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Cheaper patents☆

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ABSTRACT

The 1883 Patents Act in Britain provides perspective for modern patent policy reforms because it radically changed incentives for inventors by reducing filing fees by 84 percent. Patents increased 2.5-fold after the reform, which was evenly distributed across the geography of inventors, the organization of invention and sectors. By realizing a large demand for cheaper patents the reform increased the propensity to patent and shifted inventive activity inside the patent system. It did not increase innovation as measured by changes in the distribution of high and low value patents and citations to English inventor patents in the United States.

1. Introduction

Patents are designed to encourage investment in technological development, but the literature is mixed in its assessment of how changes in intellectual property (IP) rights protection affect both the propensity to patent and the level of innovation.[1] A number of studies have identified economically significant effects of IP reform such as on research and development investment (Park and Ginarte, 1997; Kanwar and Evenson, 2003), the direction of invention (Moser, 2005) or the transfer of technology by multinational firms to affiliates in reforming countries (Branstetter et al., 2006). Several works find a limited – or even a negative – effect of stronger patent protection on technological development (Sakakibara and Branstetter, 2001; Qian, 2007; Lerner, 2009; Encaoua et al., 2006). Patents are rejected altogether as a mechanism for spurring inventive activity by Boldrin and Levine (2008).

I examine the effects of one of the most significant reforms in patent law history: the 1883 Patents, Designs and Trade Marks Act (46 & 47 Vic., c.57) in Britain, which reduced filing fees by 84 percent. The reform was large, immediate and persistent so helps to shed light on the consequences of cheaper patent protection, which has important implications for modern patent policy. Lowering the cost of patenting is a key priority in aligning national patent systems, especially in Europe where patenting costs are high relative to in the United States and Japan. The proposed introduction of a European "Community Patent" assumes that cheaper patents will have a positive effect on the propensity to patent without any detrimental effect on the level of innovation (Straus, 1997; De Rassenfosse and van Pottelsberghe de la Potterie, 2007; London Agreement, 2008; Van Pottelsberghe de la Potterie, 2009; Harhoff et al., 2009; The Economist, July 23rd, 2009).

To analyze the effects of the reform, I use a new dataset of 13,883 patents composed of 20 percent random samples of sealed patents in each year for a ten year event window around the 1883 Act (i.e., 1878–1888).[2] I compiled data on the location of inventors, the organizational origins of the invention (independent versus corporate owned) and the sectors inventors patented in from the original patent documents. Additionally, I collected a dataset on the renewal history of each patent – whether it was kept in force or allowed to lapse each year over the patent term. Although credit constrained inventors may not pay the renewal fee on technologically important inventions (MacLeod et al., 2003) patent renewal data provide a useful indicator of patent quality. The distribution of renewals

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[1] The notion that patents provide incentives for investment in research effort is a modern one. *Hansard* records Joseph Chamberlain (a key proponent of patent reform) as stating during the debate on the 1883 Act: "[t]he objects of a good Patent Law [are] four fold. In the first place, the protection granted should give adequate protection to the inventor without creating an undue monopoly. In the second place, the cost of obtaining patents should not be so great as to put them out of the reach of any class of inventors; in the third place, the protection should be as real and effectual as possible; and, lastly, where litigation was inevitable, it should be both cheap and efficient." [BILL 3.] SECOND READING. HC Deb 16 April 1883 vol. 278 cc349-94.

[2] British patents were officially sealed as opposed to being "granted" in the United States.

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should be correlated with the value distribution of patent rights (Schankerman and Pakes, 1986; Lanjouw et al., 1998).

I study two effects of the reform: on the change in the propensity to patent and on the level of innovation.[3] The first of these effects is very clear from Fig. 1A. In 1884, the year the 1883 Patents Act first came into force, the British Patent Office received over 17,000 applications for patents from inventors compared to around 6000 applications the year before, and the number of patents officially sealed also jumped – by a factor of 2.5. The exogenous nature of the reform is highlighted in Fig. 1B which compares patenting in Britain to the United States. While the data show the propensity to patent increased, we do not know how this effect was distributed. I examine this issue using a range of patent and inventor outcome measures to test for patterns in the data consistent with the large spike in patenting following the introduction of the reform.

The second effect, on the level of innovation, is much harder to identify. Patents are a noisy measure of changes in innovation especially if the propensity to patent changes simultaneously. If inventors disclose their inventions more after the reform, for example, the resulting increase in patents is more likely to reflect a shift in their behavior towards patenting rather than any increase in innovation *per se*. In an attempt to test for an innovation effect absent of this confound, I examine patents granted to English inventors in the United States around the time of the 1883 reform. Since patent law in the United States remained constant up to 1887 when the country signed the Paris Convention for the Protection of Industrial Property (which strengthened the rights of foreigners seeking patent protection), the propensity to patent there should be unaffected by the British reform. I use difference-in-differences regressions to analyze changes in quality-adjusted English inventor patents relative to a control group of patents granted to other inventors in the United States. For quality adjusting patents, I use a dataset containing 42.8 million citations to patents granted since 1836 in U.S. patents granted between 1947 and 2008. Since innovation can respond to a change in incentives with a lag as new knowledge gets absorbed and implemented, I extend the event window for this analysis by a decade to 1898.

The results show that the large increase in the propensity to patent after the reform was driven initially by British inventors, but this effect strongly dissipated a few years after the reform as foreign inventors also took advantage of cheaper patents. I find no evidence of a shift in the geography of invention within Britain as large cities, especially London, dominated patenting activity in both the pre- and post-reform periods. The share of corporate versus independent owned patents and the sectoral distribution of patenting did not change significantly as a consequence of the reform. Main trends in the data are confirmed for patents at different points in the renewal fee distribution: those that lapsed early (low value patents) and those held to a full 14 year term (high value patents).

Although the 1883 reform led to an increase of one year in the lifespan of low value patents (because the due date for the first renewal fee payment was delayed from the end of the third year to the end of the fourth year of a patent term), I show that patent duration approximately equalized in pre- and post-reform patent cohorts for patent terms of 5 years or more. Notably, the reform more than doubled the absolute number of high value inventions being publicly disclosed. Although this led to a substantial increase in the stock of useful knowledge placed in the

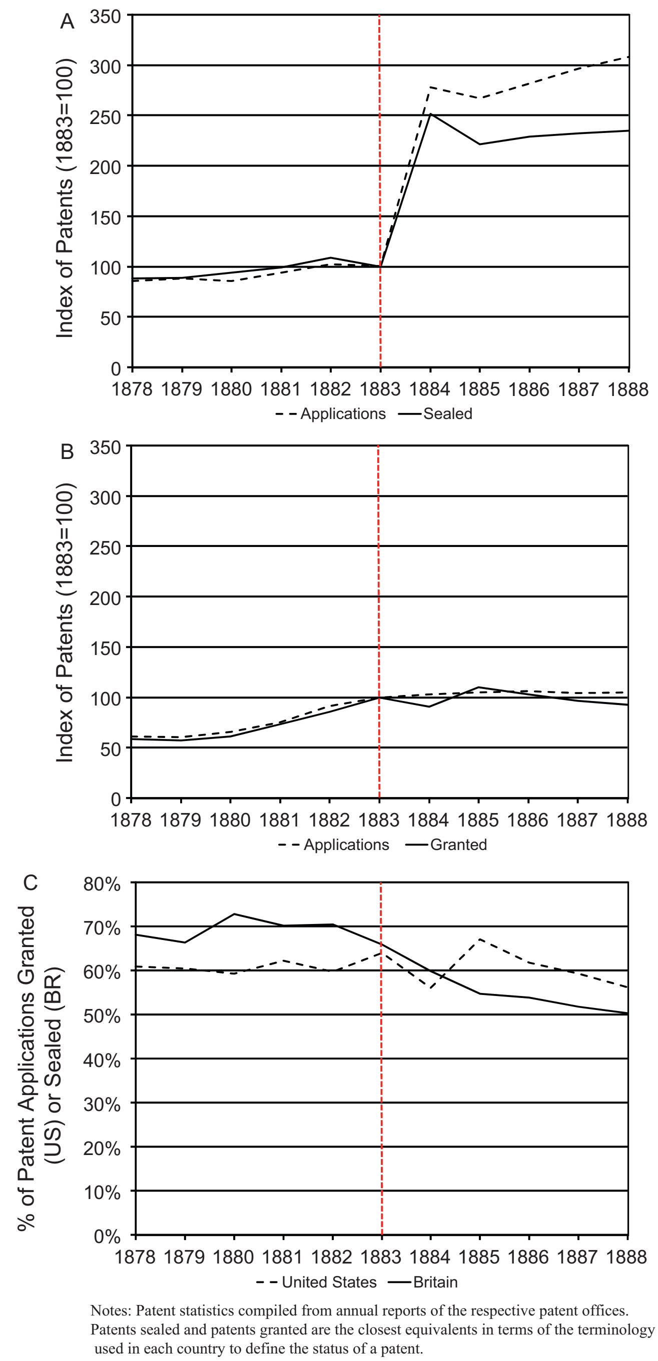


Fig. 1. (A) The size of the 1883 patent reform. (B) Patenting in the United States at the time of the 1883 reform. (C) The percentage of applications to successful patents in Britain and the United States *Notes:* Patent statistics compiled from annual reports of the respective patent offices. Patents sealed and patents granted are the closest equivalents in terms of the terminology used in each country to define the status of a patent.

public domain, I find no evidence that it was associated with an increase in the level of innovation. Five years after the reform I find the share of high value patents to be statistically indistinguishable from the share of high value patents before the reform. Furthermore, difference-in-differences estimates over five and fifteen year post-reform horizons show statistically insignificant changes in quality-adjusted patents granted to English inventors in the United States.

Overall I find that the 1883 change in the patent law led to a large shift in the propensity to patent but it did not affect the level of inno-

[3] Invention and innovation are different concepts. I use invention in the context of the propensity to patent to determine whether the reform changed the level of inventive activity. I measure innovation by the value of inventions as determined by the payment or non-payment of renewal fees at junctures of a patent term, or historical patent citations which proxy for the technological significance of inventions. For further details see Sections 4 and 5.

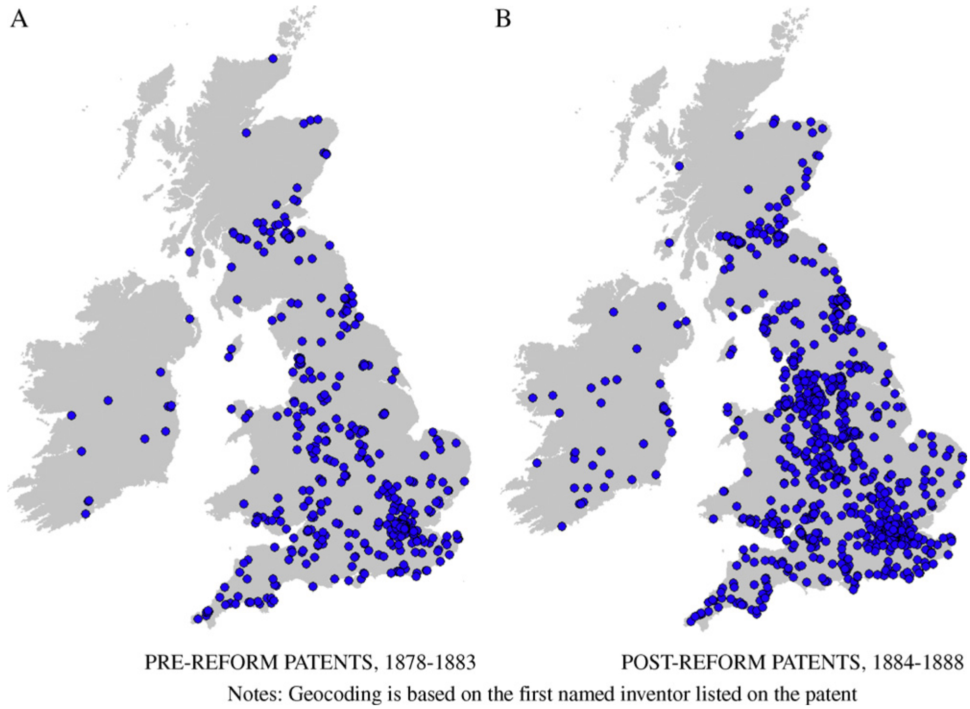


Fig. 2. The location of inventors. (A) Pre-reform patents, 1878–1883. (B) Post-reform patents, 1884–1888. *Notes*: Geocoding is based on the first named inventor listed on the patent.

vation. The reform induced a significant behavioral response on the part of inventors as inventive activity moved inside the British patent system. Importantly, this shift occurred without distorting the geography of inventive activity, the organization of invention or its sectoral distribution. Alternative scenarios where distributional distortions do occur are a perennial concern in the literature on the optimal design of patent law.

2. Background and the 1883 patents act

Changes to the patent laws under the 1883 Patents Act were conducted against a long backdrop of intense debate in European countries over the use of patents, as evidenced by the famous nineteenth century patent controversy (Machlup and Penrose, 1950).

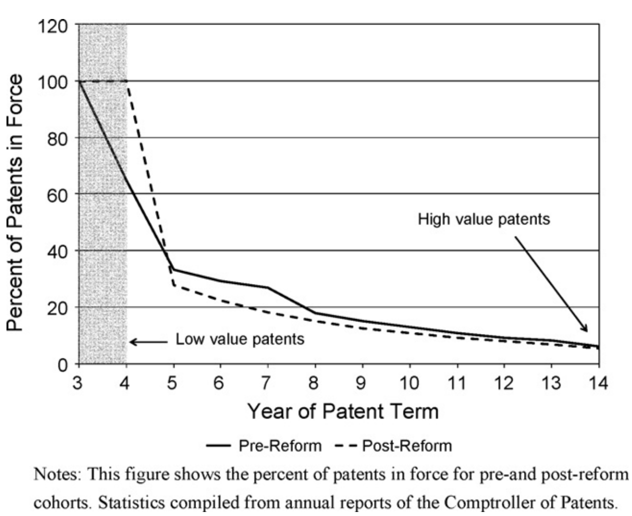


Fig. 3. Percentage of patents in force at specific years. *Notes:* This figure shows the percent of patents in force for pre-and post-reform cohorts. Statistics compiled from annual reports of the comptroller of patents.

In Britain, proposals to make patents cheaper around the time of the Crystal Palace Exhibition in London from associations such as the Committee of the Society of Arts for the Legislative Recognition of the Rights of Inventors met with derision from abolitionists on such grounds that knowledge was a public good not to be protected by a temporary monopoly; frivolous inventions were being patented too frequently; or insufficient evidence existed to show that patents incentivized inventors (Coryton, 1855). A vociferous abolitionist – Robert Macfie, a Member of Parliament and sugar refiner in Liverpool and Scotland – proposed a system of rewards to replace patents whereby the government would pay inventors for their technological discoveries (Armstrong and Macfie, 1869; Shavell and van Ypersele, 2001). In 1851 *The Economist*, also an advocate of government rewards, stated its position:

> The granting [of] patents 'inflames cupidity', excites fraud, stimulates men to run after schemes that may enable them to levy a tax on the public, begets disputes and quarrels betwixt inventors, provokes endless lawsuits... The principle of the law from which such consequences flow cannot be just.

Despite strong arguments against patents, the 1852 Patent Law Amendment Act (15 &16 Vic., c.83) was passed, representing the first major change to the governance of patenting in Britain since the Statute of Monopolies ratified patents for invention in 1623. As well as creating the Patent Office off Chancery Lane, London (the separate Irish and Scottish patent systems were abolished) the Act secured cheaper patents for inventors. Prior to the reform the official fee for a patent was £70, but additional expenses raised the actual average cost to around £120 for inventors in England and as much as £350 for inventors wanting to extend coverage of their patents to Ireland and Scotland (MacLeod, 1988, p. 76). After the 1852 reform, fees were reduced significantly to £25 with two renewal fee payments due – £50 by the end of the third year, and £100 by the end of the seventh year – to keep the patent in force for a full 14 year term. Notwithstanding these fees were non-trivial, with £25 alone representing as much as half a years' wages for a skilled worker (MacLeod et al., 2003, p. 548),

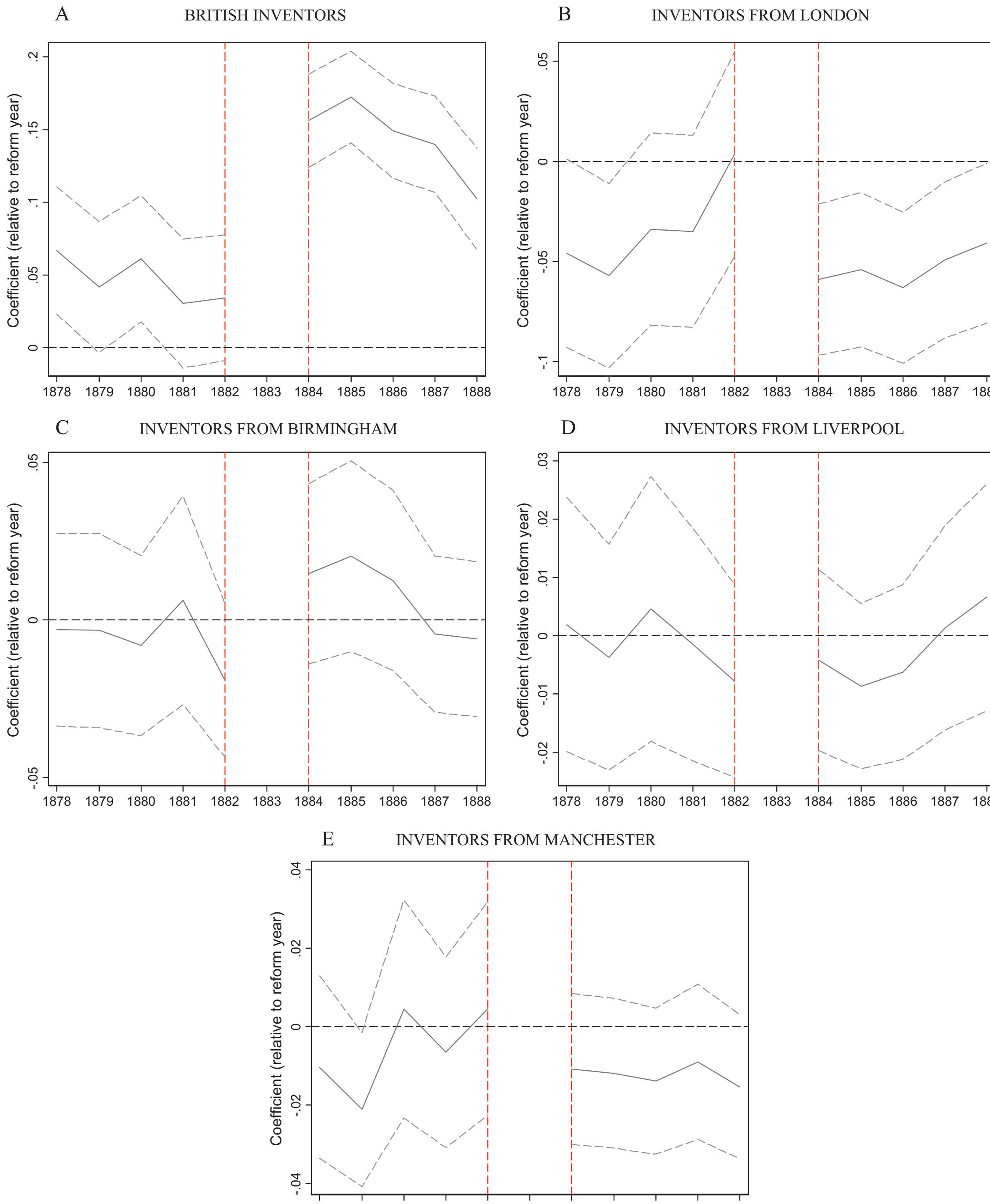


Fig. 4. The propensity to patent: pre- and post-reform plots of probit year dummy coefficients. (A) British inventors. (B) Inventors from London. (C) Inventors from Birmingham. (D) Inventors from Liverpool. (E) Inventors from Manchester. (F) Inventors in Hinterlands. (G) Inventors >50 miles from large cities. (H) Corporate versus independent. (I) Agricultural. (J) Textiles. (K) Steam. (L) Electricity. (M) Scientific instruments. (N) Chemicals. (O) Food. (P) Other mechanical. *Notes*: These figures plot the probit marginal effect year dummy coefficients from Eq. (2) estimated on all patents and the 95 percent confidence interval. The comparison year is 1883, so the coefficients are measured relative to the reform year.

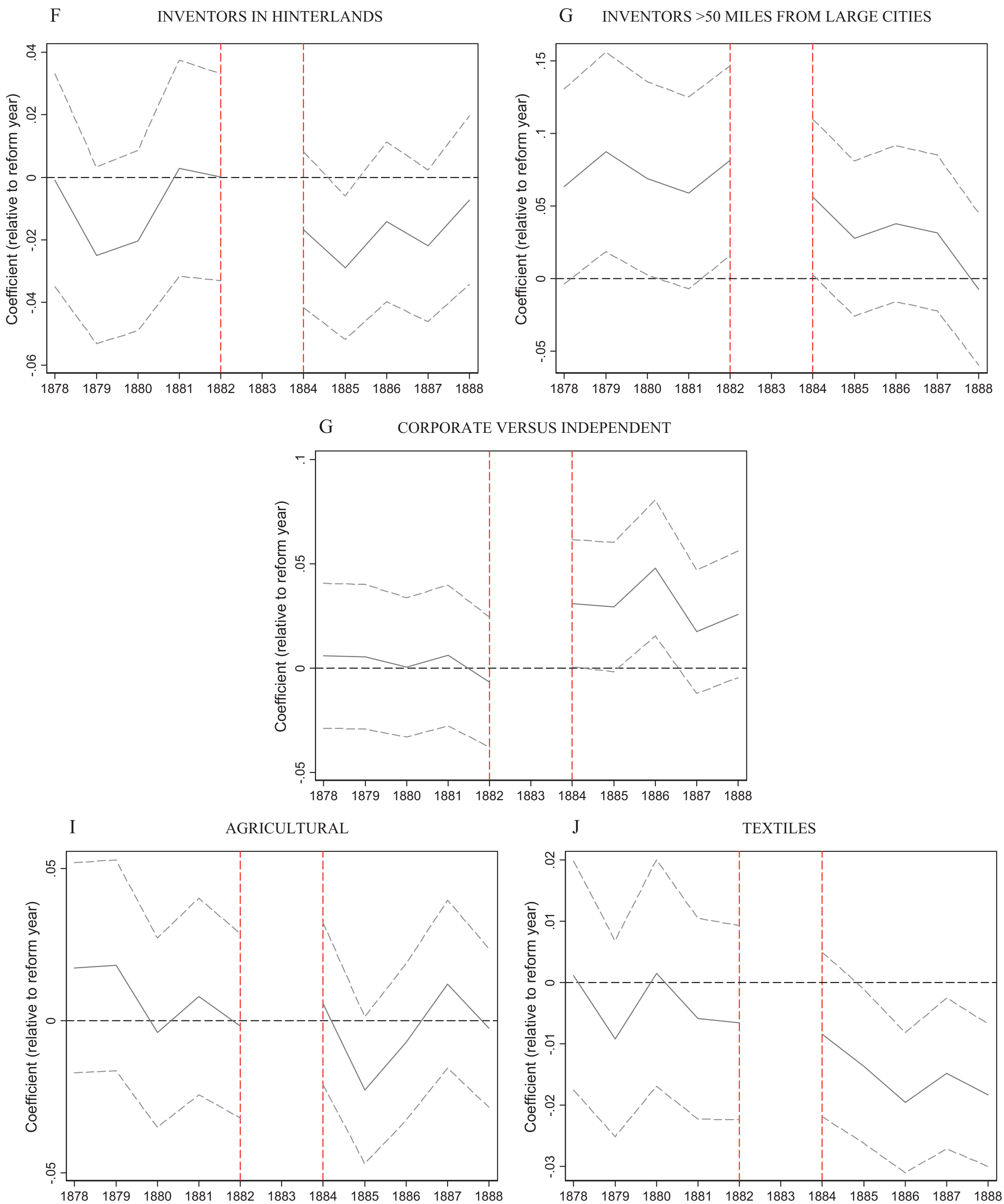
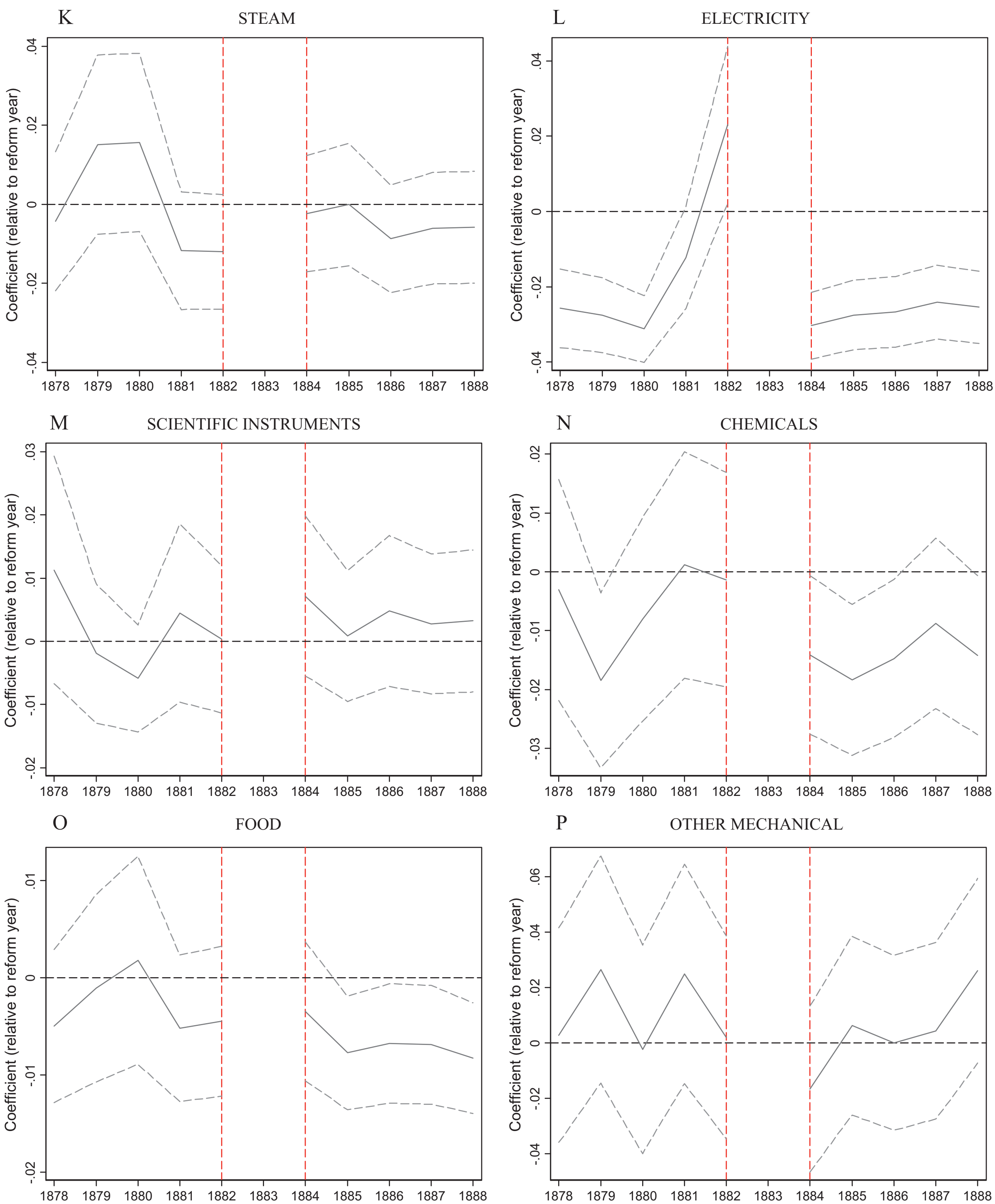


Fig. 4. *(Continued.)*



Notes: These figures plot the probit marginal effect year dummy coefficients from equation 2 estimated on all patents and the 95 percent confidence interval. The comparison year is 1883, so the coefficients are measured relative to the reform year.

Fig. 4. *(Continued.)*

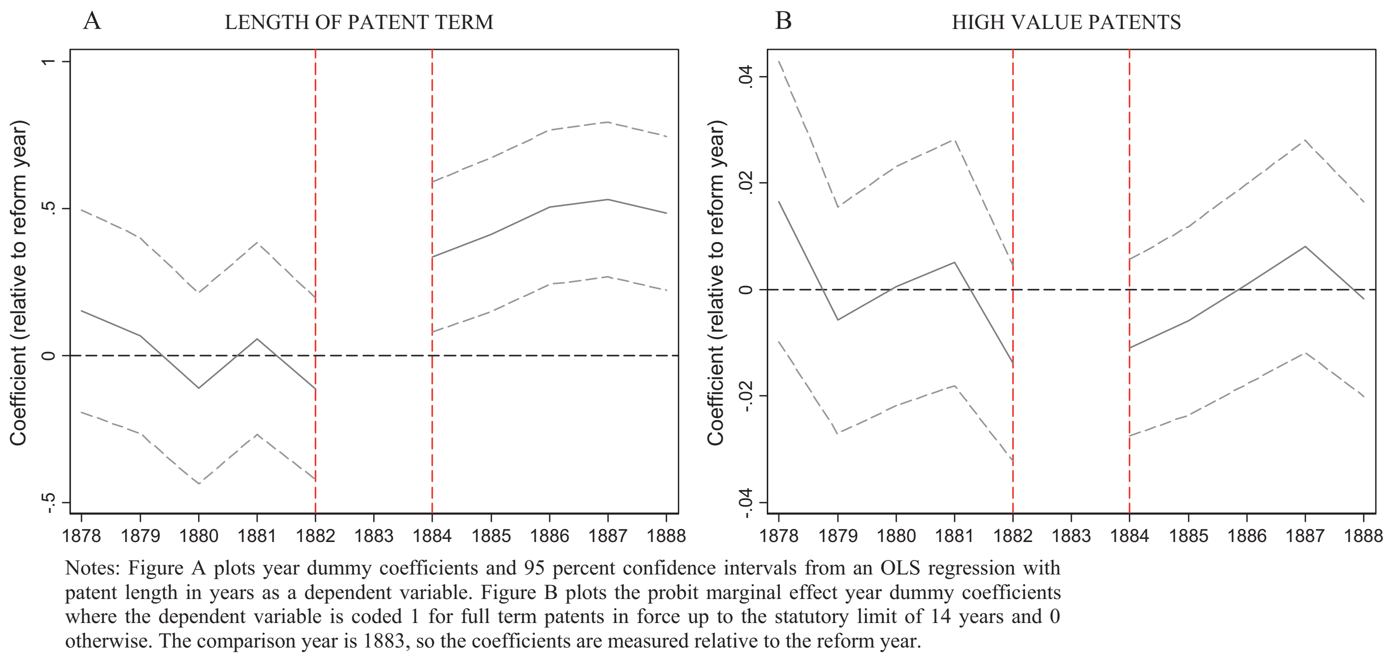


Fig. 5. Patent length: pre- and post-reform plots of year dummy coefficients. (A) Length of patent term. (B) High value patents. *Notes:* Figure A plots year dummy coefficients and 95 percent confidence intervals from an OLS regression with patent length in years as a dependent variable. Figure B plots the probit marginal effect year dummy coefficients where the dependent variable is coded 1 for full term patents in force up to the statutory limit of 14 years and 0 otherwise. The comparison year is 1883, so the coefficients are measured relative to the reform year.

patents increased by a factor of approximately 3 following the reform.[4]

The patent controversy subsided after 1875, and the movement for the abolition of patents in Britain waned. However there were renewed calls for modifications to Britain's patent laws, especially in light of international differences in the length and cost of patent protection. Although patenting in Germany under the patent law of 1877 was prohibitively expensive – a 15 year patent cost around £265 – in other European countries governments were less demanding of inventors (Lerner, 2002). In France, the total cost of a patent for 15 years was around £60, in Italy it was £54 while in Belgium £84 would secure a 20 year patent term (*The Economist*, Feb. 3rd, Mar. 17th, Mar. 24th, 1883). Of most significance was the difference with the United States where at just £7 for a 17 year patent, costs were low enough to democratize invention (Khan, 2005). A number of government appointed commissions pressed for reform on the basis of international discontinuities. Their arguments were echoed by a powerful advocate of cheaper patents – Joseph Chamberlain who in 1880 became President of the Board of Trade.

Passed in 1883, under Chamberlain's guidance, the new Patents Act represented as big a milestone in the history of patent laws in Britain as the 1852 Patents Act had, with sweeping changes to the cost and administration of patenting. The most prominent change was the reduction in fees, which fell from £25 to £4 (£1 on application and £3 for sealing), with the first renewal payment (which remained at £50) delayed by 12 months until the end of the fourth year. A fee of £100 was still due by the end of the seventh year and the patent term remained at 14 years, but inventors could opt to pay their renewal fees by annual installment rather than fixed sums, with fees being revised again in favor of the inventor under a

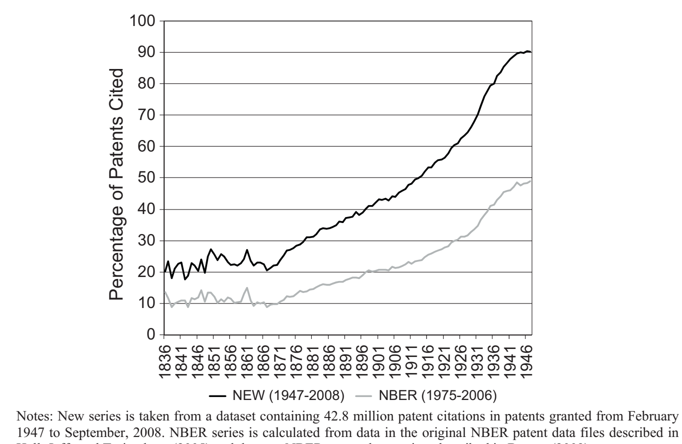
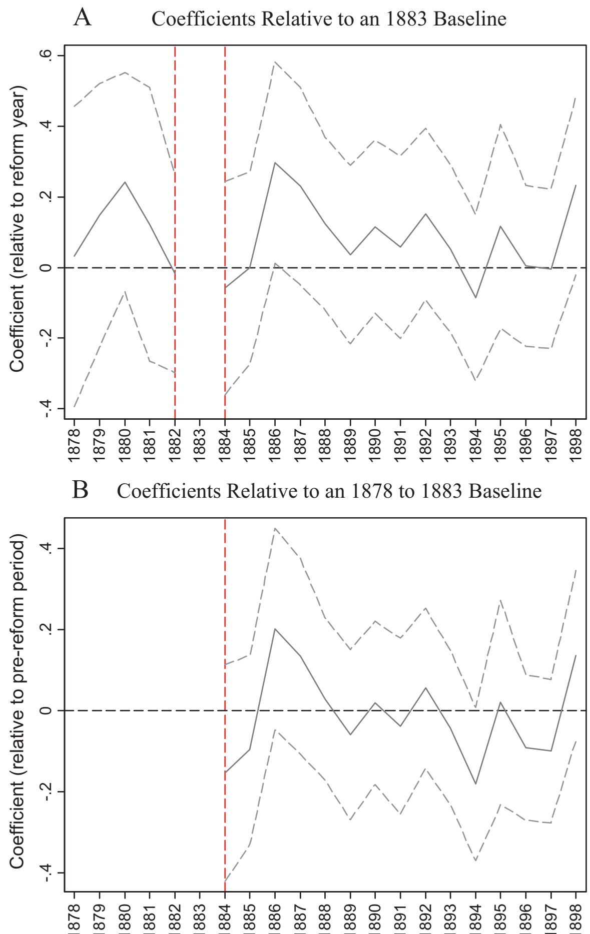


Fig. 6. . The share of patents granted 1836–1946 that are cited in patents granted 1947–2008. *Notes*: New series is taken from a dataset containing 42.8 million patent citations in patents granted from February 1947 to September, 2008. NBER series is calculated from data in the original NBER patent data files described in Hall et al. (2005) and the new NBER patent data project described in Bessen (2009).

new ruling in 1892 (see the Appendix for details). Among less significant changes, provisional protection of a patent was extended from six to nine months and patent examiners were introduced for the first time to supervise applications, although their duties did not extend to a search for prior art or change the basis of British patenting from a registration system (Khan, 2005, ch. 2).[5] Concur-

[4] This number is derived from a comparison of patents officially sealed in 1851 and 1852.

[5] A patent application could take the form of either a "complete specification" of the invention or a "provisional specification". Provisional specifications allowed inventors to claim for priority on their invention even if it was incomplete. A complete specification of the invention was required by the Patent Office within nine months of the application date under the new law. See further, Cunynghame (1894).



Notes: These figures show the English inventor year dummy interaction coefficients estimated from equation 4 and the 95 percent confidence intervals. These are difference-in-differences estimates of citations to patents granted to English inventors in the United States (by their application year) compared to a control group of all other United States patents in the same year.

Fig. 7. The level of innovation: pre- and post-reform plots of difference-in-differences coefficients. (A) Coefficients relative to an 1883 baseline. (B) Coefficients relative to an 1878–1883 baseline. *Notes:* These figures show the English inventor year dummy interaction coefficients estimated from Eq. (4) and the 95 percent confidence intervals. These are difference-in-differences estimates of citations to patents granted to English inventors in the United States (by their application year) compared to a control group of all other United States patents in the same year.

rently with the 1883 Patents Act, Britain signed up – along with ten other nations – to the Paris Convention, thereby providing full patent rights to foreign inventors from the signatory countries.[6]

Despite representing a watershed in the history of patenting, neither contemporaries nor modern researchers have systematically examined how patenting behavior or innovative activity changed after the reform. The government expected a large increase in patent applications once the new Act took effect on January 1st 1884, and it could afford the reduction in fees given the £2m surplus it had amassed since 1852 (Boehm and Silberston, 1967, p. 31).[7] Yet, the actual increase in the number of patent applications far exceeded estimates.[8] Between January and April of 1884, 7060 applications were filed, over 1000 more than had been filed in the entire year of 1883 (Report of the Comptroller General of Patents, 1884). The remainder of the paper examines who these new patentees were and the impact of the reform on innovation.

Table 1
Patent sample descriptive statistics.

	Pre-reform (1878–1883)	Post-reform (1884–1888)
Patents	4604	9279
Location (%)		
Foreign	42.9	31.1
Britain	57.1	68.9
London	23.2	20.3
Birmingham	4.8	6.0
Liverpool	2.7	2.6
Manchester	5.4	4.6
Organization (%)		
Company owned	9.7	12.4
Sectors (%)		
Agricultural	11.9	11.1
Chemicals	5.4	4.3
Electricity	6.1	3.8
Food	1.8	1.2
Scientific instruments	1.1	1.3
Steam	4.2	3.7
Textiles	5.1	3.7
Other mechanical	17.4	16.9
Patent quality		
Length of patent (years)	5.0	5.4
	(3.3)	(2.8)
High value patents (%)	5.6	5.4
Low value patents (%)	66.9	69.9

Notes: Descriptive statistics based on 20 percent random samples of sealed patents by their application date. Standard deviations are in parentheses. Percentages for London, Birmingham, Liverpool and Manchester reflect the share of patents within Britain by inventors located in these cities. Patents not allocated into one of the sectors shown fall into a miscellaneous category. High value patents are full term patents where the inventor that paid renewal fees to keep the patent in force up to the statutory limit of 14 years. Low value patents are those for which the first renewal fee was not paid.

3. The data

Patents have been used extensively as a metric for measuring inventive activity in the economics of technological development (Griliches, 1990). I use 20 percent random samples of patents by their application date between 1878 and 1888. All these patents were subsequently sealed. The data were hand entered from the original patent specifications filed by inventors and from the official journals summarizing these patents published annually by the British Patent Office. I use patents that were sealed as of their application date because the average pendency period for a patent at this time was 3–10 months in duration (Van Dulken, 1999, p. 32). This gives more temporal precision to the estimates.

Descriptive statistics are given in Table 1. The data show a high proportion – over one third – of British patents were issued to foreign inventors, around six times the share granted to foreigners in the United States. Inventors from three countries – the United States, France and Germany – accounted for the majority of patents in Britain both before and after the reform. Interestingly, the proportion of patents by foreign inventors declined by almost 12 percentage points after the reform, suggesting that British inventors accounted for a disproportionate share of the increase in patenting illustrated in Fig. 1A. To the extent that – other than France – the foreign signatory countries of the Paris Convention

[6] These are: Belgium, Portugal, France, Guatemala, Italy, the Netherlands, San Sebastian, Serbia, Spain and Switzerland. The United States signed up in 1887. If priority was established under the Paris Convention, an inventor could claim patent rights from the date of the original foreign application.

[7] The government also stated it would not collect more in patent fees than it cost to administer the patent system.

[8] Chamberlain anticipated a 50 percent increase in applications in 1884, but they increased by almost 280 percent.

Table 2
Examples of high and low value patents.

Patent	Application year	First named inventor	Town/city, county (country)	Invention
			High value	
4949	1878	H. Von Alteneck	Berlin (Germany)	Electric lamp
1358	1879	T. Nelson	Edinburgh, Midlothian (Scotland)	Printing and paper staining machine
1855	1880	C.J.W Jakeman	Greenwich, Kent	Steam fire engine
424	1881	A.R. Pechiney	Salindres (France)	Making chlorate of soda and potash
1304	1882	T. Nalder	Wantage, Berkshire	Threshing machine
4428	1883	A.P. Price	Mannheim (Germany)	Coloring matters for dyeing and printing
2155	1884	W. Lockwood	Sheffield, South Yorkshire	Spring-packing for pistons
5208	1885	P.B. Delany	New York (USA)	Facsimile or automatic telegraphy
9472	1886	H.L. Lange	Manchester, Lancashire	Rack and pinion locomotive
16,161	1887	E. Marshall	Gaythorn, Lancashire	Raising nap upon textile fabrics
3654	1888	E. Jagger	Oldham, Lancashire	Placing cop tubes upon spindles of mules
			Low value	
2772	1878	F.A. Gatty	Accrington, Lancashire	Dyeing yarns and fabrics
2223	1879	J.H. Johnson	Newark (USA)	Sewing machine
4479	1880	W. Griffiths	West Bromwich, Staffordshire	Puddling, heating, and balling furnace
2669	1881	G. Anderson	Westminster, London	Gas retorts pipe
3750	1882	J.H. Gartrell	Penzance, Cornwall	Dental plate
666	1883	H. Marlow	Shepherds Bush, Middlesex	Apparatus for speaking and hearing simultaneously
12,466	1884	F.W. Hofmann	Breslau (Germany)	Sawing machinery
7269	1885	C. Kaiser	Leipzig (Germany)	Boots
2293	1886	W.B. Gasson	Southborough, Tunbridge Wells	Cricket bat
31	1887	F. Beauchamp	Tottenham, Middlesex	Window fastner
19,024	1888	J.V. St Day	New York (USA)	Bird replica for use in theatre

Notes: High value patents are full term patents where the inventor that paid renewal fees to keep the patent in force up to the statutory limit of 14 years. Low value patents are those for which the first renewal fee was not paid.

account for only around 2 percent of patents both before and after the reform, the 1883 treaty is not a confounding influence on patenting.

The location of British inventors before and after the reform is shown in Fig. 2A and B. For patent applications in the period 1878–1883 heavy geographic clustering of inventors in London is evident with over 20 percent of British patents being issued to inventors located there in both the pre-reform and post-reform periods despite it accounting for 16 percent of the population. In the post-reform period, clusters of invention can also be seen in Fig. 2B in Birmingham, Liverpool and Manchester although in relative terms, as the percentage of patents for inventors located in these cities shows, there was no noticeable change across the different patent cohorts in Table 1. Cities – especially London – dominated the patent statistics at this time, which is consistent with the literature emphasizing the significance of urban areas as hubs of innovation in the late Victorian era (Lee, 1981; Crafts and Leunig, 2009).

Penrose (1973, p. 769) wrote that “one of the effects of patents is supposed to be to assist the small man with few resources to protect his position against the large well-financed firm”. Thus, I coded up patents to reflect those that were owned by

Table 3
The impact of the reform on the change in the propensity to patent.

	All patents		High value patents		Low value patents	
	Post reform dummy	Standard error	Post reform dummy	Standard error	Post reform dummy	Standard error
Location						
British	0.1823	[0.0253][a]	−0.0378	[0.1045]	0.2526	[0.0302][a]
London	−0.0410	[0.0265]	−0.0703	[0.1107]	−0.0584	[0.0328][c]
Birmingham	0.0239	[0.0119][b]	0.0926	[0.0392][b]	0.0238	[0.0148]
Liverpool	−0.0079	[0.0113]	0.0287	[0.0359]	−0.0098	[0.0142]
Manchester	−0.0059	[0.0135]	−0.0247	[0.0791]	0.0078	[0.0140]
Hinterlands of large cities	−0.0274	[0.0188]	−0.0816	[0.0899]	−0.0398	[0.0242][c]
>50 miles from large cities	0.0265	[0.0281]	0.0538	[0.1224]	0.0246	[0.0341]
Organization						
Company owned	0.0147	[0.0155]	0.0117	[0.0923]	0.0142	[0.0169]
Sectors						
Agricultural	0.0083	[0.0161]	0.0200	[0.0712]	0.0012	[0.0195]
Chemicals	−0.0136	[0.0116]	0.0006	[0.0588]	−0.0172	[0.0136]
Electricity	−0.0337	[0.0132][b]	−0.0252	[0.0512]	−0.0119	[0.0137]
Food	0.0023	[0.0056]	0.0019	[0.0229]	0.0033	[0.0063]
Scientific instruments	0.0068	[0.0048]	0.1701	[0.1225]	0.0050	[0.0062]
Steam	0.0066	[0.0092]	−0.0813	[0.0561]	0.0029	[0.0113]
Textiles	0.0081	[0.0094]	0.0239	[0.0419]	0.0104	[0.0109]
Other mechanical	−0.0524	[0.0206][b]	−0.0098	[0.0900]	−0.0476	[0.0244][c]

Notes: Coefficients are marginal effects from probit regressions where the dependent variable is a zero-one dummy to identify categories listed in the left-hand column. The post-reform dummy is coded 1 for the period 1884–1888 and zero otherwise. All specifications include a time trend, real GDP, a count of the population each year and Feinstein's (1972) times series on plant and machinery investment. Robust standard errors reported in parentheses.

[a] Significance is at the 1 percent level.
[b] Significance is at the 5 percent levels.
[c] Significance is at the 10 percent levels.

Table 4
Great inventor patent citation results.

	Great inventor Coefficient	Implied citation Premium
Citations 1947–2008	0.341 [0.097][a]	41%
Citations 1947–1977	0.283 [0.064][a]	33%
Citations 1978–2008	0.225 [0.104][b]	25%

Notes: Great inventor patents are those granted to inventors listed in Hughes (1989), p. 16 between 1878 and 1898 and are coded 1 and all other patents granted by the USPTO during the same time period are coded 0. The great inventor coefficient is from a patent-level negative binomial regression of patent citations on the coded variable. Three regressions are run with citations from different periods. Year dummies and technology category controls are also included in the regressions. The implied citation premium to great inventors is calculated as [exp(great inventor coefficient) − 1] × 100.

[a] Significance is at the 1 percent level.

[b] Significance is at the 5 percent levels.

independent inventors versus corporations. Although the time period for patents here (1878–1888) pre-dates the era of large scale corporations,[9] including details on the organizational origins of inventive activity is informative. For example, in a study of a modern reform – Canada's switch from a first-to-invent to a first-to-file system in 1989 – Lo and Sutthiphisal and Shin-Tse (2009) find corporations exploited the change, leading to a small adverse shift in patent protection against independent inventors and small businesses. On average, I find 10 percent of patents were owned by corporations in the pre-reform period rising to just over 12 percent in the 1884–1888 period.

Finally, in the absence of a comprehensive official classification scheme, I also coded patents by sector, relying on a description of the invention given in the specification. The British Patent Office did categorize patents as *Abridgements of Specifications*, but these are not well organized over time. Up to 1883 the scheme includes 103 categories and from 1884 it includes 146 largely different classes. Patents back to 1877 were retrospectively categorized into the second of these schemes, but since they are not arranged by patent number from 1884, patents in the post-reform sample data used here cannot be systematically located (Van Dulken, 1999, p. 129). Using the alternate coding method, the distribution of patenting by sector is revealing from the standpoint that the patent disclosure tradeoff varies significantly across industries, with sectors like chemicals and food likely to be particularly responsive to changes in underlying patent institutions (Cohen et al., 2000; Moser, 2005). The means in Table 1 reveal pre-and-post distributions of patenting by sector to be approximately equivalent.

3.1. Renewal fees

A major issue is the extent to which patent quality changed with the policy of cheaper access to patent protection. Given the large jump in patent applications, and the absence of a full examination system by the British Patent Office, it is plausible that much of the increase in patenting reflected frivolous patents that abolitionists had campaigned against half a century before. Certainly some of the increase in applications reflected this. While the standards for patentability of an invention remained the same, the number of applications increased at a faster pace than patents sealed (Fig. 1A and C). Moreover, even for patents that proceeded to sealing, the quality of invention would have varied.

To test for relative differences in the quality of technological discoveries in sealed patents, I use renewal fee data to trace the time period each patent in the sample was kept in force. The basic intuition follows Schankerman and Pakes (1986), who develop a model of patent renewal according to which inventors choose a patent term where the present discounted value of net returns to the patent are positive.[10] Accordingly, high value patents should be kept in force longer. While the application of this model to historical British patent data may lead to underestimates of the value of patent rights, because numerous examples show that credit constrained inventors did not pay renewal fees on important patents (MacLeod et al., 2003), the utility of the Schankerman–Pakes approach has been verified in numerous historical settings (Streb et al., 2006; Brunt et al., 2008). By enhancing the signal-to-noise ratio of raw patent counts, renewal fee data provide a good approximation of patent quality.

For the patents in the dataset, renewal fee data were hand entered from the official journals of the British Patent Office which list patents by their number according to those that were kept in force or allowed to lapse. Because the rules under which renewal fee payments were due changed for patent cohorts with the 1883 Patents Act – when £150 could be paid in annual installments rather than under the old system of £50 by the end of the third year and £100 by the end of the seventh year – and again in 1892 when renewal fees were charged linearly with year, I calculated the patent cohort specific cost an inventor would be charged for renewing their patent for the full term (see the Appendix for details and the empirics below). Table 1 shows that the average patent term in Britain was around 5 years pre-and post-reform.

Fig. 3 illustrates the lifespan of patent protection for pre- and post-reform patent cohorts. Following the introduction of a one year delay in the payment of the first renewal fee from the end of the third year to the end of the fourth year, which is clearly visible in the data, the distributions converge at year 5 of a patent term. Interestingly, a similar share of patents in each time period was carried to 14 years. Since the propensity to patent went up significantly in 1884 (Fig. 1A), this means that more patents were being kept open for a full term after the reform. Between 1878 and 1882, 1163 high value patents were carried to the statutory limit rising to 2519 between 1884 and 1888. The number of low value patents lapsing through non-payment of the first renewal fee also increased from 22,113 to 47,150, respectively.

Table 2 shows high value patents include technologies such as Delany's automatic telegraph system, which revolutionized the early telecommunications industry. Delany received gold medals in recognition of his invention in 1885 at the International Inventions Exhibition in London, in 1901 at the Pan-American Exposition in Buffalo, and in 1904 at the St. Louis Exposition. T. Nalder, of Nalder & Nalder, the agricultural equipment manufacturer from Wantage in Berkshire won a silver medal for his threshing machine at the 1882 Royal Agricultural Show in Reading, England. Low value inventions include W.B. Gasson's cricket bat, or the theatrical bird patented by J.V. St. Day. Not all these low value patents were technologically inferior. Rather, the inventor failed to pay the renewal fee

[9] For example, in 1885 there were 60 domestic manufacturing and distribution firms quoted on the London stock exchange compared to over 600 a decade later (Hannah, 1983, p. 20).

[10] That is, if an inventor holding a patent i in cohort j receives a return R to patent protection (which absorbs the probability of technological obsolescence) in each year t and holds the option of keeping the patent term open by paying the renewal fee C, up to a statutory limit T, with discount rate π, the patent will be kept in force so long as the economic value of the patent $V \geq 0$:

$$V_{ijt} = \sum_{t=1}^{T} R_{ijt}(1+\pi)^{-t} - \sum_{t-1}^{T} C_{ijt}(1+\pi)^{-t} \; t = 1, 2.., T.$$

Table 5
The impact of the reform on the level of innovation.

	Post = 1884–1888		Post = 1884–1886		Post = 1884–1898	
	All citations	Citations > 0	All citations	Citations > 0	All citations	Citations > 0
	0.1112	0.0188	0.1125	0.0204	0.1129	0.0179
	[0.0587][c]	[0.0461]	[0.0586][c]	[0.0461]	[0.0587][c]	[0.0461]
Post	0.1236	0.0558	0.0976	0.0468	0.2471	0.1020
	[0.0102][a]	[0.0081][a]	[0.0081][a]	[0.0097][a]	[0.0083][a]	[0.0066][a]
English·post	0.0497	0.0544	−0.0096	−0.0087	0.0081	0.0386
	[0.0757]	[0.0593]	[0.0883]	[0.0666]	[0.0632]	[0.0498]
observations	206,708	69,368	163,975	54,202	427,121	154,591

Notes: Coefficients are from patent-level negative binomial difference-in-differences regressions where the dependent variable is a count of citations in United States patents granted between 1947 and 2008. The treatment group is coded 1 for patents granted to English inventors in the United States and zero otherwise. The post-reform dummy is coded 1 according to the time period given in the top row of the table. All specifications include technology category controls. Robust standard errors reported in parentheses.
[a] Significance is at the 1 percent level.
[c] Significance is at the 10 percent levels.

either because the expected private value of the patent was less than the fee required (Schankerman and Pakes, 1986), or credit constraints prevented otherwise economically valuable patents from being renewed (MacLeod et al., 2003).

4. The change in the propensity to patent

I use the data categories listed in Table 1 to test for changes in the propensity to patent that parallel the trends illustrated in Fig. 1A. Consider the following two regressions specified at the patent-level i for pooled cross sections t = 1878, 1879. . .,1888.

$$\text{OUTCOME}_{it} = \alpha_0 + \alpha_1 \text{POST}_t + \alpha_2 \text{TIME}_\text{t} + \mathbf{X}'_t \gamma + \varepsilon_{it} \quad (1)$$

$$\text{OUTCOME}_{\text{it}} = \beta_0 + \sum_{t=1878}^{t=1888} \delta \text{YEAR}_t + \varepsilon_{it} \quad (2)$$

In a discrete choice model with, for example, the outcome variable coded 1 for British inventor patents and 0 for foreign inventors, the parameter on POST, the post-reform dummy in Eq. (1), measures the change in the probability of observing a British inventor patent in the post-reform period *relative to in the pre-reform period*. The time trend, *TIME*, and the vector **X** control for any contemporaneous omitted variables as proxied by real GDP from Officer (2008), a count of the population each year from the censuses and Feinstein's (1972) times series on plant and machinery as a measure of demand. In Eq. (2) the set up is such that a full set of year dummies (YEAR) is included with 1883 omitted so that the δ coefficients are measured *relative to the year of the reform*. Because there were no other confounding macro shocks, tracing out the year dummy coefficients provides an empirical test of whether changes in the outcome measures are coincident with the patent reform.[11] Notice also from Fig. 1A that both the pre-reform period and the year of the reform – 1883 – exhibit stable trends in patenting. They are therefore useful baselines for estimating pre- and post-reform differences under the assumption that pre-existing trends would have continued absent of a change in the patent law.

In addition to running these regressions on the full sample of patents, I run them on sub-samples of high and low value patents, to test for changes in inventor and invention characteristics within these categories of invention after the reform relative to before.

[11] In that sense my empirical approach is related to Sakakibara and Branstetter (2001) who look for evidence of more innovation after Japanese legal reforms expanded patent scope in 1988. Their identification comes from examining year dummy shifts in firm-level regressions to see if they could plausibly be explained by the 1988 legal changes.

4.1. Results

Table 3 provides marginal coefficients on the variable POST from probit estimates of Eq. (1) on all patents and high and low value patent sub-samples. Fig. 4A–R plot the coefficients from the year dummies in Eq. (2). These plots are observationally similar in most cases whether the regressions are run on all patents or for high or low value patent sub-samples, so I only include the former to illustrate the changes.

The parameter estimate for all patents in Table 3 shows that there was an economically large and statistically significant change in the share of British versus foreign inventors after 1883. The probability of observing a patent by a British inventor increases by [exp(0.1823) − 1] × 100 = 20 percent relative to the pre-reform period and this effect was concentrated in the low value distribution of patents. The year dummy plot in Fig. 4A reveals a pattern in the data consistent with Fig. 1A, although note that the strong positive effect of the reform on British inventors attenuates towards the end of the event window. The probability of observing a patent by a British inventor falls from 16 percent in 1884 to 10 percent in 1888. The immediate effect of the change in the patent law was to increase the rate of patenting by British inventors, but foreign inventors closed the gap within half a decade of the reform being implemented.

Within Britain, London was the single most important location for patentees in the late nineteenth century (Table 1) and the probability of observing a patent by a London-based inventor does not change significantly in the post-reform period based on the full sample estimates with only a small (6 percent) change in the probability when comparing low value patents after the reform to low value patents before the reform. While the year dummies for 1884–1888 in Fig. 4B are all statistically significant from zero, indicating an effect relative to the baseline year of 1883, the 95 percent confidence intervals also overlap with the confidence intervals for the coefficients for the pre-reform years 1878–1882.

The estimates in Table 3 imply a small positive increase in the probability of observing a patent from an inventor in Birmingham and a larger increase when comparing high value patents. None of the year dummies, however, is statistically significant at the customary levels either for the full sample (Fig. 4C) or for high value patents. The probability of observing a patent from an inventor located in Manchester or Liverpool does not change significantly. Neither does the probability of observing an inventor in the hinterlands of major cities (within a 5–10 mile band of London, Birmingham, Liverpool and Manchester) change in an economically meaningful way. Although the reform permitted inventors to post their applications to the Patent Office off Chancery Lane, central London, rather than delivering them directly in person (or through a patent agent) the results show that patenting rates by inventors who were fully delocalized (more than 50 miles) from a major city did not change significantly after the reform.

Turning to the organization of invention, none of the coefficients of the post-reform dummy are statistically significant. Although some of the year dummy coefficients are statistically different from zero in Fig. 4H (i.e., 1884, 1885 and 1886) implying the probability of observing corporate patentees increased after the reform, the estimates do not parallel the step jump in aggregate patenting illustrated in Fig. 1A. Lowering the cost of patenting, while it may have increased access to patent protection for less wealthy inventors, did not significantly change the mix of patents issued to independent inventors and corporations.

Given that the patent disclosure tradeoff varies strongly across industries (Cohen et al., 2000), some of the most important null results occur with respect to the sectoral distribution of patents. Out of 24 post-reform dummy coefficients in Table 3, only three are statistically significant in two sectors – electricity and other mechanical, while none of the year dummy coefficient plots (Fig. 4I–P) has a similar shape to Fig. 1A even though some of the individual year effects are statistically different from zero (e.g., Fig. 4J, N and O). Moreover, although the probability of observing an electric related patent falls by 3 percent in the post-reform era according to the estimate reported in Table 3, this is driven by outlying years (Fig. 4L). In 1882, for example, the number of electric inventions increased to 101 from 47 in the previous year. The coefficients for the other mechanical sector, while statistically significant in regressions using both all patents and low value patents, are economically small.

In sum the sizeable aggregate effect shown in Fig. 1A does not mask any location-based, organizational or industry-specific shifts in patenting. Rather, the effect of cheaper patents was to induce a step jump in the overall propensity to patent.

5. The level of innovation

Patents are commonly used as an output measure of innovation, but in this case the propensity to patent and the level of innovation are highly conflated. Fig. 5A and B illustrates the lifespan of patented inventions between 1878 and 1888. The point estimates and 95 percent confidence intervals in Fig. 5A are from an OLS regression of patent length, defined as the number of years that a patent was kept in force through the payment of renewal fees, on year dummies. The time path of the coefficients indicates that post-reform patents were kept in force for approximately an additional half a year, which is shorter than would be implied by the one year mechanical increase in patent life caused by the change in the renewal fee structure.[12] But this was not associated with a change in the share of high value patents.[13] Fig. 5B illustrates the coefficients from a probit regression with a dependent variable coded 1 for full term patents and 0 for patents that were allowed to lapse before the statutory limit. The economic value of these patents would exceed the renewal cost so the regression will be less likely to be confounded by the changing structure of the renewal fees. The year dummy coefficients show that the probability of observing full term patents is statistically the same before and after the reform.

These results have conflicting implications. To the extent that the absolute number of low value patents increased after the reform (also shown by Fig. 3), it may not have boosted innovative activity, or even harmed it if patent protection on low value inventions enabled inventors to engage in rent-seeking activities (Boldrin and Levine, 2008). On the other hand, the arrival of cheaper patent protection meant that the absolute number of high value inventions disclosed through patenting more than doubled after the 1883 reform which may have positively impacted innovation through the diffusion of useful knowledge and cumulative technological developments (Scotchmer, 2004). The number of visitors to the British Patent Office library increased more than 20 percent from 32,748 in 1883 to 39,508 in 1884, while sales of patent specifications increased by 37 percent from £2833 to £3893, so there was certainly additional interest in consulting patent documents at the time.[14]

To test for an effect of the reform on the level of innovation I examine the technological significance of patents granted to English inventors in the United States. While the reform could have changed both the quality and intensity of research effort, only the former can be determined with any degree of precision using the available data. The United States provides a useful baseline country because patent policy remained constant there until 1887 when it signed up to the Paris Convention treaty. In other words, patented inventions observed there are less likely to be contaminated by changes in the propensity to patent.[15] The approach is analogous to Lerner (2009) who examines major patent policy changes in sixty nations over the past 150 years. He looks for shifts in patent applications in Britain made by residents of the nation where the policy change took place. I identified 9425 patents by English inventors that were filed between 1878 and 1898 at the United States Patent and Trademark Office and subsequently granted. I extended the data collection to 1898 to test for longer run shifts in patenting due to the gradual diffusion of new knowledge after the 1883 reform.

Because raw patent counts are a very crude measure of innovation, I examine changes in citations to patents under the assumption that citations reflect the stock of useful knowledge on which subsequent technological development builds (Hall et al., 2005; Nicholas, 2008). I obtained counts of citations to each patent using a dataset of prior art references in United States patents granted between 1947 and 2008 as described in Nicholas (2010). 1947 is the first year that patent citations were systematically included on patent documents. Although the lag between citing and cited cohorts is long, it is much shorter than in the NBER data files, where citing patents start with those granted in 1975. Fig. 6 highlights the additional citations that are observed with the new data. 35 percent of patents granted during the period 1878–1898 are cited in patents granted between 1947 and 2008 compared to 17 percent in the NBER data file which captures patent citations in patents granted between 1975 and 2006.

One concern with the citations data is that the signal-to-noise ratio decays over time. That is, patent citations are an effective measure of technological significance within around a decade of the patent grant date when most citations typically occur (Caballero and Jaffe, 1993) but they are less effective as the gap between citing and cited patents becomes larger. To test for this possibility I collected an additional dataset of 1263 patents granted to great inventors between 1878 and 1898. Great inventors are defined as

[12] Recall that after the 1883 reform renewal fees could be paid by annual installment and the first renewal fee was due by the end of the fourth year, rather than at the end of the third year under the prior system of patent renewal.

[13] Patents in the middle of the lifespan range appear to have been kept open for slightly shorter terms. See Fig. 3, which highlights a dip for post-reform patent cohorts between years 5 and 8 of the patent term.

[14] Numbers taken from the 1884 and 1885 report of the Comptroller General of Patents.

[15] Inventor addresses were identified off optical character recognition of the patent specifications. I use English inventors rather than British inventors to filter out Commonwealth country inventors who identified themselves as British, but who would have been less likely to be influenced by the 1883 reform.

those listed in Hughes' *American Genesis* as prominent figures in the rise of U.S. technological development.[16] These individuals pushed out the innovation frontier so citations to their patents should be higher relative to otherwise equivalent patents. Table 4 reports the results of negative binomial regressions of a count of patent citations on a great inventor indicator variable, year and patent class dummies. The implied citations premium is large and highly statistically significant when the dependent variable is citation counts between 1947 and 2008. Furthermore, the coefficient on the great inventor indicator is positive and clears the customary threshold for statistical significance when the regression is run separately with citations from 1947 to 1977 and citations from 1978 to 2008. This implies that historical citations are useful for identifying the technological significance of inventions even at long and variable lag lengths.

To estimate the effect of the 1883 reform I use the historical citations counts in a simple difference-in-differences framework. In Eqs. (3) and (4) the treatment group is English inventor patents and the control group is all other patents granted in the United States. In Eq. (3) the post-reform dummy is coded 1 to identify the period 1884–1888, and then in additional regressions it is coded 1 for the period 1884–1886 to avoid potential confounds arising from the signing of the Paris Convention treaty in 1887 and finally 1884–1898 to test for longer run changes in the quality of patenting. Note that because of the citations lag shown in Fig. 6 where the knowledge contained in earlier patents gets absorbed into later patents over time, or earlier patents become technologically obsolete, the coefficient on the post-reform dummy will be positive as later patents receive higher citations counts. This mechanical difference in citation counts over time does not affect the main coefficient of interest in the difference-in-differences specification which tests for relative differences between treatment and control patents after the reform compared to before. In Eq. (4) individual year dummies are used with two baselines: 1883 dropped so that any differences between the treatment and control groups are evaluated relative to this year; and the years 1878–1883 dropped so that differences are evaluated relative to the entire pre-reform period. In both specifications the coefficients of interest are those on the interacted variables.

$$\text{CITATIONS}_{it} = \theta_0 + \theta_1 \text{ENGLISH}_{it} + \theta_2 \text{POST}_t + \theta_3 \text{ENGLISH} \cdot \text{POST}_{it} + \varepsilon_{it} \quad (3)$$

$$\text{CITATIONS}_{it} = \pi_0 + \pi_1 \text{ENGLISH}_{it} + \sum_{t=1878}^{t=1898} \delta \text{YEAR}_t + \sum_{t=1878}^{t=1898} \varphi \text{ENGLISH} \cdot \text{YEAR}_{it} + \varepsilon_{it} \quad (4)$$

Table 5 shows that the coefficient θ_3 from Eq. (3) is statistically insignificant across all the specifications: changing the post-reform period to filter out the effect of the Paris Convention; when accounting for short and long run effects of the reform; and when estimating the treatment effect of the reform on all patents and higher quality patents cited at least once. As expected, due to the effect of the citations lag, θ_2 is positive and statistically significant.

Fig. 7A, which plots the φ coefficients from Eq. (4), reveals that the treatment effect is statistically significant from zero in only one of the post-reform years – 1886 – and even this effect is not robust to changing the baseline in the difference-in-differences regression, as shown in Fig. 7B.[17] Moreover, because the odds of finding an effect are much higher in these specifications because any serial correlation will bias the standard errors downward (Bertrand et al., 2004) the failure to reject the null hypothesis of no effect is even more compelling. The evidence strongly suggests that the 1883 patent reform did not increase the level of innovation as measured by relative differences in the technological significance of inventions.

6. Conclusion

This paper has studied one of the most significant reforms in the history of patent laws – the 1883 Patents Act – in an attempt to determine the effect of cheaper access to patent protection on both the propensity to patent and the level of innovation. The new law, by reducing fees for a patent, led to a large spike in the number of patents in force, but it did not change the geographic structure of invention, its organizational composition, its sectoral distribution or the quality of technological developments that were patented. Although the reform took place over a century ago the findings are relevant for current patent policy debates concerning large cross-country differences in filing fees, especially in Europe relative to in the United States and Japan. Policy makers have long been concerned that implementing changes in patent laws can lead to large distortions by changing the incentives for inventors. The current findings show, as would be expected, that lowering the cost of patents increases the propensity to patent, but more importantly that this can occur without distorting distributional consequences.

Equally it is important to recognize that bringing inventive activity inside of the patent system does not equate with a boost to innovation. In the case of the 1883 reform inventors were highly responsive to the reduction in fees, but the propensity to patent effect dominated the level of innovation effect. While the number of patents increased 2.5-fold, I find no evidence of a change in citations to patents by English inventors in the United States in response to the British patent reform in the short or the long run. Furthermore, some inventors who patented immediately following the implementation of the 1883 Act must have been incentivized through other ways than patents at their current cost prior to the patent regime change. Cheaper patents can satisfy a latent demand for patent protection without detrimental distortions, but other mechanisms may be more desirable if the goal is to shift the overall level of innovation.

Appendix A. Renewal fee rules

See Tables A1–A3.

[16] See further Hughes (1989), p. 16. These are Hiram Stevens Maxim, Alexander Graham Bell, Thomas Edison, Elihu Thomson, Nikola Tesla, William Stanley, Elmer Sperry, Reginald Fessenden, Wilbur and Orville Wright, Lee de Forest and Edwin Armstrong. The Wright brothers did not patent in the time frame and Edwin Armstrong was only born in 1890. Therefore the patents used in this analysis were granted to the other inventors in the list.

[17] Fig. 7A and B look observationally similar when the regression are run on non-zero citations.

Table A1
Renewal fee system prior to the reform.

		First fee	Annual renewal fee (assuming first fee of £50 paid)												Total
			1885	1886	1887	188518	189	1890	18931	1892	1893	1894	1895	1896	
Year of patent	1878	50	10	10	10	15	15	20	20						150
	1879	50		10	10	10	15	15	20	20					150
	1880	50			10	10	10	15	15	20	20				150
	1881	50				10	10	10	15	15	20	20			150
	1882	50					10	10	10	15	15	20	20		150
	1883	50						10	10	10	15	15	20	20	150

Table A2
Renewal fee system after the reform.

		Annual renewal fee (assuming all fees paid by annual installment)																	Total
		1885	1886	1887	1888	1899	1890	18991	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	
Year of patent	1881	10	10	150	150	15	15	20	20	20	20								150
	1882		50	150	150	150	15	15	20	20	20	20							150
	1883			150	150	150	150	15	15	20	20	20	20						150
	1884				150	150	150	150	15	15	20	20	20	20					150
	1885					150	150	150	150	15	15	20	20	20	20				150
	1886						150	150	150	150	15	15	20	20	20	20			150
	1887							150	150	150	150	15	15	20	20	20	20		150
	1888								150	150	150	150	15	15	20	20	20	20	150

Table A3
Renewal fee system under the rules of 1892.

		Annual renewal fee									New	Old	Total
		1893	1894	1895	1896	1897	1898	1899	1900	1901			
Year of patent	1880	14									14	130	144
	1881	13	14								27	110	137
	1882	12	13	14							39	90	129
	1883	11	12	13	14						50	70	120
	1884	10	11	12	13	14					60	55	115
	1885	9	10	11	12	13	14				69	40	109
	1886	8	9	10	11	12	13	14			77	30	107
	1887	7	8	9	10	11	12	13	14		84	20	104
	1888	6	7	8	9	10	11	12	13	14	90	10	100

Notes: These tables show the renewal fee rules as reported in the official journals of the British patent office. The left-hand vertical set of years refers to the year of the patent cohort. The horizontal years refer to the year that a renewal fee was due to keep the patent in force subsequently. Total is the amount (in £) that a patentee would be required to pay to keep the patent in force for a full term of 14 years. Since patent cohorts could fall under different rules, in Table A3, New refers to the total amount that an inventor would pay to keep their patent in force under the 1892 ruling. Old refers to the total amount an inventor would pay under the renewal fee schedules in Tables A1 and A2. Total is then the sum of the new and old amount required to keep a patent in force up to the statutory limit.

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