What do Inventors Patent?*

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Understanding what inventors choose to patent (and what they choose not to patent) is essential not only to accurately measuring innovation, but also to predicting the effects of patent laws. For the 19th century, a study of 18,092 European innovations at 19th-century world fairs reveals that, despite the institutional importance of patent laws, countries without patent systems created some of the most productive environments for innovation (Moser 2003). Such findings not only call into question the effectiveness of patent laws to create incentives for innovations, but they also heighten concerns about the usefulness of patent data to measure innovation (as outlined, for example, in Griliches 1990).

This paper uses a new data set of more than 6,000 British and American exhibits at the Crystal Palace fair in 1851 to examine inventors' propensity to patent. Data from 19th-century world fairs create a unique opportunity to study patenting behavior because exhibits at these fairs include innovations both with and without patents. Despite the most fundamental differences between the cumbersome and costly British patent system and its reformed and highly-praised American counterpart, inventors' patenting behavior was surprisingly similar across these countries. In both patent systems only one in eight inventions appears to have been patented. Moreover, the propensity to patent varies strongly across industries, suggesting a strong industry-specific component of the usefulness of patent grants. Patenting rates, calculated as the share of innovations that are patented, range from less than six percent in chemicals to more than forty percent in machinery for manufacturing. These patterns are robust to different ways of calculating patenting rates, to comparisons across rural and urban areas, and to adjustments for the quality of innovations.

Current theoretical and empirical findings on innovation rely on the implicit assumption that all innovations are patented. Nordhaus (1969), Klemperer (1990), and Gilbert and Shapiro

(1990) build on this notion to show that increases in patent length raise levels of innovation. Alternative theories of innovation, such as Scotchmer (1991) and Gallini (1992), employ the equivalence of patenting and innovation to demonstrate that increases in patent length may lower levels of innovation (as they reduce expected profits to future generations and raise the risks of costly imitations). Similarly, empirical analyses of innovation have relied almost exclusively on patent data, and the validity of these results depends crucially on understanding the relationship between patents and innovations.[1]

Patent data have proven themselves to be a useful though imperfect measure of innovation. On the one hand, only a small proportion of patents develop into economically useful innovations. As early as 1852, an editorial in the *New York Times* observes that

> There is no gain in the thousand and one useless articles patented yearly at Washington… Visit the patent office, and overhaul the records' and out of the many thousand inventions entered there, learn how few are not in actual use (*New York Daily Times* April 26, 1852.)[2]

At the same time, inventors appear to rely on a variety of alternative mechanisms, including secrecy and speed to the market, to protect their intellectual property. Industry surveys ranging from the 19th to the late 20th century indicate that inventors' attitudes towards patenting vary strongly across industries (*Procès Verbal* 1883, Levin, Klevorick, and Nelson 1987, Cohen, Nelson, and Walsh 2000, Harabi 1991). These issues raise a variety of questions about the relationship between patents and innovations: What proportion of innovations are patented? Does the propensity to patent vary across industries? And how are inventors' choices influenced

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1 For example, see Schmookler 1966, Sokoloff 1988, Lamoreaux and Sokoloff 1999, Moser and Nicholas 2004 for historical analysis of patent data, and Trajtenberg, Jaffee, Henderson 1993, Hall, Trajtenberg, and Jaffe 2001 for contemporary analyses of patent data.

2 A proponent of patent laws counters this claim without giving much credit to the system either: "As you remark, they are no doubt many useless articles patented; but it is not so true that 'society is so miserably deceived and defrauded by them' for scarcely one in a hundred of them are ever seriously offered for sale." (Letter to the Editor of the *New York Daily Times*, April 29, 1852, p.1)

by the characteristics of patent systems? Answers to these questions will be helpful for assessing the implications of patent-based theoretical and empirical research on innovation.

Data from 19th century exhibitions create an invaluable opportunity to examine these questions about patenting behavior. By enabling researchers to examine the actual patenting decisions of inventors, they provide a useful complement to survey data, which has to rely on the accuracy of survey returns. Exhibition data include innovations with and without patents, and references to patents in the descriptions of exhibits make it possible to distinguish both types of innovations. Although the terms *innovation* and *invention* are used interchangeably it bears repeating that 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 innovation, whereas patents count a subset of inventions, which inventors chose to patent.

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 state of patent protection. From these records, I have constructed data for all 6,377 British and 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 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 construct proxies for the share of 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, patenting rates are constructed by matching American exhibitors to lists of all US patents granted between 1841 and 1851. These data are publicly available in the annual Patent Gazettes of the US Patent Office.

Comparisons of patenting rates reveal remarkable similarities in patenting behavior, despite the most fundamental differences between the US and the British patent laws. Although the upfront costs of patenting were extremely high in Britain but modest in the US, the share of innovations that are patented is almost identical in Britain and in the US: 11.2 percent in Britain compared to only 14.2 percent in the US.

Moreover, British and American inventors chose to patent (and not to patent) in the same industries. In Britain and the US, innovations in machines, such as new types of engines, manufacturing machinery or agricultural tools, were patented more frequently than innovations in any other industry. Almost half of American innovations in engines, manufacturing machinery and agricultural machinery were patented, compared to one in five American innovations in all industries. Similarly, around one third of British innovations in these industries referred to patents, compared to one eighth of British innovations across economy-wide. In contrast, inventors chose to patent between three and ten percent of innovations in mining and metallurgy, food processing, chemicals, textiles, and scientific instruments.

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.[3] 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, American, and French exhibitors at the Crystal Palace Fair in 1851 to examine the patenting behavior of inventors. Section I formalizes some basic ideas about the inventors' choice to patent. Section II describes the exhibition data, including awards for inventiveness and distinctions between innovations with and without patents. Section III presents proxies for patenting rates across industries, across countries, and across quality levels. Section IV examines evidence on the importance of patenting and alternative mechanisms from contemporary narratives, and section V concludes.

I. The Choice to Patent

To begin, it may be useful to formalize the major influences on inventors' choice to patent. For example, consider a closed economy with L potential inventors, where L may be regarded as the country's labor force. The key characteristics of patent systems, such as patent fees and the maximum duration, T, of patent grants, vary across but not within countries. To begin, let us assume that development costs, which reduce initial returns R_i in industry i, include patenting costs, such as patent fees and time spent in researching prior art. Let d_i represent the

[3] Counting each reference as a separate occurrence, which may lead to a slight upward bias in patenting rates.

proportion of returns in industry i that carries over from one period to the next.[4] 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.[5] For simplicity I 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 payoffs to invention are positive and entry reduces the maximum returns from invention until they are only slightly greater than patenting costs, C.[6] Then,

$$(2) \quad (1-d_i^T)(1-d_i)^{-1} g^{ni-1} R_i = C$$

which implies

$$\mathit{(3)} \quad n_i = \ln(g)^{-1}[\ln(C) - \ln(R_i) + \ln(1-d_i) - \ln(1-d_i^T)] + 1.$$

Equation (3) allows me to check the comparative static effects of an increase in patent length on levels of invention. Taking first derivatives yields

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[4] 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.

[5] 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.

[6] With a discrete number of invention projects, returns may not be strictly zero.

$$(4) \qquad \frac{\partial ni}{\partial T} = \ln(g)^{-1} \ln(d_i)\, d_i^T (1- d_i^T)^{-1} > 0$$

Equation (4) confirms that increases in the duration of patent grants increase the number of inventions. Similarly, increases in initial returns and decreases in patenting fees raise the number of inventions.

However, it seems plausible that the effects of patent laws may vary across industries. In their 1994 survey of 1,478 American manufacturing firms, Cohen, Nelson, and Walsh (2000) find that firms typically rely on a range of mechanisms, including patents, secrecy, lead time, and the use of complementary marketing and manufacturing capabilities to capture profits from their innovations. Of these mechanisms, patents are unambiguously the least important. In contrast, secrecy, whereby inventors protect their intellectual property by preventing disclosure, appears to be emphasized most heavily. Cohen, Nelson, and Walsh (2000) find patenting to be the most frequently used mechanism in 2 of 33 industries, while secrecy is the most used mechanism in 17 of 33 industries.[7] This method proves most effective for inventions that are difficult to copy or reverse-engineer.

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 $s_i^t R_i$ 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

[7] Cohen, Nelson, and Walsh (2000): 10.

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. (For the sake of generality, 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.[8] 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.[9]

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[8] 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.

[9] The *New York Daily Times*, October 16, 1851, p.2.

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.[10]

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.[11] 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 (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 four times that of St. Peter's in

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[10] 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.

[11] Together with the American Centennial Exhibition of 1876, the Crystal Palace has the highest quality of data. Participation in the two most promising alternatives, the 1873 *Weltausstellung* in Vienna and the 1889 International Exposition in Paris suffered from political turmoil among participating countries.

Rome, or six times that of St. Paul's Cathedral in London. Catalogues were written to guide visitors through the walkways of the exhibition and to inform them about all innovations that they could see along the way.

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.

From the Crystal Palace catalogues, I have classified 6,377 British and 549 American according to 30 industry classes, distinguishing innovations with and without patents.

Among the major benefits of the exhibition data is that the exhibits cover innovations from all industries, regardless of their state of patent protection. Industry classes at the Crystal Palace span the entire spectrum of production, from mining and minerals, chemicals, and food processing, to engines, manufacturing machinery, and scientific instruments. Such coverage has been difficult to attain with patent data, partly because patented inventions are classified by functional principles, and often cannot be assigned to a specific industry of use. To recall a famous example, the functional class "dispensing liquids" includes holy water dispensers and water pistols, while "dispensing solids" combines tooth paste tubes with manure spreaders (Schmookler 1972, p.88). As a result, studies of historical patent counts have been unable to classify vital innovations such as power plant inventions or electric motors (Schmookler, 1972 p. 89). Moreover, economy-wide patent data are not available for countries that exclude specific industries from patenting. For example, there is no patent data on 19th-century French inventions in medicines, because they were excluded from French patent laws. (Coryton, 1855 pp. 241-266).

Entries in the Crystal Palace Exhibition represented a wide sample of the best inventions across entire countries. 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 typically 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.[12] 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. 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.

All-inclusive evaluations and a system of awards helped to enforce the criteria for selection. 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 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

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

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. Griliches (1990 p. 1669) observes that patented inventions differ greatly in quality and in the magnitude of inventive output associated with them. 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 are extremely costly to collect and are as yet unavailable to measure the quality of nineteenth-century inventions. In contrast, reliable proxies for quality can be created with relative ease from the records of the world fairs. I have collected data on more than 4,000 awards from the reports of the German Commission to the Crystal Palace (*Berichterstattungs-Kommission der Deutschen Zollvereins Regierungen*, 1853) and matched them by exhibitors name, country, exhibit number, and innovation, with my lists of 18,049 exhibits from the exhibition catalogues.

Two different methods are used to measure the proportion of innovations that are patented. For Britain, patented innovations can be identified directly from the exhibition records. Exhibitors from those countries 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; exhibitors without patents are unlikely to claim patents, because they would be discovered easily. I check this assumption by constructing an alternative measure for the American data.

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

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.

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 show that 11.2 percent of British exhibits referred to at least one patent, compared to 14.2 percent of Americans table 3 shows British award-winner info. This difference is small considering the vastly disparate costs of patenting in the US and Britain.

A. Patenting Across Industries

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,

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

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 Britanny

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, napthaline, 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.

B. 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]

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 were 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.

C. 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

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[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 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.

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.

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.

IV. Contemporary Reports on Patenting and Alternative Mechanisms

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. … We will say only that from the point of view of the watch-making industry and what has happened in the American firms, 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

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[16] *Procès-Verbal du Congres Suisse…*(1883): 34-35, my translation.

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, 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.

IV. 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 patens. 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

[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).

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.

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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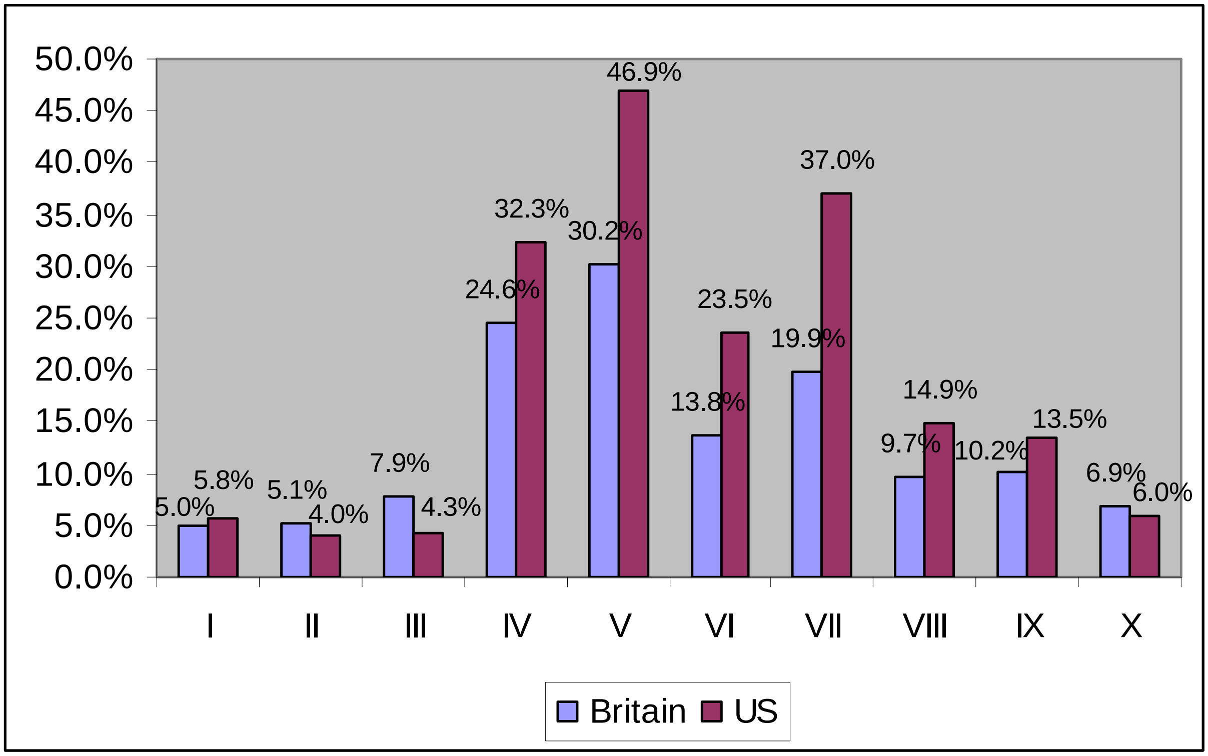
Figure 1 Shares of Innovations that are Patented for Different Industries in 1851



For Britain, innovations with patents are identified as innovations whose descriptions in the exhibition catalogue refer to a patent. For the U.S., innovations are matched with patent counts from the United States Patent Office Patent Gazette. Industry 1 represents Mining and Metallurgy, 2 Chemicals, 3 Food, 4 Engines and Carriages, 5 Manufacturing Machinery, 6 Civil, Military, and Naval Engineering, 7 Agricultural Machinery, 8 Scientific Instruments, 9 Manufactures, and 10 represents Textiles.

Table 1 Patenting rates for British and American Exhibits at the World Fair of 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%

For Britain, innovations with patents are identified as innovations whose descriptions in the exhibition catalogue refer to a patent. "All Patents" counts each patent as a separate occurrence. For the U.S., innovations are matched with patent counts from the United States Patent Office Patent Gazette. Sources: *Official Catalogue* 1851, *Patent Gazette* 1841 to 1850.

Table 2 Prolific Patentees 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

American innovations in the British catalogue are matched with patent counts from the United States Patent Office Patent Gazette. Sources: *Official Catalogue* 1851, *Patent Gazette* 1841 to 1850. In the column awards 1 records *Honorable Mention*, 2 *Prize Medal*, and 3 *Council Medal* (the highest honor).

Table 3

	Award-winning British exhibits in 1851							
	All awards		Gold		Silver		Bronze	
Industry	**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.