[54] D. Hudson and K. W. Luckhurst, The Royal Society of Arts, 1754-1954, London: John Murray, 1954, p. 177.

of the Lancashire textile industry. It may even be doubted whether the awards of prizes and medals would have had the least effect in strengthening enormous economic forces."[55]

The general conclusions of authors, including insiders and officers of the Society, is that the policy of granting prizes resulted in a few successes, but that industrialization in Britain was largely independent of such awards. Their views are supported by the data, drawn from the archival records of the RSA. Figure 1 shows the time series of awards bestowed during the eighteenth century, and reveals a sharp drop-off in the total amount of prizes in the decade after the Society's founding in 1754. The levels after 1770 comprise a much lower plateau of activity, which do not reflect the expansion and structural change in the wider economy. Table 2 examines the patterns of awards at a more disaggregated level. These data indicate that the awards of the Society within the declining patterns over time were for innovations that were primarily outside of the burgeoning manufacturing sector, which accounted for just 7.3 percent of total funds allocated through 1782.[56] Prizes were given in agriculture for the introduction of imported fodder-crops such as Swedish turnips, rhubarb and the mangold-wurzel, but not for innovative plant breeding. However, over twenty million trees were planted owing to awards that were largely offered to the landed gentry. As in France, the sector that benefited most from the premiums that the RSA bestowed was the "polite arts," including watercolours, sketches,

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[55] Rupert Hall, "The Royal Society of Arts: Two Centuries of Progress in Science and Technology," Journal of the Royal Society of Arts, Vol. 122 (5218) 1974: 641-658, p. 644. He adds, "the main pioneers … went without recognition, perhaps because of patent protection. It is my impression that such awards had negligible effects on major industrial changes" p. 645. For a debate about such issues in the early textile industry, see Trevor Griffiths et al., "Inventive activity and the British textile industry , 1700-1800," Journal of Economic History, 52 (4) 1992: 881-906; Richard Sullivan, "Patent counts and Textile invention: A comment of Griffiths, Hunt and O' Brien," Journal of Economic History, 55 (3) 1995:667-670; Patrick O' Brien et al., "There is nothing outside the text and there is no safety in numbers: a reply to Sullivan," 55 (3) 1995:671-672.

[56] Similarly, between 1731 and 1839, the prestigious Copley Medal was largely given for optics, heat and electricity, anatomy, and chemistry, with just 12 percent of the awards in the area of mechanics. The vast majority of these awards (90 percent) went to higher status gentlemen and professionals, with only 10 percent given to artisans or tradesmen, and the authors note some degree of "internal favoritism" in the selection process. See M. Yakup Bektas and Maurice Crosland, "The Copley Medal: the Establishment of a Reward System in the Royal Society, 1731-1839," Notes Rec. R. Soc. Lond. 46 (1) 1992: 43-76.

sculpture, and "musick." The analysis by contemporary insiders and the data are thus consistent with the notion that the course of British industrialization was not significantly altered or aided by the policies of the premier prize-granting institution of its time.

It is therefore not surprising that, in both England and France, the systematic institution of "inducement prizes" that had prevailed in the eighteenth and early nineteenth centuries failed to survive except for sporadic instances. In England, by the 1820s the Royal Society realized the inefficiencies associated with prizes, and instead switched to lobbying in favour of patents. By the time of the Crystal Palace Exhibition in 1851, the RSA had not only acknowledged the value of patents, it had become active in lobbying for reforms to strengthen the British patent laws along the lines of the U.S. model.[57] The system of inducement prizes in France and England was typically replaced by research grants to underwrite the costs of R&D inputs into the technology production process.[58] Both institutions also switched their mandate towards the provision of information and technical education.[59] The RSA even refused to accept further funding from benefactors who wished to designate prizes, because such endowments hampered their desire to reform their policies away from such targeted awards and towards more productive endeavours for "the advancement of Natural Knowledge."[60]

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[57] H T Wood, History of the Royal Society of Arts, London: John Murray, 1913, p. 212:"Indeed, it was only in our own generation that the value of protection by patent was fully realised, and that - to quote once more an often-quoted saying of the late Sir William Siemens - if an invention were found lying in the gutter, it would be worth while to assign it to an owner who would have an interest in looking after it."

[58] See, for instance, Maurice Crosland, "From Prizes to Grants in the Support of Scientific Research in France in the Nineteenth Century: The Montyon Legacy," Minerva, Vol. 17, No. 3 (Autumn, 1979): 355-380; Roy M. MacLeod, "The Royal Society and the government grant: Note on the Administration of Scientific Research, 1849-1914", Historical Journal , XIV, 2 (1971): 323-358; and Robert Fox, "Scientific Enterprise and the Patronage of Research in France 1800-70," Minerva, Vol. 11, No. 4 (October 1973): 442-473.

[59] "Arthur Aikin, the Society's Secretary from 1817 to 1839, clearly perceived about halfway through this period that a more valuable function for the Society would be the communication of knowledge of technical or commercial matters, and the discussion of papers, rather than prize awards," Rupert Hall, Journal RSA, p. 648.

[60] "In the majority of cases the terms of gift have limited the application of the money to certain definite purposes, and, in particular, to the award of medals or other prizes for scientific discoveries… The President and Council have again and again had the experience that the usefulness of the Society for the advancement of Natural Knowledge has been greatly hampered by the lack of funds of which they could freely make use according to their own judgment."

III. EMPIRICAL RESEARCH ON PATENTS AND PRIZES

The patent and innovation policy controversies of the twenty-first century have often unknowingly replicated concerns from the past regarding the nature and consequences of technology institutions.[61] For instance, pivotal Supreme Court decisions have in part been justified with references to history that exhibit a faulty understanding of the actual development of intellectual property markets.[62] Policy debates would therefore benefit from an historical perspective on the design, operation and consequences of incentive mechanisms for promoting technological change and innovations. At the same time, even if selected supporting anecdotes are accurate, their representativeness needs to be determined through the systematic empirical analysis of data drawn from a number of independent sources.

Patent institutions have played a primary role in the technology policy of the world's leading industrial nation, so it is perhaps not coincidental that a significant amount of research has already been directed towards the empirical analysis of patent systems and outcomes.[63] Such

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"Memorandum as to the wishes of the Council in respect of benefactions to the Society," unnumbered page in Year-book of the Royal Society of London, Issue 11, London: Harrison and Sons, 1900.

[61] B. Zorina Khan, "Trolls and Other Patent Inventions: Economic History and the Patent Controversy in the Twenty-First Century," George Mason Law Review, vol. 21 (2014): 825-863.

[62] In eBay Inc. v. MercExchange, L.L.C., 547 U.S. 388 (2006), Justices Kennedy, Stevens, Souter, and Breyer noted in a concurring opinion that injunctive remedies might not be as appropriate because "the nature of the patent being enforced and the economic function of the patent holder present considerations quite unlike earlier cases. An industry has developed in which firms use patents not as a basis for producing and selling goods but, instead, primarily for obtaining licensing fees." For evidence that such considerations are not "quite unlike earlier cases," see Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Market Trade in Patents and the Rise of a Class of Specialized Inventors in the Nineteenth -Century United States,"American Economic Review, Papers and Proceedings, 91 (May 2001):39-44.

[63] For surveys, see the special issue of Business History Review, 87 (1) 2013; B. Zorina Khan and Kenneth L. Sokoloff, "The Early Development of Intellectual Property Institutions in the United States," Journal of Economic Perspectives, vol. 15 (3) 2001: 233-246; Petra Moser, "Patents and Innovation: Evidence from Economic History," Journal of Economic Perspectives, 27(1): 23-44; B. Zorina Khan, The Democratization of Invention: Patents and Copyrights in American Economic Development, NBER and Cambridge University Press (2005); Fiona Murray et al. "Grand Innovation Prizes: A theoretical, normative, and empirical evaluation." Research Policy 41.10 (2012): 1779-1792; Williams, Heidi. "Innovation Inducement Prizes: Connecting Research to Policy." Journal of Policy Analysis and Management 31, no. 3 (2012): 752-776. A sample of research on more specific historical issues

scholars as Kenneth Sokoloff have produced extensive evidence that patents played a substantial role in influencing the rate and direction of inventive activity during industrialization, and were also associated with advances in productivity.[64] Inventions and inventors of all backgrounds were responsive to economic incentives.[65] From the first decades of the nineteenth century, strongly enforced property rights in patents facilitated trade and commercialization, with all the attendant benefits of market exchange.[66] The vast majority of "great inventors" who produced the transformative innovations in both the United States and Britain (especially after the latter reformed their patent laws towards the U.S. model) were patentees.[67] A major feature of the

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includes: Tom Nicholas, "The Role of Independent Invention in U.S. Technological Development, 1880-1930," Journal of Economic History, 70 (1) 2010:57-82; Tom Nicholas, "Did R&D Firms Used to Patent? Evidence from the First Innovation Surveys," Journal of Economic History, 71 (4) 2011:1032-1059; Dhanoos Sutthiphisal and Shih-Tse Lo, "Crossover Inventions and Knowledge Diffusion of General Purpose Technologies: Evidence from the Electrical Technology," Journal of Economic History, 70 (3) 2010:744-764. For the European experience, see Christine MacLeod, Inventing the Industrial Revolution, Cambridge, UK: Cambridge University Press, 1988; Liliane Hilaire-Perez, L'invention technique au siècle des Lumières. Paris : Albin Michel, 2000. Relevant articles include Alessandro Nuvolari and Valentina Tartari, "Bennet Woodcroft and the value of English patents, 1617-1841," Explorations in Economic History, 48 (1) 2011:97-115; Richard J. Sullivan, "The Revolution of Ideas: Widespread Patenting and Invention During the English Industrial Revolution," Journal of Economic History, 50 (2) 1990: 349-363. For examples of innovation from freely shared information among competitors, see Alessandro Nuvolari, "Collective Invention during the British Industrial Revolution: The Case of the Cornish Pumping Engine." Cambridge Journal of Economics 28(3) 2004: 347-63; and Robert Allen, "Collective Invention," Journal of Economic Behavior & Organization, 4 (1)1983:1-24.

[64] Kenneth L. Sokoloff, "Inventive Activity in Early Industrial America: Evidence From Patent Records, 1790–1846," Journal of Economic History, vol. 48 (04) 1988: 813-850; Kenneth L. Sokoloff, "Invention, Innovation, and Manufacturing Productivity Growth in the Antebellum Northeast," in Robert Gallman and John Wallis, eds, Growth and Standards of Living Before the Civil War. Chicago: University of Chicago Press, 1992:345 378; B. Zorina Khan and Kenneth L. Sokoloff, "The Early Development of Intellectual Property Institutions in the United States," Journal of Economic Perspectives, vol. 15 (3) 2001: 233-246. B. Zorina Khan and Kenneth L. Sokoloff, "Patent Institutions, Industrial Organization and Early Technological Change: Britain and the United States, 1790-1850," in Technological Revolutions in Europe, 1760-1860, eds. M. Berg and K. Bruland, Edward Elgar, London (1998):292-313. See also B. Zorina Khan, "Looking Backward: Founding Choices in Innovation and Intellectual Property Protection," in Douglas Irwin and Richard Sylla (eds), Founding Choices: American Economic Policy in the 1790s, NBER and University of Chicago (2010): 315-342.

[65] B. Zorina Khan, "Creative Destruction: Technological Change and Resource Reallocation during the Civil War," Journal of Interdisciplinary History (forthcoming 2015); B. Zorina Khan, "Married Women's Property Laws and Female Commercial Activity: Evidence from United States Patent Records, 1790-1895," Journal of Economic History, vol. 56 (2) 1996: 356-88.

[66] B. Zorina Khan, "Property Rights and Patent Litigation in Early Nineteenth-Century America," Journal of Economic History, vol. 55 (1) 1995: 58-97. See also Adam Mossoff, "The Rise and Fall of the First American Patent Thicket: The Sewing Machine War of the 1850s," 53 Arizona Law Review 165 (2011), and Adam Mossoff "Patents as Constitutional Private Property: The Historical Protection of Patents under the Takings Clause," 87 Boston University Law Review 689 (2007).

[67] B. Zorina Khan and Kenneth L. Sokoloff, "A Tale of Two Countries: Innovation and Incentives among Great Inventors in Britain and the United States, 1750-1930," in Roger Farmer (ed) Macroeconomics in the Small and the Large, Edward Elgar (2009): 140-156; B. Zorina Khan and Kenneth L. Sokoloff, "Institutions and Technological Innovation During Early Economic Growth: Evidence from the Great Inventors of the United States, 1790-1930," in Institutions and Economic Growth, (eds) Theo Eicher and Cecilia Garcia-Penalosa, MIT Press (2006):123-158; B. Zorina Khan and Kenneth L. Sokoloff, "Institutions and Democratic Invention in 19th Century America," American

patent system is that it allows for a separation of the assessment of technical value (determined by examiners through a centralized process) and the economic value (determined by the market through a decentralized process) of an invention. Impecunious inventors in particular benefited from markets in patents, because they were able to specialize in inventive activity, and obtain returns in the market place by selling or licensing their patent rights to others who were better equipped to commercialize their discoveries.[68] An extensive network of specialized intermediaries facilitated patent sales and licensing, and helped to reduce the transactions costs of trades in new technologies, in both national and international markets.[69]

The central role of patents and the market for technology in American policy was recognized by prominent foreign observers. Sir William Thomson (Lord Kelvin), a British inventor and scientist, was a judge at the 1876 Centennial Exhibition in Philadelphia, which featured displays for Bell's telephone, the Westinghouse airbrake, Edison's improved telegraph, sewing machines, refrigerator cars and numerous other patented discoveries. He reported : "Judged by its results in benefiting the public, both by stiumulating inventors and by giving a perseveringly practical turn to their labours, the American patent law must be admitted to be most successful, and the beneficence of its working was very amply illustrated throughout the

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Economic Review, vol. 94 (May) 2004: 395-401; B. Zorina Khan and Kenneth L. Sokoloff, "Lives of Invention: Patenting and Productivity among Great Inventors in the United States, 1790-1930," Les archives de l'invention (eds) Marie-Sophie Corcy et al. (2004): 181-199; B. Zorina Khan and Kenneth L. Sokoloff, "`Schemes of Practical Utility': Entrepreneurship and Innovation among `Great Inventors' During Early American Industrialization, 1790-1865," Journal of Economic History, vol. 53 (2) 1993: 289-307; B. Zorina Khan and Kenneth L. Sokoloff, "Entrepreneurship and Technological Change in Historical Perspective: A Study of Great Inventors During Early Industrialization," Advances in the Study of Entrepreneurship, Innovation, and Economic Growth, vol. 6 (1993): 37-66.

[68] Kenneth L. Sokoloff and B. Zorina Khan, "The Democratization of Invention during Early Industrialization: Evidence from the United States," Journal of Economic History, vol. 50 (2) 1990: 363-78; B. Zorina Khan and Kenneth L. Sokoloff, "A Tale of Two Countries: Innovation and Incentives among Great Inventors in Britain and the United States, 1750-1930," in Roger Farmer (ed) Macroeconomics in the Small and the Large, Edward Elgar (2009): 140-156.

[69] Naomi R. Lamoreaux, Kenneth L. Sokoloff, and Dhanoos Sutthiphisal, "Patent Alchemy: The Market for Technology in U.S. History," Business History Review 87 (Spring 2013): 3-38; Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Long-Term Change in the Organization of Inventive Activity," Proceedings of the National Academy of Sciences 93 (Nov. 1996): 12686-92; Naomi R. Lamoreaux and Kenneth L. Sokoloff, "The Market for Technology and the Organization of Invention in U.S. History," in Entrepreneurship, Innovation, and the Growth Mechanism of the Free-Enterprise Economies, eds. Eytan Sheshinski, Robert J. Strom, and William J. Baumol, Princeton: Princeton University Press, 2007, 213-43; B. Zorina Khan, "Selling Ideas: An International Perspective on Patenting and Markets for Technology, 1790-1930," Business History Review, vol. 87 (Spring) 2013: 39–68..

American region of the Exhibition, where, indeed, it seemed that every good thing deserving a patent was patented."[70] A Swiss Commissioner to the Philadelphia Exhibition likewise successfully urged his own countrymen to model its policy after the U.S. and introduce a patent system.[71] A special commission from Japan was even more emphatic, asking "'What is it that makes the United States such a great nation?'… we investigated and we found it was patents, and we will have patents."[72]

Patents comprised a central feature of U.S. innovation policies, and this orientation is reflected in the stock of academic research. By way of contrast, relatively little systematic evidence has been produced in the area of prize incentives. In the earliest such attempt, an insightful nineteenth-century observer in England, Samuel Sidney, sought to determine "Whether … manufacturing inventions [can be] stimulated, by invitations to compete for substantial or honorary awards?"[73] Sidney spent ten years investigating the data on prizes at exhibitions, as well as the incentives that various societies offered for encouraging industry. His investigations led him to conclude that prizes generally tended to be inefficient, and improvements in market demand and competition offered more effective inducements for inventive activity. The prize system, he found, merely encouraged "a long list of machines which, for practical purposes, are no better than toys."[74] For instance, the market value of useful inventions tended to be far greater than any prize that could be offered, whether by private or state initiative. Even prestigious

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[70] See Great Britain Parliament, House of Commons, Parliamentary Papers, House of Commons and Command, Volume 34 , London: H.M. Stationery Office, 1877, p. 271.

[71] "We must introduce the patent system. All our production is more or less a simple copy. ... It is evident that this absolute want of protection will never awaken in a people the spirit of invention. ... America has shown us how in a few years a people, in the midst of circumstances often embarrassing, can merit by its activity, its spirit of enterprise, and its perseverance, the respect and admiration of the whole world, and acquire in many respects an incontestable superiority." cited in "Arguments before the Committee on Patents of the Senate and House of Representatives," 45th Congress, 2nd Session, Mis. Doc. No. 50, Washington, D.C.:Government Printing Office, 1878: 448–49.

[72] Cited in "Patents in relation to Manufactures," Story B. Ladd, 12th Census of the United States, vol. 10 (4) pp. 751–66.

[73] Samuel Sidney, "On the Effect of Prizes on Manufacturers," Journal of the Society of Arts, Vol. 10 (April) 1862: 374-382, p. 374. Sidney was an Assistant Commissioner of the Crystal Palace Exhibition in London in 1851.

[74] Sidney, op. cit., p. 376.

institutions such as the Royal Agricultural Society and the Royal Society of Arts had failed to develop truly significant inventions.[75] Moreover, the competitor for a prize had an incentive to overspend on the item in an attempt to win, regardless of whether such investments were practicable in the marketplace. As a result, winners tended to be among the wealthiest of the competitors: "The 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 when hundreds of pounds must be expended to win ten."[76] However, he found that, from the perspective of manufacturers or retailers, prizes served as a useful marketing strategy, comparable to advertisements and enhanced brand name capital. Sidney's thoughtful assessment are all consistent with the quantitative analysis of national and international prize systems discussed here.

Systematic insights into the relationship between incentives and innovation can be gleaned from a large sample of British inventors who were responsible for the great inventions of the period before the Second World War.[77] The sample includes information on all of the prizes and other forms of official recognition the British great inventors received, and indicates that less than 40 percent of these eminent inventors were recipients of awards. When many might be equally deserving, a question arises about why one is selected, and some observers identify instances when such awards, medals and prestigious appointments owed to nepotism, bias and even corruption.[78] Statistical analysis of the factors that influenced the probability that an

[75] For a more positive assessment of the effectiveness of the Royal Agricultural Society, see Liam Brunt, Josh Lerner, and Tom Nicholas, "Inducement Prizes and Innovation," 60 (4) 2012: 657-696.
[76] Sidney, op cit., p. 376.
[77] B. Zorina Khan, "Premium Inventions: Patents and Prizes as Incentive Mechanisms in Britain and the United States, 1750-1930" in Dora L. Costa and Naomi R. Lamoreaux (eds), Understanding Long-Run Economic Growth: Geography, Institutions, and the Knowledge Economy, NBER and University of Chicago (2011): 205-234. The British sample of over 400 inventors and several thousand inventions 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.
[78] An extensive survey in Britain concluded that presenters were concerned about "the indiscriminate manner in which awards are often bestowed" (Great Britain, Board of Trade, Report of the Committee appointed by the Board

inventor would receive a prize shows that patentees were more likely to get prizes, so the incremental incentive effects of an additional prize were likely quite low. The grants of prizes to British great inventors owed in part to their personal connections rather than to factors that might have enhanced the technical value of the discovery. The most significant variable affecting the award of a prize was an elite or Oxbridge education, which doubled the likelihood of such winning recognition, despite the contemporary hostility of such institutions to pragmatic studies. At the same time, specialized education or employment in science or technology fields, which might be expected to enhance inventiveness and productivity, did not significantly affect the probability of getting a prize. Such findings are consistent with the growing disillusionment in Europe with prizes as an incentive mechanism for generating innovation.

A number of empirical studies have been based on samples of prizes and exhibits at international fairs, as a means of gauging the relationship of prizes and patents to overall inventive activity.[79] Such studies offer valuable insights; however, counts of the prize entries at international exhibitions are unlikely to be representative of the inventive capital either within or across individual industries or countries.[80] In the first place, the size and content for displays for

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of Trade to make enquiries with reference to the participation of Great Britain in great international exhibitions, Exhibitions Branch, London: Wyman and Sons, 1907, p. 3.) See, also, "The recent disclosures of the underhand dealing which had been found to be present at certain exhibition awards could not be but a powerful factor in the consideration of the worth or worthlessness of such awards…" The Electrical Engineer, Volume 6 (August 8) 1890, London: Biggs & Company, 1890, p. 116. On Nobel prizes, see S.Sri Kantha, "The question of nepotism in the award of Nobel prizes," Medical Hypotheses, 34 (1) 1991: 28-32. "Could science history be compiled on the basis of the Nobel prizes? I think not," is the view of István Hargittai, The Road to Stockholm: Nobel Prizes, Science, and Scientists, Oxford/New York: Oxford University Press, 2002, p. 247. See also Herbetz Claus and Dirk Sliwka, "When higher prizes lead to lower efforts—The impact of favoritism in tournaments," Economics Letters, 120 (2) 2013: 188-191, suggesting that perceived favoritism may tend to reduce effort.

[79] Such studies are summarized in Petra Moser, "Patents and Innovation – Evidence from Economic History," Journal of Economic Perspectives, 27 (1) 2013: 23–44.

[80] Since many of the exhibitors tended to be firms, agents or commercializers, rather than inventors, it is impossible to accurately determine which items had been patented. Contemporary observers noted that a number of the entries at the Crystal Palace were actually copies of articles invented and patented in the United States. Crystal Palace Juries were instructed to "reward an important Machine without undertaking to pronounce whether the novelties exhibited in its construction have been originated by the Exhibitor, or have been borrowed or adapted by him from some one else." (Official Catalogue of the Great Exhibition of the Works of Industry of All Nations, Reports by the Juries, p. xxv.) According to the rules, exhibits did not have to be new and some were several decades old, and

any group of products or country were determined in part by distance and political expedience, rather representing random draws from the underlying population of inventions.[81] As Table 3 indicates, at the 1851 Crystal Palace event, Britain and its dependents accounted for 7,381 or 53 percent of all exhibitors, in comparison to 12 exhibitors from the entire continent of South America, 12.3 percent from France, and 499 or 3.6 percent from the United States. At the Paris Universal Exhibition of 1855, by way of contrast, France and its dependents now comprised 50.1 percent of all 21,779 exhibitors, while Britain and its colonies were a mere 15 percent, and the United States, at 0.6 percent, was the same size as the Greek contingent.

Even if the "home court advantage" is accounted for, there were significant differences in participation within and across industries and countries that were uncorrelated with technological capability. For instance, the funding for the exhibitions, as well as variation in costs (travel, insurance, and other expenses), influenced the number and composition of the displays. Some financing derived from private initiative, while others were funded by national governments, and this variation occurred across products and countries at any specific event, as well as across time.[82] Exhibitors tended to be export-oriented firms seeking customers, and were not necessarily representative of the population of inventors or inventions. Their presence was affected by the conditions for the market for their specific products at home, relative to their

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without a time-limited test of novelty, counts of exhibits cannot be usefully compared across industries, countries or fairs. Instead, juries were instructed to give prizes for criteria that had little or nothing to do with technological inventiveness or patentability, such as beauty of design and appearance, "adaptability to use, economy in first cost, durability, economy of maintenance, excellency [sic] of workmanship, strength." The percentage of prizes by country tended to be proportionate to the exhibitors rather than to technological value, and above fifty percent of exhibits typically received recognition of one sort or another. Many of the Judges were chosen because of their personal prestige rather than because they were familiar with the latest technologies and, even if qualified, political issues, differences in language and personal preferences complicated the already opaque decision-making process.

[81] B. Zorina Khan, "Trolls and Other Patent Inventions: Economic History and the Patent Controversy in the Twenty-First Century," George Mason Law Review, vol. 21 (2014): 825-863.

[82] The United States was in the middle of a war at the time of the Paris Universal Exhibition of 1862, and Congress allowed only $2,000, so just 128 Americans participated among the total of 26,348 exhibitors, whereas the U.S. government allocated more than $1.4 million to the Paris exhibition of 1900, which obviously boosted participation. The French government was typically generous in supporting participation at all international exhibitions, relative to other countries, especially in certain industries which it considered politically expedient.

expected gains overseas.[83] The prize entries reflected this commercial orientation, and numerous items on display were not patentable or even innovations; many comprised agricultural produce, interesting specimens of minerals and taxidermy, embroidery, and final goods that illustrated good workmanship or attractive design elements rather than innovation.[84] Moreover, the award of prizes tended to be proportional to the number of exhibitors and did not necessarily proxy inventive quality or quantity.

One way to control for some of the biases of samples drawn from prize-granting events at the international or national levels is to consider within-city variation. 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.[85] However, innovation institutions sponsored industrial fairs in most large cities in the United States, on a roughly annual basis, which attracted a majority of entries from nearby areas. These exhibitions were sampled to construct a panel data set of technological innovations that were submitted for prizes, comprising some 20,000 entries from major cities, including Boston, New York, Philadelphia, San Francisco, Cincinnati, St. Louis, Raleigh (North Carolina), Charleston (South Carolina), and

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[83] See Great Britain, Board of Trade, Exhibitions Branch, London: Wyman and Sons, 1907, p. 3:
"an exhibition which may offer special advantages as an advertisement for one trade may prove to be of little or no value to another, owing to the highly developed state of that industry in the country in which the exhibition is held. Thus a manufacturer of agricultural machinery, who could expect but little profit from exhibiting his goods at an Exhibition in the United States of America, might derive benefit through showing them in Russia, and a maker of aniline dyes, who might be reluctant, for the same reason, to exhibit his products at Berlin, might be willing to show them at, St. Louis or Chicago."

[84] Representative entries for Switzerland, for instance, included machines, but also various paintings, "a double American rifle," gemstones, lace, fringed shawls, miniature milk tubs, goat skins, cow bells, embossed drinking cups, wood carvings, and a watch-stand "made by a pupil of the Asylum for the Blind." An examination of Swiss entries at international exhibitions indicates that many prizes were awarded for workmanship and design rather than new inventive ideas. This is confirmed by contemporary observers, "The novelties [chronometers] were improved designs rather than new movements," B.P. Johnson, Report on the International Exhibition of industry and Art, London, 1862, (1863), p. 74.

[85] For instance, the John Scott Medal and premium was funded by a legacy from the London pharmacist, who bequeathed $4000 in 1815 for "premiums to ingenious men or women who make useful inventions." Awards and honours from foreign governments and institutions were liberally bestowed on famous American patentees such as Thomas Edison, Samuel Colt, and Sir Hiram Maxim (the first American to be knighted by the Queen of England).

Atlanta, over the course of the nineteenth century.[86] These individual-level observations were matched with the patent records to identify the inventions that were patented. The matched data were then linked with the manuscript population censuses, to obtain information on the backgrounds of individual inventors, such as occupation, age, wealth and geographical mobility. The subsequent analysis at the level of individual innovations and inventors was conducted separately by city, as opposed to a higher level of regional aggregation, and the revealed consistency in the results across cities lends some confidence in the generality of the patterns.

As shown before, observers of the U.S. patent system in the nineteenth century noted that almost everything that could be patented was patented, and the data on the propensity to patent for American "great inventors" support these claims.[87] At the same time, it is also true that a considerable and diverse amount of creativity was indeed occurring outside the formal patent system, and we can speculate why such items were not patented. First, some might argue that such inventors actively rejected the patent option, and instead decided to appropriate returns through other means such as trade secrecy. However, secrecy seems somewhat implausible as a general explanation for data based on prize competitions, since it is unlikely that secrecy would be promoted by participating in a public exhibition. Second, if inventors rationally compare the costs to the benefits of patent protection, and decide to forego patenting, it is possible that a number of these unpatented inventions were of minimal technical or economic value. Third, many exhibits at prize competitions were simply not eligible to be considered for a patent, either

[86] For a description of two of these samples, see B. Zorina Khan, Inventing in the Shadow of the Patent System: Evidence from 19th-Century Patents and Prizes for Technological Innovation, NBER Working Paper No. w20731, December 2014; and B. Zorina Khan, Of Time and Space: A Spatial Analysis of Knowledge Spillovers among Patented and Unpatented Innovations, NBER Working Paper No. w20732, December 2014.

[87] A lobbyist for changes in patent laws noted with disgust that "Every lady is enveloped in patents, from the crown of her head to the soles of her feet" and pointed to the numerous "patented inventions with which the kitchen of every family is infested." See Pamphlets, Patents: "The Patent Laws," 1846-1879, Volume 1 (1879): 3-21, p. 9.

because they lacked novelty, or because the innovation fell outside the subject matter that could be patented.[88]

The stated objective of such industrial exhibitions was to advance the standing of innovative workers and artisans. Nevertheless, participants in these events were drawn from markedly more prominent socioeconomic backgrounds than the general population of patentees.[89] Indeed, the information on occupations show that exhibitors were significantly less likely to be artisans and ordinary labourers than were patentees, and the representation of artisans at the exhibitions also declined over time. Occupational class does not directly translate into economic or social status or influence, but the information on wealth-holding from the population censuses of 1850, 1860 and 1870 provides additional evidence on the economic status of exhibitors relative to patentees in general. These data confirm Samuel Sidney's finding, since the participants in the exhibitions were substantially wealthier than the general population and the population of patentees.[90] For instance, in 1860 the sample from the industrial fairs owned average personal property that was almost twice as extensive as that of patentees in general, and more than double their average real estate holdings.

Patents must satisfy specific rules and standards that are outlined in the laws; applications are examined through an objective rule-based centralized process; and applicants have the right to appeal the decisions of examiners. None of these criteria was true of prizes, and leads to the

[88] Patent examiners in the United States have the task of filtering applications for novelty and for conformity with the rules and standards of the Patent Office and the patent laws. The descriptions for the vast majority of exhibits tend to be quite vague and, without detailed specialized knowledge about each exhibit, it is impossible to determine the amount of novel inventive capital vested in unpatented exhibits. However, it is straightforward to categorize the patentability of each item in terms of subject matter. Application of this minimal filter of subject matter indicates that prize-oriented exhibits were typically quite different from patents and, indeed, the majority of exhibits that were not patented were actually unpatentable.

[89] B. Zorina Khan, "The Social and Economic Consequences of Patent Institutions and Prizes in Technology Markets," in D. Halbert and W. Gallagher (eds), Law and Society Perspectives on Intellectual Property, Cambridge: Cambridge University Press (forthcoming 2015).

[90] See, for instance, B. Zorina Khan, Inventing in the Shadow of the Patent System: Evidence from 19th-Century Patents and Prizes for Technological Innovation, NBER Working Paper No. w20731, December 2014.

key question of what determined whether an entrant received a prize or not. The statistical analysis of separate datasets, including prizes and awards to great inventors in Britain, and to great inventors in the United States, exhibitions of the Massachusetts Mechanics Institute, and the American Institute of New York, are all consistent. These studies indicate that, unlike patents, almost all of the variation in prize awards remains unexplained, implying that these grants were based on fairly random and unsystematic rationales.[91] The multivariate regression results from the industrial exhibitions show that the most significant factor that influenced outcomes was financial status: exhibitors with greater personal wealth were more likely to win gold and silver medals. However, the mechanism through which wealthier exhibitors gained an edge over their competition is unclear. Advantages for wealthy applicants may have been associated with greater expenditures on their presentation at the fairs, name recognition, or perhaps to less obvious connections with the award juries. It is also possible that the individual's wealth was correlated with unobserved variation in the ownership of businesses.[92] In general, the results indicate that the awards reflected characteristics of the inventor, rather than characteristics of the invention.

The judges for these technology classes in the industrial exhibitions stated their objective was to reward novelty and inventive ingenuity. In practice, they bestowed medals for an array of other reasons besides inventiveness, including overcoming adversity (such as age or physical handicaps), cheapness of the item, neatness, and aesthethic factors.[93] In addition, as in the European institutions, a nationalistic orientation towards import substitution was evident when

[91] B. Zorina Khan, Inventing in the Shadow of the Patent System, op cit.
[92] A panel study of national industrial exhibitions in France shows that women who were associated with family firms experienced more success at these events. B. Zorina Khan, Invisible Women: Entrepreneurship, Innovation and Family Firms in France during Early Industrialization, NBER Working Paper w20854, January 2015.
[93] Some contemporary assessments in the United States similarly refer to the process as "invidious"("Awards at Exhibitions," Electrical Review, 1885.); as well as "impractical and liable to the grossest abuse… special systems , where favors are sought for and obtained by particular parties in a particular manner" (Scientific American, March 1852, vol 7, p. 221.)

awards were given to the producers of American goods that attempted to replicate innovations originally created in foreign countries. The decentralization of judging committees, the lack of transparency and the private nature of their decision making process, and the absence of appeal from their rulings, all encouraged idiosyncratic and inconsistent decisions.[94] It is thus not surprising that observers continually criticized the arbitrary way in which the awards were given out, at domestic and international fairs alike. This mattered, because a lack of systematic methods of allocating awards reduced the incentives for inventors who realized that prizes in many instances were uncorrelated with inventive merit.

Research has also been directed towards the assessment of positive spillovers (benefits that ensue to others besides the parties directly involved in an activity) from inventive activity.[95] Scholars typically contrast patents as monopolies (that offer the right to exclude) to prizes (assumed to offer free access to ideas) and hypothesize that the latter are likely to confer a greater benefit on society. This focus on the patentee's right to exclude risks underestimating the effects of the corresponding obligation to disclose. The usual justification for offering patent protection proposes a bargain or a social contract by means of which inventors obtain a temporary monopoly in their discoveries, in return for disclosing their ideas in sufficient detail

[94] Numerous research papers find such biases in a diverse array of review contexts. See for instance, D. Ginther, et al., "Race, Ethnicity, and NIH Research Awards," Science, 333 (6045) 2011:1015-1019, (in response to which the NIH proposes to offer prizes for solutions to avoid such biases!); Tom Coupé, "Peer review versus citations – An analysis of best paper prizes," Research Policy, Volume 42 (1) 2013: 295-301, finds that winners of prizes for academic articles are rarely the best papers as gauged by citations; Jordi Blanes i Vidal and Clare Leaver, "Bias in Open Peer-Review: Evidence from the English Superior Courts," Journal of Law, Economics and Organization, forthcoming 2015.

[95] B. Zorina Khan, Of Time and Space: A Spatial Analysis of Knowledge Spillovers among Patented and Unpatented Innovations, NBER Working Paper No. w20732, December 2014. For related studies, see Petra Moser, "Do Patents Weaken the Localization of Innovations? Evidence from World's Fairs, 1851-1915," Journal of Economic History, 71 (2) 2011:363-382; Ralf Richter and Jochen Streb, "Catching-Up and Falling Behind: Knowledge Spillover from American to German Machine Toolmakers," Journal of Economic History, 71 (4) 2011:1006-1031; Dhanoos Sutthiphisal and Shih-Tse Lo, "Crossover Inventions and Knowledge Diffusion of General Purpose Technologies: Evidence from the Electrical Technology," Journal of Economic History, 70 (3) 2010:744-764.

that the invention can be recreated by someone who is skilled in the arts.[96] However, this is not necessarily the case in practice; for instance, in Britain and France, ineffective rules about specifications, and limited access to patented information owing to high transactions and monetary costs, meant that the disclosure mechanisms were quite weak.[97] Trade secrets or prizes, on the other hand, might impose a social cost if the information is not made available to others in a usable format despite its low incremental cost. On net, both theory and practice are unclear about whether unpatented ideas would tend to generate knowledge spillovers, or to inhibit them.

Patents and prize-winning innovations at the U.S. industrial exhibitions differed in many regards, including the propensity to create external benefits beyond those accruing to the inventors themselves. Prizes were less systematic, were not significantly associated with location and geography, and did not generate geographical and technological spillovers. Spatial autocorrelation analysis of patents and prizes revealed that patents led to spillovers that significantly increased both patented and unpatented innovations in nearby counties.[98] This is consistent with the bargain or contract view of patents, which proposes that the limited grant of a monopoly right to inventors benefits society, because in exchange the public gains information about the discovery that increases social welfare. From the earliest years of the patent system,

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[96] A nineteenth-century observer noted that "the assertion that the patent-system interferes injuriously with intellectual progress by blocking the course of thought is curiously at variance with the evidence of history." See James Richardson, Our Patent System and What We Owe to It, Scribner's Monthly, Nov. 1878, p. 103.

[97] B. Zorina Khan, The Democratization of Invention: Patents and Copyrights in American Economic Development. NBER and Cambridge University Press, 2005. Tom Nicholas's interesting study of Japan during the Meiji era finds that nonmonetary prizes increased patents, created large spillovers of technical knowledge, and enhanced the diffusion of information. Such results may owe to poor measures by the patent authorities to ensure disclosure, effective efforts by prize-grantors to disseminate information, or both. Tom Nicholas, "Hybrid Innovation in Meiji Japan," International Economic Review, 54 (2) 2013:575-600.

[98] B. Zorina Khan, Of Time and Space: A Spatial Analysis of Knowledge Spillovers among Patented and Unpatented Innovations, NBER Working Paper No. w20732, December 2014. Spatial autocorrelation exists when the values of a variable comprise a function of its location and spatial characteristics that are defined in terms of a specific measure of distance. See Luc Anselin, Spatial econometrics: methods and models, Springer, 1988.

policy makers engaged in discussions about how to ensure that information was available to the broader public. The patent grant requires a specification that is sufficiently detailed to enable a person who is skilled in the arts to recreate the patented invention. Patent legislation included measures to publish information about patents that were granted in annual reports that were widely disseminated, and expired patents were published in newspapers, while the U.S. Patent Office maintained local depositories throughout the country. Thus, even if the patentee had acquired a monopoly for (at that time) fourteen to seventeen years, access to the information about the discovery likely facilitated inventions that worked around the initial patent, or led to ideas for follow-on inventions.

By way of contrast, the patterns for prizes were inconsistent with the presence of technological spillovers. Thus, access to technological exhibits did not generate as much diffusion of information as was the case for inventions that were protected by patent grants. Exhibits sponsored by the American Institute of New York or the Cincinnati Mechanics' Association might have been open to the public, and some inventors might have been able to copy from the displays, but there was likely a selection effect that influenced the owners of valuable inventions that were readily duplicable to avoid displaying them at fairs. Moreover, if competitors did not attend the events, there were relatively few effective mechanisms that might have led to the spread of unpatented information embodied in prize-winning innovations. This was of course a function of the decentralized nature of the prize system in industrial exhibitions, but even in European countries that offered centralized institutions such as the Royal Society of Arts, access to unpatented inventions and knowledge about them was quite limited.

Awards and prizes undoubtedly facilitated the efforts of businesses to advertise and commercialize their innovations. Manufacturers at many exhibitions had the choice of monetary

awards rather than medals of equivalent value, but typically opted to reject the cash, choosing instead to accumulate medals from numerous fairs, and touting their success in magazines, journals and on product packaging. Medals may have proven useful in competitive markets as a means of product differentiation, and as a way of signaling higher quality or brand-name capital, although this function became less relevant with the advent of mass advertising and trademarking.[99] Some scholars propose that such ex post prizes at exhibitions stimulated new inventions because they generated publicity for promising areas of endeavor.[100] Even if a prize system were successful in generating new inventions, it would also be necessary to ensure that additional incentives were provided to effectively manage the unpredictable and often lengthy processes required to transform an idea into a commercially viable product. In short, the jury is still out on the question of whether prizes served to induce inventive activity and productivity gains, and the subject remains an important topic for future research.

IV. CONCLUSION

Today both developed and developing societies have a vital interest in determining the optimal policies towards technological innovation, including the nature and consequences of different rules and standards. At the same time, as Harold Demsetz pointed out, "much public policy economics implicitly presents the relevant choice as between an ideal norm and an existing

[99] According to testimony to the British Parliament, "Considerable progress has been made of recent years in the art of advertising, and the advertisement afforded by displaying goods at an International Exhibition is consequently regarded by many as being of less importance than formerly" (p. 3). Moreover, "when a business is young you reap very great advantage in bringing it before the public through the medium of exhibition; but when a business is well established like ours is I do not think you do reap so much advantage." See Great Britain, Board of Trade, Report of the Committee appointed by the Board of trade to make enquiries with reference to the participation of Great Britain in great international exhibitions, Exhibitions Branch, London: Wyman and Sons, 1907.

[100] Petra Moser and Tom Nicholas, for example, find that prizes at the Crystal Palace Exhibition offered publicity that significantly enhanced technological progress, in "Prizes, Publicity, and Patents – Non-Monetary Awards as a Mechanism to Encourage Innovation," Journal of Industrial Economics, 2013 Volume 61: pp. 763–788. This mechanism is plausible, and suggests that future work is needed that attempts to control for unobserved variation in all the other private and public sources of information that were simultaneously available to inventors, including patent documents, on-the-job insights, technical supply factors, and the pressures of market demand.

"imperfect" institutional arrangement. This nirvana approach differs considerably from a comparative institution approach in which the relevant choice is between alternative real institutional arrangements."[101] What lessons does the evidence from the past about "real institutional arrangements" offer for designing an effective mechanism to create incentives for new and useful forms of technological creativity? Any answer to this question is obviously speculative, since it requires an accurate assessment of the characteristics of prize systems that are inherent to this institution, relative to discretionary features that can be adjusted through careful and conscious design of specific instruments. However, historical evidence presents a valuable opportunity for exploring key features of this debate.

The framers of U.S. policies were aware of the options that had prevailed in the colonial period and in Europe, but rejected the use of "premiums" in favour of property rights in patents.[102] The patent system was market-oriented, offered open access to creative individuals regardless of their social status and background, enabled strong enforcement of such rights, ensured useful disclosure, and promoted extensive markets for technology. The empirical evidence on the early patent system in the United States suggests that patents and their effective legal enforcement played a substantial role in influencing the rate and direction of inventive activity in a country that would become the world's leading industrial nation. Patent institutions were not perfect but, as Demsetz points out, their imperfections did not necessarily imply the

[101] Harold Demsetz, "Information and efficiency: Another viewpoint," Journal of Law and Economics, 12 (1) 1969: 1–22, p.1 (emphasis removed).
[102] The use of prizes and bounties was common in the colonial period, and the Continental Congress in 1783 "recommended to the Legislatures of the several states to … encourage the establishment of useful manufactures either by premiums or by such other means as they may find most effectual." See B. Zorina Khan, "Looking Backward: Founding Choices in Innovation and Intellectual Property Protection," in Douglas Irwin and Richard Sylla (eds), Founding Choices: American Economic Policy in the 1790s, NBER and University of Chicago (2010): 315-342.

superiority of any other system.[103] Perhaps the most telling evidence comprises the endogenous diffusion and adoption of the distinctive U.S. rules and standards towards property rights in patents by other countries who wished to emulate its industrial achievements,.

Whereas, the majority of organizations that had specialized in granting prizes for industrial innovations ultimately became disillusioned with this policy, and the practice of bestowing technology awards declined among both private and public institutions. As observers noted in the nineteenth century, industrial prizes faltered in part because of their lack of market-orientation, and even the democratic nature of economic institutions in the United States could not overcome such drawbacks in administered prize systems.[104] Judges had to combine technical and industry-specific knowledge with impartiality, but even the most competent personnel could not ensure consistency; decision-making among panels was complicated by differences in standards, interpretation, capture, and risk-aversion. Such difficulties tended to lead to haphazard decisions, or were often overcome by simply making the award to the person or the firm with the most established reputation. Juries were not immune to the effects of outright bias, capture, cognitive dissonance, lobbying, and "marketing."[105] Prizes tended to offer private benefits to both the proposer and the winner, largely because they served as valuable advertisements, with few geographical spillovers. Winners of such awards were generally unrepresentative of the most significant innovations, in part because the market value of useful

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[103] "Not that the system as developed in this country or anywhere else is perfect; no one claims that; but it is infinitely better than any substitute for it that has ever been proposed," James Richardson, "Our Patent System and What We Owe to It, " Century Magazine,1878.

[104] Adam Smith had early on noted that "pecuniary rewards for the inventors of new machines … would hardly ever be so precisely proportioned to the merit of the invention" as in the case of patents, where "if the invention be good and such as is profitable to mankind, he will probably make a fortune of it; but if it be of no value he also will reap no benefit." Smith, Adam, Lectures On Jurisprudence, Meek, R. L. et al. (eds), vol. V, Glasgow Edition, Indianapolis: Liberty Fund, 1982, p. 103.

[105] When the Nobel Prize was awarded to two cliometricians, William Parker noted that the event held a "lesson in marketing" for business historians. SeeWilliam N. Parker, "A "New" Business History? A Commentary on the 1993 Nobel Prize in Economics," The Business History Review, 67 (4) 1993: 623-636.

inventions would typically be far greater than any prize that could be offered by private or state initiative. Even prestigious and well-funded institutions such as the Royal Society of Arts failed to develop truly valuable inventions.

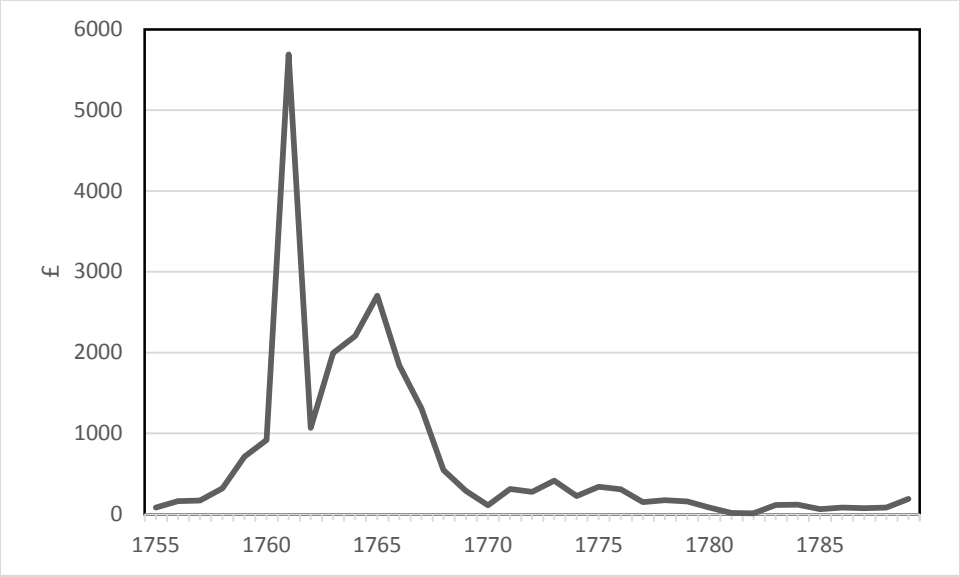
A systematic assessment of the role of incentives for innovation in the nineteenth century therefore highlights the advantages of market-oriented policies which economize on information, especially in the decentralized determination of price, value, and "winners." Market mechanisms also bypassed many of the high transactions costs attendant on negotiating, monitoring, and contracting with applicants and winners. This is not to say that administered inducements are never effective, especially in the context of such market failure as in the provision of medicines or vaccines characterized by significant gaps between private and social returns. However, in distinguishing between the numerous ingenious theoretical mechanisms that have been proposed, such transactions costs need to be recognized and incorporated. In particular, governance issues and the potential for rent-seeking and corruption should be explicitly addressed, especially in the context of countries where complementary institutions and political control mechanisms are weak or nonexistent. In any event, history indicates that the evolution of the institution of innovation prizes over the past three centuries serves as a cautionary tale rather than as a success story. As such, significantly more research needs to be completed before we can conclude that such awards should be re-introduced in the twenty-first century as a preferred means of promoting technological change and economic progress.

Table 1: Awards of the French Society for the Encouragement of National Industry, 1802-1851
(French Francs)

	Prizes	%	Medals and Other	%	TOTAL	%
Agriculture	28600	12.3	21980	8.3	50580	10.1
Beaux-Arts	16100	6.9	32040	12.1	48140	9.7
Boats	11000	4.7	8935	3.4	19935	4.0
Ceramics	34700	14.9	28810	10.8	63510	12.7
Chemical products	6600	2.8	2480	0.9	9080	1.8
Clocks and opticals	0	0.0	8575	3.2	8575	1.7
Domestic economy	1200	0.5	1000	0.4	2200	0.4
Dyes	0	0.0	3990	1.5	3990	0.8
Foods	8500	3.6	9150	3.4	17650	3.5
Forges	0	0.0	11050	4.2	11050	2.2
Hats and Shoes	4000	1.7	3930	1.5	7930	1.6
Heat and Light	9000	3.9	9670	3.6	18670	3.7
Legacies	0	0.0	16613	6.3	16613	3.3
Locomotives	0	0.0	6185	2.3	6185	1.2
Machine tools	8500	3.6	23350	8.8	31850	6.4
Metals	22000	9.4	11180	4.2	33180	6.7
Music	2000	0.9	4495	1.7	6495	1.3
Orthopedics	1000	0.4	5315	2.0	6315	1.3
Paper	5000	2.1	3030	1.1	8030	1.6
Political economy	0	0.0	1500	0.6	1500	0.3
Prize Argenteuil	24000	10.3	0	0.0	24000	4.8
Steam engines	17500	7.5	15900	6.0	33400	6.7
Sugar	21700	9.3	6620	2.5	28320	5.7
Weapons	0	0.0	795	0.3	795	0.2
Weaving	11800	5.1	27665	10.4	39465	7.9
Wines	0	0.0	1280	0.5	1280	0.3
Total	233200	100	265538	100.0	498738	100

Source: Annuaire de la Societe d'Encouragement pour L'industrie Nationale, Paris, 1852.

Figure 1: Premiums (£) Bestowed by the Royal Society of Arts, 1755-1790



Source: Summary Abstracts of the Rewards Bestowed by the Society, 1754-1782, London: Royal Society of Arts, 1806; and Annual Transactions of the Royal Society of Arts, London, various years.

Table 2: Royal Society of Arts Payments (£), by Sector, 1754-1782

	Prizes	Medals	TOTAL	%
Agriculture	3281	596	3876.9	13.7
Chemistry	1391	25	1415.9	5.0
Colonies	2786	103	2888.9	10.2
Manufacturing	2058	11	2069.2	7.3
Mechanics	2453	80	2532.6	9.0
Polite Arts	8596	588	9184.3	32.5
Miscellaneous	6141	132	6273.3	22.2

Source: Summary Abstracts of the Rewards Bestowed by the Society, 1754-1782, London: Royal Society of Arts, 1806. The categories correspond to the titles of the Committees that administered the awards.

Table 3: Exhibitors at International Exhibitions in 1851 and 1855, by Country

Exhibitors at Crystal Palace Exhibition, 1851

	Number	Percent
Austria	731	5.2
Belgium	506	3.6
Britain & Colonies	7381	53.0
China	30	0.2
France	1710	12.3
Germany	1536	11.0
Netherlands	113	0.8
Others	870	6.2
South America	12	0.1
Spain	286	2.1
Switzerland	263	1.9
United States	499	3.6
Total	13937	100.0

Exhibitors at Paris Universal Exposition, 1855

	Number	Percent
Austria	1298	6.0
Belgium	687	3.2
Britain & Colonies	3269	15.0
China	0	0.0
France & Colonies	10914	50.1
Germany	2198	10.1
Netherlands	411	1.9
Portugal	443	2.0
South America	38	0.2
Spain	569	2.6
Switzerland	408	1.9
United States	131	0.6
Greece	131	0.6
Others	1282	5.9
Total	21779	100.0

Source: Official Catalogue of the Great Exhibition of the Works of Industry of All Nations, 1851, London: Spicer Brothers, 1852; Paris Universal Exhibition of 1867: Catalogue of the British Section, London, 1867; Reports of the Commissioners of the United States to the International Exhibition held at Vienna, edited by Robert H. Thurston, 1876.