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What do Inventors Patent?*

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Recent debates on patent policies have been dominated by the lobbying efforts of sectoral interest groups, typically with opposing attitudes towards strong patent rights. Differences in policy demands across industries suggest that the way in which patents protect inventors varies across industries. This paper uses a unique, economy-wide historical data set on more than seven thousand British and American innovations at the Crystal Palace World's Fair of 1851 and at the American Centennial Exhibition in Philadelphia in 1876 to examine the patenting behavior of inventors across industries, across countries, and over time. Such data indicate that inventors' propensity to patent varies strongly across industries but not across countries. In 1851, patenting rates, calculated as the share of innovations that are patented, ranged from five percent in chemicals to more than twenty percent in machinery. Differences across industries are almost identical for the British and American data, despite substantial differences in the patent laws of these countries. Innovations of high-quality show similar differences in the propensity to patent across industries. These results suggest that differences in the nature of technologies across industries may play a more important role in determining the patenting decisions of inventors than differences in patent laws.

Beginning in the 1880s, surveys have suggested that inventors' attitudes towards patenting vary across industries. In 1883, a survey of 100 Swiss firms revealed a strong opposition of dyers to the introduction of patent laws, while members of the mechanical trades expressed a strong desire to see such laws in place. Surveys of more than 100 manufacturing firms of publicly traded American firms in 1983 and 1,478 U.S. research labs in 1994 found that chemical and pharmaceutical firms considered patenting to be the most effective mechanism to protect intellectual property, whereas firms in all other industries considered alternative

mechanisms to be more effective (Richard C. Levin, Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter 1987, Wesley M. Cohen, Richard R. Nelson, and John P. Walsh 2000, p.10).

Data on innovations at the Crystal Palace Exhibition make it possible to test how such differences in attitudes translate into the patenting decisions of inventors. Exhibition data cover the entire range of industries, from mining and chemicals, to metallurgy, manufacturing machinery, and textiles, and other manufactures, such as glass. They include important innovations, such as engines, that had to be excluded from patent data, because patent data are classified by function, and such innovations cannot be assigned to a specific industry. Exhibition data enable cross-country comparisons; exhibits are selected according to identical criteria of “novelty and usefulness” across countries, and international juries enforce these selection criteria at the fair. Jurors assign prizes to the best inventions, and these awards provide a relatively straightforward measure for quality. Such measures have proven extremely difficult to construct from patent data. Most importantly, exhibition data include innovations with and without patents, which allows me to compare the share of innovations that are patented across industries, across countries, and across different levels of quality.¹

A typical entry in the exhibition catalogues begins with the inventor’s name, address, and country of origin, followed by a brief description of the innovation, as well as some information about the exhibitor’s occupation and the innovation’s state of patent protection. From these records, I have constructed data for all 6,377 British and all 569 American innovations at the Crystal Palace exhibition 1851. Contemporary records confirm that exhibition data are a useful measure of innovation. The reports of several national committees illustrate that national

¹ Although the terms innovation and invention are used interchangeably innovation — the commercial introduction of new or improved products and processes — is distinct from invention—the conception of such products and processes. Exhibition data measure innovations, whereas patents count inventions, or more precisely, those inventions which inventors chose to patent.

committees selected their most innovative products to be exhibited at the fairs. Participation was competitive; a uniform system of selection admitted less than one third of all applicants to exhibit at the fairs. Most importantly, exhibition data measure innovation independently from differences in domestic patent laws. Exhibitors displayed innovations regardless of whether they could be patented at home, including many inventions that they had chosen not to patent.

I use two different methods to identify innovations that are patented. For Britain's innovations, the descriptions in the catalogues include references to patents. Patenting rates are constructed by dividing the number of exhibits with references to patents by the total number of exhibits. For American innovations, I construct patenting rates by matching all American exhibitors to with the lists of U.S. patents in the *Annual Reports of the United States Patent Office* between 1841 and 1851. As a cross-check to control for patenting activity after the exhibition, I also match U.S. exhibitors with patents granted between 1851 and 1860.

Data from the Crystal Palace Exhibition on more than six thousand British and American innovations with and without patents make it possible to measure differences in the propensity to patent across industries and across countries. Such data indicate that inventors' propensity to patent varies strongly across industries but not across countries. In Britain one in nine innovations appears to have been patented, compared to one in eight in the United States. The propensity to patent, however, varies strongly across industries in both countries, suggesting significant sectoral differences in the usefulness of patent protection. Patenting rates, calculated as the share of innovations that are patented, range from seven percent in textiles, eight percent in food processing, and less than ten percent in scientific instruments to more than twenty percent in manufacturing machinery, engines, and other types of machinery.

Differences across industries are almost identical for the British and American data, despite the fact that British patenting rates are constructed from references to patents in the exhibition data, while American rates are constructed by matching exhibits with entries in the lists of all patents in the *Annual Reports of the United States Patent Office* between 1841 and 1851. These parallels in patenting behavior are especially remarkable considering the vast differences between the British and the American patent system, at a time when patent applications were 60 times more expensive in Britain than in the United States.

These inter-industry differences in patenting are robust to quality adjustments. For 1,449 British innovations that received awards for inventiveness, the proportion of patent holders is only slightly higher than in the overall population of British innovations: 14.1 percent of British award-winners refer to patents, compared to 11.2 percent of all British innovations. Moreover, the patenting behavior of award-winning innovations corroborates the patterns of cross-industry variations in the overall data. Forty-seven percent of British award-winners in manufacturing machinery and thirty-six percent in agricultural machinery refer to patents, compared to three percent in mining and metallurgy, eight in chemicals, five in food-processing, and seventeen in scientific instruments. Contemporary industry reports, letters from inventors, and government surveys attest to the importance of patenting innovations in machinery, and point towards secrecy as an effective alternative for food processing and scientific instruments.

The remainder of this paper uses data on British and American exhibitors at the Crystal Palace Fair in 1851 to examine the patenting behavior of inventors. Section I presents a simple formalization of the trade-off between secrecy and patenting under different patent systems, and section II describes key differences between the Britain and American patent law. Section III introduces the exhibition data and describes the data's advantages and potential sources of bias.

Section IV presents evidence on differences in patenting rates across industries, countries, and high- versus average-quality innovations. Section V summarizes historical evidence on the use of secrecy and patenting, and section VI concludes.

I. The Choice to Patent

Major characteristics of patent systems, such as patent fees and the maximum duration of patent grants, T , vary across but not within countries. Development costs, which reduce initial returns R_i in industry i , may be generalized to include the costs of patenting, such as patent fees and time spent in researching prior art. Let d_i represent the proportion of returns in industry i that carry over from one period to the next.² Then, the payoff to an innovation in industry i at time t equals $d_i^t R_i$. All industries experience decreasing returns to invention: each inventor picks the most promising project and with every choice the next best available project becomes less valuable.³ For simplicity, assume that the quality of projects declines at the same rate g in all industries. Then the total payoffs to the n_i -th invention in industry i are

$$(1) \quad \sum_{t=0}^{T-1} d_i^t g^{ni-1} R_i = (1-d_i^T)(1-d_i)^{-1} g^{ni-1} R_i$$

Equation (1) includes the implicit assumption that patent protection is the only means to profit from inventions. Its right-hand side makes explicit the common notion that expected profits from invention are zero without patent laws. Inventors compete for the best projects and the number of potential inventors exceeds the number of potential projects, $L_j > N_j$, where N_j represents the maximum number of invention projects in country j . Inventors enter as long as the

² Schankerman and Pakes (1986) define $d_i = (1-\delta_i)^{-1}$ such that δ_i represents the rate of obsolescence and discount future returns by $(1+i)^{-1}$. In this paper $0 < d_i < 1$ may be defined to discount by the interest rate.

³ This assumption follows Machlup (1962) who argues that inventors solve problems with tools available within a given framework of knowledge. Inventors distinguish easy from hard problems and attack easy problems first.

payoffs to invention are positive and entry reduces the maximum returns from invention until they are only slightly greater than patenting costs, C .

Now assume that inventors can also protect their inventions through secrecy. The inventors' choice between patenting and secrecy represents a trade-off between certain protection for a finite period of time (through the patent) and uncertain protection to infinity (through secrecy). Let us define s to be the share of inventions that remain secret after one year and suppose that s equals 1 for patented inventions. Then $(1-s)$ represents the risk of discovery that inventors incur if they choose not to patent their inventions. In period t they receive payoffs $s^t R_i$ without patent protection. By patenting, inventors incur an upfront cost that includes patent fees as well as expenses for researching prior art and writing up the patent. They also incur non-monetary costs through the increased risk of copying after the patent has been published. At that point, competitors lower the payoffs to the original inventor, as they attempt to invent around and invalidate the original patent. To represent these facts, the per-period patenting cost c_{ij} may be allowed to vary with the original costs of patenting, the requirements for disclosing the secret of patented inventions, and with the attitudes of the courts towards protecting the rights of original inventors; c_{ij} is also allowed to vary across industries. Payoffs from secrecy exceed payoffs from patenting if

$$(5) \quad \sum_{t=0}^{T-1} c_{ij}^t d_i^t g^{ni} R_i \leq \sum_{t=0}^{\infty} s_i^t d_i^t g^{ni} R_i$$

Patent length (T) and the costs of patenting (c_{ij}) vary across countries. In industries where the payoffs of inventions are long-lived, and their duration exceeds patent length T , inventors have an added incentive of keeping their invention secret rather than patenting them. This implies that, in countries with long patent grants (T) and low costs of patenting (c_{ij}), a larger

proportion of inventors will choose to patent.⁴ In contrast, inventors in industries where inventions can be kept secret, or where the risks from disclosure are high, are less likely to patent new technologies.

II. Differences in National Patent Laws

In 1851, patent length was 14 years in both Britain and the US. However, other characteristics of these patent systems could not have been more dissimilar.

In England, the letter patents of the commonest article, if so drawn as to protect it through the whole empire, call for an expenditure of something like £350 or \$1,700. In America, the mere nominal outlay of \$50 insures the mechanic of all the virtue there is in the laws.⁵

Translated into 1998 US dollars, this fee was about \$37,000 for a British patent, compared to \$618 for a US patent carried to full term (Lerner 2000). American inventors could send their applications by mail, whereas their British counterparts faced numerous administrative hurdles and more often than not, had to rely on the advice of patent agents to negotiate the cumbersome application process. Even proponents of patent grants, such as Jeremy Bentham, described the inefficient nature of the British system.

A new idea presents itself to some workman or artist... He goes, with a joyful heart, to the public office to ask for his patent. But what does he encounter? Clerks, lawyers, and officers of state, who reap beforehand the fruits of his industry. This privilege is not given, but is, in fact *sold* for from £100 to £200 – sums greater than he ever possessed in his life. He finds himself caught in a snare which the law, or rather extortion which has obtained the force of the law, has spread for the industrious inventor. It is a tax levied upon ingenuity, and no man can set bounds to the value of the services it may have lost to the nation.⁶

⁴ Necessity forces the omission of some other characteristics of patent laws, such as production requirements for maintaining patents or restrictions on patenting by foreigners. See Khan (2002) for thorough descriptions of these criteria.

⁵ The *New York Daily Times*, October 16, 1851, p.2.

⁶ From the *Works of Jeremy Bentham*, cited in Moureen Coulter (1991:76). Along with numerous contemporary accounts, Charles Dickens' story "A Poor Man's Tale of a Patent" illustrate the inefficiency of this process.

Data on innovations at the Crystal Palace makes it possible to examine how these differences in national patent laws influenced inventors' choice to patent.

III. The Data

Exhibition catalogues for the Crystal Palace Exhibition in London in 1851 serve as the main source of data for this study. The Crystal Palace exhibition was the most spectacular event of its century. In 1851, more than six million people, exceeding the combined populations of London, Paris, and Berlin, visited its exhibition grounds. There, 17,062 exhibitors from 25 countries and 15 colonies displayed their innovations at Hyde Park (see *Bericht III*, 1853 p. 674; Kretschmer, 1999 p. 101, Kroker, 1975 p. 146). At its time the Crystal Palace was the largest enclosed space on earth; its exhibition halls covered 772,784 square feet, an area six times that of St. Paul's Cathedral. Exhibition catalogues listed all exhibits and guides visitors through the walkways of the fairs.

A. Description of the Data

A typical entry in the catalogues includes a brief description of the exhibited innovation as well as its owner's name and home location. For example, Britain's exhibit number 32 in the class "agricultural machinery" is described as

32 Bendall, J. Woodbridge, Manu. – A universal self-adjusting cultivator, for skimming, cleaning, pulverizing, or subsoiling land; pat.

I have classified 6,377 British and 549 American entries in *Official Catalogue* according to 30 industry classes, distinguishing innovations with and without patents.

Two different methods are used to measure the proportion of innovations that are patented: British patenting rates are constructed from references to patents in the exhibition data, while American rates are constructed by matching exhibits with entries in the lists of all patents in the *Annual Reports of the United States Patent Office* between 1841 and 1851. In the British data, patented innovations can be identified directly from the exhibition records. Exhibitors added references such as “patented”, or “pat.” to the description of their innovations. For example, the aforementioned exhibitor J. Bendall, listed his patent after the description of his innovation: “A universal self-adjusting cultivator,...; pat.”. I construct a proxy for patenting rates by dividing the number of exhibits with references to patents by the total number of exhibits in each industry class. This would be a perfect measure of patented innovations if exhibitors listed patents if and only if they held patent grants. As an approximation, this assumption seems plausible: exhibitors with patents advertise their patents to raise the value of their innovations.⁷ On the other hand, exhibitors without patents are unlikely to claim patents, because they would be discovered easily.⁸

For the American data, patenting rates are constructed by matching exhibitors at the Crystal Palace with records on U.S. patents between 1841 and 1851. Exhibitors are matched by first and last name, address, and the descriptions of their innovations. For example, the following entries are counted as a match:

US patent No. 4387; Otis, Benjamin H.; Dedham, Mass; Mortising machine; granted Feb. 20, 1846

and

US exhibit 23; Otis, B.H.; Cincinnati, Ohio; Boring and mortising machine

⁷ For example, Christine MacLeod observes that patents raised customer’s valuation of proprietary medicines in early 18th century England (MacLeod 1988, p.85)

⁸ Exhibitors knew that their innovations were subject to intense scrutiny by the international juries, whom they could reasonably expect to check references to patents.

Only unambiguous matches between exhibitors and patentees are included in the patent counts. I construct alternative measures with less restrictive matching rules to perform sensitivity analysis, and keep track of patent numbers for all potential matches.

B. The Process of Selecting and Evaluating Exhibits

A comprehensive system of local commissions and collection points ensured that the best technologies from both rural and urban inventors were presented at the fair. National commissions delegated the authority to select exhibits to local branch commissions. For example, Britain's national commission for the Crystal Palace nominated 65 local commissions to select exhibits.⁹ In their applications to local commissions, potential exhibitors reported "what is novel and important about the product, how its production shows special skillfulness and proves an original approach" (*Bericht*, 1853 pp. 50 and 117). Based on this information, local commissions chose the most promising exhibits, and national commissions then checked their choices, accepting the majority of all suggestions (*Bericht*, 1853 pp. 40 and 64). By requiring that exhibitors cover transportation costs only to local collection points, this system also ensured the representation of all regions.

Comprehensive evaluations and awards to the most innovative exhibits helped to enforce the selection criteria. For each of 30 industry classes, international juries evaluated and ranked all exhibits according to their "novelty and usefulness". Panels were between six and twelve people strong, and membership was divided equally among university professors, representatives of professional organizations, and businessmen. Exhibitors could not opt out of these evaluations. For example, signs such as "Not entered in the competition" were explicitly

⁹ Local commissions typically consisted of two to ten academics and business people, representing the area's main industries (*Bericht*, 1852 pp. 37 and 90.)

prohibited. At the Crystal Palace, 5,438 exhibits received awards (*Bericht III*, 1853 p. 707; Haltern, 1971 p.155). Juries awarded Council Medals as gold medals to the most innovative exhibits, Prize Medals as silver medals to the second-most innovative exhibits, and Honorable Mentions to honor bronze. One percent of all exhibits received Council Medals, the highest honor for inventiveness, 18 percent received Prize Medals, the second-highest honor, and 12 percent received Honorable Mentions. Data on these awards creates a relatively straightforward way to adjust for the quality of innovations.

C. Advantages over Patent Data

Empirical analyses of innovation typically rely on patent data despite the shortcoming of these data. Most importantly, the way in which patent data measure innovation changes with changes in patent laws, and the definition of what constitutes a patentable invention varies considerably across countries. For instance, in the nineteenth-century U.S. only “first and true” inventors were allowed to patent. At the same time, the French patents were granted to the first one to import a new technology (Coryton 1855, pp. 235-264). In the best case, patents measure new ideas that have proven to be feasible at least in theory. But such patents measure a relatively early input in the process of innovation and only a small share of patented inventions ever reach the later stages (Harold I. Dutton 1984, p.6-7, Griliches, 1990 p.1669). For the twentieth century, for example, firm-level surveys have found that only between 5 to 20 percent of patents become economically useful innovations (Meinhardt, 1950 p. 256). In the nineteenth century, utility often was often not even required for a patent grant (Coryton, 1855 pp. 235 and 239). On the other hand, economically useful innovations can originate from sources other than patented inventions, such as learning-by-doing or the type of incremental increases in cumulative

knowledge as described in Scotchmer (1991) and Mokyr (2002). As a further complication, patented inventions are classified by functional principles, and often cannot be assigned to a specific industry of use.¹⁰ Empirical studies based on patent data counts had to exclude important innovations such as power plant inventions, electric motors, or bearings (Schmookler, 1972 p. 89).

Finally, Griliches (1990 p. 1669) observes that patented inventions differ greatly in quality.¹¹ Manuel Trajtenberg (1990) addresses this problem by constructing measures of the value of patented inventions based on the number of succeeding patents that refer to them. However, citation measures may underestimate the quality of innovations if inventors are less likely to patent their inventions in some industries than in others. Exhibition data offer a complement to nineteenth century patent data, which addresses these concerns. Most importantly, exhibition data measure innovations regardless of whether they were patented or not, control for quality, and are comparable across countries.

D. Potential Sources of Bias in the Exhibition Data

There are however potential sources of bias in the exhibition data. Space restrictions and transportation costs appear to be the most important distortions for the number of innovations. At the Crystal Palace, Britain's Central Commission allocated exhibition space according to their subjective perception of a country's relative importance as an innovator. Space restrictions

¹⁰ The functional class "dispensing liquids" includes holy water dispensers along with water pistols, while "dispensing solid" groups tooth paste tubes with manure spreaders (Schmookler, 1972 p. 88).

¹¹ Without an effective system of examining prior art, patents may also vary in their degree of novelty. In 1864 a study for the Royal Commission found that a quarter of recent patents were potentially invalid, because they failed to meet a standard of novelty (John Hewish 2000, p.80). In a study commissioned by the Fry Committee in 1901, 42 percent of 900 British patents were found to have been anticipated by earlier patents (Neil Davenport 1979, p.48) The committee was given examples of identical inventions that had been patented repeatedly in the previous two decades: eight patents for soda water, seven for pneumatic heads on crutches, and fourteen for channels on billiard tables to rerun the balls to the players. (Parliamentary Papers, 1901, XXIII, p.541-2, 632, cited in MacLeod 1988).

appear not to have been too stringent. Visiting countries could request larger allocations or construct additional buildings to house their exhibits. When the United States Commission to the Crystal Palace thought that U.S. exhibitors would be short on space, it asked the British Commission for more room and was granted its request (Haltern, 1971 p.150). Heavy and fragile innovations, which would otherwise have been under-represented due to transportation costs, could be exhibited as models or as blueprints. Of 194 British exhibits in class 7, “Civil Engineering, Architecture, and Building Contrivances”, 88 exhibits, or 45 percent, were represented by models. For example, T. Powell of Monmouthshire, Britain, exhibited a “Model for apparatus used for shipment of coals from boats or waggons (sic) at Cardiff dock”; A. Watney of Llanelly, Wales, exhibited “Models of anthracite blast furnaces.” Among the engineering exhibits there was a model of the suspension bridge that was being constructed across the river Dnieper in Kiev. Robert and Alan Stevenson (grandfather and uncle to Robert Louis Stevenson) displayed models of lighthouses for the Bell Rock and for Skerryvore (see Rolt, 1970 p. 157).

Another potential weakness of the exhibition data is that they may underreport innovations that are easy to copy, if such innovations were not displayed for fear of imitation. Thus, exhibition data may be biased against innovations that are omitted from the patent counts. Contemporary records suggest that this fear of imitation was the most serious concern for exhibitions whose host country did not have patent laws, such as 19th-century Switzerland. Even at Swiss exhibitions, however, only one in hundred exhibits withdrew their applications after legal protection was refused (*Procès-verbal du Congrès Suisse*, 1883 p. 68).¹² Exhibitors may have felt less dependent on legal protection because they found ways to advertise without disclosing the secrets of their innovations. Rather than exhibiting a new piece of machinery, or

¹² Switzerland adopted a rudimentary draft of patent laws in 1888, which Schiff (1971) calls “the most incomplete and selective patent law ever enacted in modern times” (Schiff 1971, p. 93).

describing a new process, inventors often chose to display samples of their final output. For example, Drewsen & Sons of Silkeborg, Jutland, exhibited “Specimens of paper, glazed by a machine constructed by the exhibitor”, instead of the machine itself, which he kept secret (see *Official Catalogue, First Edition*, 1851 p. 210). P. Claussen of London, an inventor and patentee, exhibited “Samples of flax in all its stages, from straw to cloth, prepared by the exhibitor’s process” (*Official Catalogue*, 1851 p. 28). In addition, a system of registration, which was available to all exhibitors, acted as a cheap and fast patent system; at the Crystal Palace only 500 of 13,750 exhibitors took advantage of it (*Bericht III*, 1853 pp. 697-701). If exhibition data undercount innovations that were protected by secrecy they may overstate the share of innovations that are patented and underestimate inter-industry differences in the use of patenting.

IV. Patenting Across Industries and Patent Systems

Proxies for the propensity to patent, calculated from exhibition and patent data, suggest that patenting behavior was remarkably robust to even the most fundamental differences in patent laws. Columns 3 and 4 in table 3 reveal that 11 percent of British exhibits referred to at least one patent, compared to 14 percent of American patents. This difference is small considering the vastly disparate costs of patenting in the US and Britain.

The variability of patenting rates across industries proves equally robust to differences in patent laws. Inventors in both countries were consistently more likely to patent inventions in machinery and less likely to patent inventions in chemicals, food processing, and scientific instruments. Thirty percent of Britain’s exhibits in manufacturing machinery were patented, compared to 47 percent of American exhibits. Thirty-two and 37 percent of American inventors sought patent protection in engines and agricultural machinery, compared to 25 and 20 percent of

British inventors, respectively. High patenting rates in both countries may reflect the fact that 19th century inventions in machinery were easy to reverse-engineer and imitate.

The man of capital, owns, perhaps, a foundry; and by aid of a planning machine, can finish his work much more readily, cheaply and handsomely, than the industrious worker next door, whose narrow finances forbid the purchase of the machine. Were the monopoly removed, he would make one for himself in a week, and so regain the lost advantage.¹³

If such inventions were kept secret, the risk of discovery was high, and inventors would have lost all rights to exclusivity. On the other hand, patents offered a certain level of security, even if reverse-engineering was successful.

In comparison, inventors in resource-intensive industries, such as chemicals and mining and metallurgy were less prone to patent. In mining and metallurgy, only one in twenty British and the same share of American exhibits were patented. In the mid-19th century, improvements in mining and metallurgy, such as new processes of coal extraction or of producing steel, were strongly tied to natural resources. Although unaltered natural resources were excluded to patent protection, process to extract and treat them could be protected under patent grants. However, the dependence on resources may have discouraged patents in two ways. On the one hand, strong ties to resources reduce the risk of copying if such inputs are difficult to obtain and reproduce. On the other hand, resource-specificity reduces the value-added by the right to trade, a major benefit of patent grants. For instance, Britain's exhibit 482 in class 1 (mining and minerals)

482, J. Hunt, Machine for washing poor slimy ores, employed in Brittany

¹³ *New York Daily Times* April 26, 1852, p.2

may not have been patented because it was most useful when applied to “slimy ores”, auspiciously uncommon. With a small number of potential beneficiaries, advertising the innovation by word of mouth or direct contact created larger payoffs than would have an expensive patent.

Chemical inventions experienced similarly low patenting rates, about five percent of British and four of American inventions. Alaun, potash, naphthaline, quinine, caffeine, tannin, and other chemical discoveries continued to be very resource-dependent, and, 18 years before Dimitri Mendelyev published his periodic table in 1869, they proved almost impossible to reverse-engineer. Likewise only eight percent of British and four percent of US innovations in food processing appear to have been patented. Knowledge in both industries was both difficult to codify (and write up in a patent grant) and also, as a logical equivalent, difficult to reverse-engineer. For chemical inventions, Mendelyev’s structuring of the elements changed this property so that chemical innovations are now among the most suitable to patent protection (Cohen, Nelson, and Walsh 2002), but secrecies in food processing remain more suitable to secrecy.

Inventors of scientific instruments were also less likely to patent their inventions, and appear to have opted for alternative protection. Only 10 percent of Britain’s exhibits in scientific instruments were protected under patent grants, compared to less than 15 percent of US exhibits. Optical and medical devices, such as false teeth, metal corset for curing scoliotic spines, marine clocks, thinner and more accurate watches, as well as instruments of physical measurement, such as barometers and theodolites, formed the majority of Britain’s entries. Innovations in instruments depended on specific skills and knowledge of production processes, such as mixing, melting, blowing, and cutting glass. The resulting difficulty of reverse-engineering may have

reduced the risks from secrecy and motivated inventors to shy away from patenting. Upright pianofortes, and other advances in musical instruments, were included in this class as well, and it was the large shares of pianos, patented because of their mechanical nature, which lead to the higher proportion of patents in the American data.

A. Multiple Patents and Strategic Patenting

The gap between the American and British data only widens, if we count every single patent, by the same inventor and for facets of the same invention, as a separate occurrence of a patent grant. (This is how patenting rates per year – total number of annual patents are generally calculated in the literature using patent data.) By this measure, one in four American innovations was patented, still a surprisingly small share (table 1, columns 5 and 6).

No more than a handful of prolific patentees are responsible for this boost to patenting rates. Among them Horace Day of New York, and Charles Goodyear of New Haven, Connecticut, held seven and five patents respectively for their exhibits of India-rubber goods (See table 2 for a list of the most prolific patentees in the exhibition data). Both men litigated passionately. Goodyear alone pursued 32 cases of infringements, and together Goodyear and Day soon began to battle each other over who invented vulcanization (Dragon 1995). In 1852, Samuel Colt, holding five patents to his exhibit, sued the Massachusetts Arms Company, who had produced a revolver under Leavitt's patents (*New York Times*, October 14, 1852, p.6). Colt succeeded in a widely published trial, which helped to discourage competing designs. Later advertisements for the Colt revolver warned: "be aware of patent infringements" (Tower and Belden 1940: 84-86).¹⁴

¹⁴ Another pattern emerges over the life-cycle of inventors. For inventors with multiple patents, one early patent most often constitute the important innovation, followed by numerous later patents on improvements of that same

Contemporaries deplored the deleterious effects of litigation.

Our federal courts are wearied with litigation between the assignees of inventors and the alleged pirates upon their rights. The land is flooded with patent peddlers, for machines, who dispose of territory to uninformed men, of machinery which use has proved useless, and which are impositions upon the public. The Patent examiners should decide upon the value, as well as the originality of an invention; and refuse protection to unimportant improvements. And some statutory prevision should be made to prevent ruinous litigation, to which innocent parties, without notice, are subjected; or what is worse, the exorbitant payments which they are obliged to make to avoid the uncertainties, perplexities and expense of a law suit.¹⁵

In an environment where litigation is the norm, multiple patents may be suggestive of defensive legal strategies as much as innovation. However, seven of twelve exhibits that were connected with more than four patents also received an award for exceptional quality. This suggests that, even under the American system with low patent fees, inventors may be more likely to patent inventions of high quality. The following paragraphs examine this relationship.

B. Patenting and Quality

The quality or size of innovations may be another key factor to influence inventors' patenting decision. The obvious explanation is that inventors choose to patent only those inventions whose value exceeds the costs of patenting. Since these costs were extremely high in Britain, inventions of the highest quality were patented more frequently. In addition, the risk of imitation may be higher for prominent inventions, since outsiders have greater incentives to reverse-engineer or pry the secret from those in the know. I examine the patenting behavior of 1,449 British prize winners at the Crystal Palace to examine the effects of these factors.

invention. This may be consistent with a life cycle story of innovation, that inventors are most creative when they are young and then shift their attention to defend their early ideas. Another interesting fact is that three of nine prolific patentees were foreign born.

¹⁵ The *New York Daily Times*, October 16, 1851, p.2.

Data on awards at all levels (gold, silver and bronze) in the first column of table 2 suggest that differences in patenting rates are robust to differences in quality. Inventors were only slightly more likely to patent innovations of high quality; 14.1 percent of Britain's award-winning innovations at the Crystal Palace referred to patents, compared to 11.2 percent of all exhibits. Data on 75 Council Medal awards, the gold medal at the Crystal Palace, suggest that exhibits of the most exceptional quality may have been patented more frequently. This could be because the most valuable innovations surpassed the threshold of exorbitant patenting costs more easily, or it could be a reflection of the fact that radical innovations attracted much attention, and were thus at a higher risk of imitation without patenting.

Cross-industry comparisons of the awards data corroborate the earlier finding that machinery inventions were predisposed to patenting. Forty-seven percent of British award-winning exhibits in manufacturing machinery and 36 percent of exhibits in agricultural machinery referred to patents. In comparison, inventors patented only 3 percent of innovations in mining, 8 in chemicals, 5 in food processing, and 17 in scientific instruments. Regardless of quality, patent protection appears to have been most important to protect innovations in machinery, and less likely to patent innovations in resource-dependent industries, or industries where innovations can be kept secret. These results are also corroborated by contemporary reports.

V. Contemporary Accounts of Patenting and Secrecy

Nineteenth-century sources confirm that patents were essential to the protection of machinery inventions. In a 19th-century survey of 100 Swiss firms, all representatives of

manufacturing firms expressed support for the introduction of patent laws because they were expected to strengthen innovation in manufacturing machinery and tools.

The Commission that had been sent to America ... after having examined *in situ* the means of production and specifically giving attention to the machine tool industry came to the following conclusion: Among other things we recommend the introduction of a patent system. ...the patent law is a powerful stimulant to the efforts to improve which happened on a daily basis in the factories.¹⁶

At the same time, inventors of chemicals and textile innovations continued to oppose the introduction of such laws.

In the US, key inventions in manufacturing machinery, such as sewing machines, depended heavily on patent protection. Proponents of patent laws focus their arguments on the importance of patent protections in machinery (*New York Times*, Letter to the Editor April 29, 1852). In 1850, it took Isaac Singer less than eleven days to reverse-engineer Lerow & Blodgett's prototype, and then improve it, to create the first dependable sewing machine (Fenster 1994, p.46). Singer's design also incorporated many features of Elias Howe's earlier model, but he did not manage to break Howe's patent (Fenster 1994, p.50, Cooper 1968, p.13). The ability to brandish a patent enabled Elias Howe to charge \$25 in royalties for every sewing machine sold in America. (Fenster 1994, p.50; Cooper 1968, p.42.)

Blodgett's misfortune illustrates that profitable innovations in machinery could rarely be kept secret. Likewise, in 1820, Thomas Hancock invented the "masticator", a cylinder studded with sharp teeth that gnawed and macerated rubber into scraps. This machine packed together scraps of rubber that were left over from the manufacture of gloves, shoes, or suspenders. These leftovers were then rolled into sheets, and, with sufficient pressure and heat, could be recycled into usable pieces of rubber. To disguise the nature of his rubber-saving machine, Hancock and his colleagues nicknamed it the "pickle", and took an oath never to discuss it. By using secrecy,

¹⁶ *Procès-Verbal du Congrès Suisse...*(1883): 34-35, my translation.

Hancock followed a strategy which was common in the rubber industry during its period of rapid innovation (Dragon 1995, p.222 and Korman 2002, p.127-128). However, a former worker broke the promise in 1832, and competitors rushed in. Deprived of secrecy, Hancock's only protection came from patents that he had taken out on rainwear and other products from recycled rubber. (Korman 2002: 26)

At the same time, secrecy appears to have been extremely effective in protecting innovations in scientific instruments and food processing. In 1851, a jury of 12 watchmakers and academics failed to reconstruct the watch springs invented by F. Lutz of Switzerland. The German Commission also reports that Dutch and Swiss inventions in optical instruments, such as the rectangular prisms of Swiss glassmaker T. Daguet of Soleure, or Danish barometers and surgical instruments, proved impossible to reverse-engineer (*Bericht I*, 1852 pp. 813, 819, 930, and 941). Secrecy also appears to have been important in many profitable fields of chemistry, most notably for rubber and textile dyes. Until Perkins' discovery of aniline dye in 1856 set in motion the discovery of synthetic dye stuffs, the dyeing industry was completely dependent on natural resources such as locally available yellows, indigo, madder or kermes red in Europe, or cochineal insects, brazilwood, and annatto from the Americas. Such compositions were difficult to describe and proved virtually impossible to copy before significant advances of chemistry in the late 19th century.

In food processing, the history of margarine illustrates the relative effectiveness of secrecy. Margarine first turned profitable in the Netherlands, at a time when this country did not have patent laws. Two Dutch firms, Jurgens and Van den Bergh, began to manufacture margarine in 1871, after the original patent holder, a French chemist by the name Mège Mouriès, willingly described how this butter substituted could be produced, considering himself protected

by his 1869 French patent. Trade secrets protected future improvements: When the Van den Bergh factory succeeded in producing a new and less repulsive type of margarine, they kept this innovation secret. As late as 1905, long after the original patent would have expired, the Jurgens firm had not succeeded in reverse engineering by chemical analysis or by efforts to obtain information from his rival's workers. Many other important innovations in food processing originated in late nineteenth-century Switzerland, when that country did not have patent laws: milk chocolate, liquid soup seasoning, bouillon, and baby food (see Schiff, 1971 pp. 54-58, 111-112).

Thus, contemporary reports corroborate patterns in inventors' propensity to patent that were suggested by the Crystal Palace innovations. Blodgett's loss of the sewing machine and Hancock's of the masticator illustrate how easily 19th-century machinery inventions could be reverse-engineered and reproduced. In industries with easy imitation, skilful patentees, such as Elias Howe, relied to patenting to extract huge rents from later generations. On the other hand, imitation appears to have been close to impossible for 19th century innovations in chemistry, instruments, and food processing, and inventors in those industries appear to have been less prone to patent their inventions.

VI. Conclusions

This paper has used data on more than 6,000 American and British innovations at the Crystal Palace World's Fair of 1851 to examine patterns in the patenting behavior of inventors. Exhibition data show that inventors in both Britain and the US chose to patent only a small share of their inventions, despite the low costs of patenting in the US and the apparent effectiveness of

US patent laws. 14.1 percent of American exhibits appear to have been patented, compared to 12 percent of Britain's exhibits.

One potential explanation for these surprisingly small differences is that other characteristics of the US patent system offset the benefits of low patent fees. For example, high non-monetary costs of disclosure may have decreased the propensities to patent in the American system. Although inventors were required to specify and disclose the inventions in all patent systems, only the American laws ensured that the public could have easy access to these patents. In the US system, the disclosure of information was intended as the true price of patenting. As early as 1805, Congress required that the Secretary of State publish complete lists of patents every year, and from 1832 onwards, expired patents had to be published in the *Scientific American* and other specialized newspapers. (Khan 2002, p.18)¹⁷ Disclosure may have benefited the overall level of innovation in the economy by creating a knowledge base for later generations, but it increased the costs of patenting to original inventors. Easy access to patent specifications gave potential competitors the opportunity to appropriate a patented idea, make slight modifications, and thus invalidate or “invent around” the original patent. Then, even with the most favourable courts, patenting increased the risk of having to defend one's intellectual property from imitators, and, perhaps more importantly, patenting raised the expected costs of litigation. Such non-monetary costs of disclosure may have helped to undo the gain that was achieved by lower fees. Nevertheless, the closeness of overall patenting rates in the British and the American patent data is conspicuous.

¹⁷ In comparison, British inventors may have faced relatively low costs of disclosure, because the French and British systems provided no practicable access to patent specifications. There were no opportunities for systematic searches, the location of patent manuscripts was uncertain, and many bureaucratic hurdles created hardships for a curious competitor (Khan 2002, p.13).

Another finding of this paper is that inventors patent more (and less) in the same industries despite the most fundamental differences in patent laws. Both American and British inventors were prone to patent inventions in machinery, and appear to have been reluctant to patent in mining and metallurgy, chemistry, food processing, and scientific instruments. Exhibits that won awards for inventiveness reveal the same distribution of patenting across industries. This suggests that inventors' patenting decisions were determined by the characteristics of the innovation itself and that the effect of differences in institutions was minimal compared to the intrinsic usefulness of patents, which varies strongly across industries.

These results suggest that the accuracy of both theoretical and empirical analyses may be improved by accounting for differences in the usefulness of patents across industries. If patenting rates vary across industries, and, if patent protection is most beneficial to inventors in industries with weak alternatives, the effects of patent laws will be much different from what they are thought to be at present. Changes in patent laws are then likely to have strong effects on the direction of industry. For example, the focus of American innovation on manufacturing machinery, which has traditionally (Habbakuk 1962, Rosenberg 1969) been explained by the scarcity of labor, may at least in part be credited to the US' strong patent system. Similarly, the strengthening of patent laws in developing countries today may encourage inventors in those countries to focus on patent-friendly industries, such as pharmaceuticals. Finally, the finding of significant and persistent difference in patenting rates across industries draws attention to the need for further historical and contemporary data on innovations, both with and without patents, to aid empirical analyses.

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Tables

TABLE 1 –PATENTING RATES FOR BRITISH AND AMERICAN EXHIBITS IN 1851

	Exhibits		At least 1 patent		All patents	
	Britain	US	Britain	US	Britain	US
Mining and metallurgy	418	52	5.0%	5.8%	5.0%	9.6%
Chemicals	136	25	5.1%	4.0%	7.4%	4.0%
Food Processing	140	70	7.9%	4.3%	8.6%	11.4%
Engines and Carriages	406	31	24.6%	32.3%	32.8%	54.8%
Manufacturing Machinery	242	32	30.2%	46.9%	35.5%	50.0%
Civil and Military Engineering	559	17	13.8%	23.5%	15.4%	35.3%
Agricultural Machinery	261	27	19.9%	37.0%	28.4%	48.1%
Scientific Instruments	577	74	9.7%	14.9%	11.4%	28.4%
Manufactures	1,955	104	10.2%	13.5%	11.9%	39.4%
Textiles	1,679	117	6.9%	6.0%	7.6%	6.0%
Total	6,373	549	11.2%	14.2%	13.3%	24.6%

Notes: For Britain, innovations with patents are identified as innovations whose descriptions in the exhibition catalogue refer to a patent. For the U.S., American exhibitors at the Crystal Palace are matched with patentees and their inventions in the *Annual Reports of the United States Patent Office*, 1841 to 1851. “All Patents” counts each patent as a separate occurrence.

TABLE 2 –PROLIFIC PATENTEEES IN THE UNITED STATES:
EXHIBITS AND PATENTS BETWEEN 1841 AND 1851

Exhibitor	Innovation	U.S. Patents	Awards
Day, H.H.	India-rubber manufactures.	7	0
Chilson, Richardson, & Co.	Furnaces and stoves	6	2
Gilbert & Co.	Pianofortes.	6	1
Stafford, J.R.	Specimens of steam-dried corn meal.	6	0
Cornelius & Co.	Lamps, chandeliers, and gas fixtures.	5	2
Goodyear, C.	India-rubber goods	5	3
Pond M. & Co.	Cooking ranges.	5	1
Ericsson, J.	Instruments for measuring distances at sea. Marine barometer.	4	2
Billings & Ambrose	Methods of connecting hubs and axles	3	0
Colt, S.	Specimens of fire-arms	3	1
Detmold, C.E.	Specimens of pig-iron, iron-ore, coal, and coke.	3	0
Emerson, F.	Ship ventilators.	3	0

Note: Patentees are identified by matching American exhibitors at the Crystal Palace with patentees and their inventions in the *Annual Reports of the United States Patent Office*, 1841 to 1851.

TABLE 3 – AWARD-WINNING INNOVATIONS FROM BRITAIN AT THE CRYSTAL PALACE
GOLD, SILVER, AND BRONZE

Industry	Award-winning British exhibits in 1851							
	All awards		Gold		Silver		Bronze	
	Total	% Patented	Total	% Patented	Total	% Patented	Total	% Patented
Mining	102	2.9%	2	50.0%	53	1.9%	47	2.1%
Chemicals	74	8.1%	0	NA	42	11.9%	32	3.1%
Food processing	63	4.8%	1	0.0%	39	7.7%	23	0.0%
Engines and Carriages	12	25.0%	6	50.0%	4	0.0%	2	0.0%
Manufacturing Machinery	72	47.2%	14	42.9%	57	47.4%	1	100.0%
Civil Engineering	36	19.4%	3	0.0%	25	20.0%	8	25.0%
Military and Naval Engineering	65	10.8%	8	0.0%	49	14.3%	8	0.0%
Agricultural Machinery	47	36.2%	5	40.0%	37	37.8%	5	20.0%
Scientific Instruments	72	16.7%	14	21.4%	43	12.5%	15	26.7%
Manufactures	424	18.6%	19	10.5%	294	16.9%	111	6.3%
Textiles	482	8.9%	3	100.0%	308	8.8%	171	8.8%
All industries	1,449	14.1%	75	24%	951	16%	423	8%

Sources: *Official Catalogue 1851, Bericht 1853.*