THE QUALITY OF ENGLISH PATENTS, 1617-1841: A REAPPRAISAL USING MULTIPLE INDICATORS

by

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VERY PRELIMINARY DRAFT!!!

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1. INTRODUCTION

In two influential papers Richard Sullivan (1989, 1990) argued that patent statistics can shed light on the ongoing debates on the timing and the nature of innovation during the industrial revolution. The time series of English patents exhibits a significant structural break around 1760 and this would seem to indicate, at least according to Sullivan, an acceleration of technical progress taking place around that period. Furthermore, the distribution of patents across sectors displays a rather low level of concentration, pointing to a widespread nature of inventive activities. Considered together these two findings could be regarded as providing evidence for the "traditional" interpretation of the Industrial Revolution as a phase of rapid and widespread economic change, while contradicting the recent revisionist view put forward by Crafts and Harley arguing for a more gradual dynamics, initially restricted to only a handful of modernized sectors (Crafts and Harley, 1992).

Sullivan's findings are, however, critically dependent on the reliability of patents as indicators of innovation. In this respect, it is well known that the use of patent counts as indicator of innovation is fraught with two major difficulties (Griliches, 1990, pp 1169). The first difficulty is that not all inventions are patented. Historians such as MacLeod (1988), O'Brien, Griffiths and Hunt (1995) and more recently Nuvolari (2004) and Moser (2005, 2010) have suggested that in this period a significant share of inventive activities was undertaken outside the coverage of patent protection. Therefore, one should be extremely cautious in gauging the dynamics of invention during the industrial revolution by looking at trends in patent counts. The second difficulty is the variation in the quality of patents.[1] As noted by O'Brien, Griffiths and Hunt (1996):

> Even recorded inventions cannot be aggregated without some system of weighing to account for variations in their economic and technological significance. If this were not done, Hargreaves' spinning jenny would be accorded the same weight in the aggregate as Peter Valloton's patent for manufacturing hosiery pieces adapted for the wear of persons afflicted with rheumatism and gout, which was taken in the same year.

Clearly, the use of simple patent counts as indicator of inventive output amounts to consider each patented invention as having the same economic value ('quality'). This appears immediately as an unduly restrictive assumption, especially, if one is interested in the reconstruction of the contours of technical change in an historical phase when inventive activities where punctuated by fundamental technological breakthroughs as it is the case for the industrial revolution period.

In this paper we try to address this problem by constructing a new composite indicator of the quality of English patents granted in the period 1617-1841. Our approach is inspired by Lanjouw and Schankerman (2004) and van Zeebroeck (2011) who have developed two methods for constructing composite indicators of patent quality for modern patents. Our composite indicator is based on the combination of three proxy variables of patent quality constructed using three different type of sources: i) the relative "visibility" of each individual patent in the contemporary technical and legal literature as summarized in Bennet Woodcroft' s *Reference Index of Patents of Invention*, ii) the relative "visibility" of the invention covered by the patent in authoritative reference texts and catalogues of history of technology, iii) the relative "visibility" of the inventor of the patent in reference texts and specialized biographical dictionaries.

The second step of our analysis is to examine the distribution of high quality patents both over time and across industrial sectors. We find that, in comparison with the distribution of total patents over time, the distribution of high quality patents is clustered on an earlier period. Additionally, the distribution of high quality patents across industries is significantly more

[1] In the words of Kuznets (1962, p. 37): "[T]he main difficulty with patent statistics is, of course, the enormous range in the magnitude of the inventions covered…patented inventions do differ widely in their potential economic magnitude".

concentrated than the distribution of total patents. In this way, our proposed indicator of patent quality seems to offer a way of reconciling the patent evidence with the "revisionist view" put forward by Crafts and Harley (1992). Concerning the timing of the industrial revolution, our findings seem in line with the traditional chronology, confirming that the second half of the eighteenth century (1762-1801) was characterized by a clustering of critical technical breakthroughs (high quality patents). In terms of the scope of the change, our findings indicate that, although patents were relatively widespread across industries, patents of relatively high quality were localized in a more restricted number of sectors. Our findings can be reconciled with the dynamics of productivity growth posited in the Crafts-Harley view (Crafts and Harley, 1992) by interpreting the pattern of innovation of the industrial revolution as a two-stage process, as suggested by Mokyr (1999, pp. 20-23) and more recently by Allen (2009, pp. 135-155). The first stage, broadly coinciding with the "take-off" of the traditional chronology (1760-1800) is the phase when, in a number of key-sectors, critical technical breakthroughs, or macroinventions in the sense of Mokyr (1990, pp. 13-14), such as steam engines and textile machinery were invented. The second stage, corresponding to the period (1810-1840), may be seen as the phase during which the potential of the macroinventions became fully realized by virtue of streams of microinventions that greatly improved their performance. Obviously, it is in the second phase that we should expect to find a significant impact of technical change on productivity growth.

2. Sources and data

Economists of innovation have tried to deal with the variation in the technological and economic "importance" of patents by constructing indicators of patent quality using patent characteristics that are likely to be positively correlated with their economic value. The most widely used approach, pioneered by Trajtenberg (1990), is the assessment of the economic value of patents using the number of citations received. The intuition is relatively straightforward: when a patent has received many citations, this means that it contains knowledge that was used in a large number of subsequent technological developments. The actual existence of a positive correlation between citations received and the economic value of patents was documented by Trajtenberg (1990) for the case of US patents in computed tomography and it has been subsequently confirmed in a number of empirical studies both for US and European patents. Moreover, besides citations, other patent characteristics such as claims, family size, oppositions and legal cases have been used to construct indicators of patent quality and several studies have indeed documented, in more or less "controlled" settings, the existence of a positive, albeit noisy, correlation between these quality proxies and the economic value of patents (see van Zeebroeck, 2011 for a useful survey). On this ground, Lanjouw and Schankerman (2004), and more recently van Zeebroeck (2011) have suggested to make a further step and assess the quality of patents using "composite" indicators that should be less sensible to the vagaries of each individual proxy.

The use of patent quality indicators has surely significantly improved the effectiveness of patent data as indicators of inventive activities. Unfortunately, modern patent quality indicators cannot be applied straightforwardly to historical cases. This is also the case for the English patent system in the period 1617-1852. At that time, the English patent system did not prescribe the use of citations to previous patents for defining prior art. Furthermore, the system did not impose the payment of renewal fees after the granting of the patent. Therefore, it is necessary to look for an alternative sources suitable of being used for constructing plausible proxies for the quality of patents.

The first source we use is the *Reference Index of Patents of Invention, 1617-1852* edited by Bennet Woodcroft and published in 1855.[2] The *Reference Index* is structured in

[2] Bennet Woodcroft (1803-1879) was himself a talented inventor, who took several patents (at least two of major technical importance). During his life, he enjoyed friendships with some of the most important engineers of the time such as J. Whithworth, J. Nasmyth and R. Roberts. In 1843 he opened in London an office as patent agent and consulting engineer. In 1847 he was appointed professor of machinery at

chronological/numerical order and for each patent it reports the office of enrolment where the specification was filed.[3] Additionally, for each patent, the index gives a list of references providing information on the patent in question. These references comprise mentions in technical journals and books, law commentaries and reports, Record Office reports and other official publications such as Parliamentary Select Committees.[4] A typical entry of Woodcroft's *Reference Index* is reported here as figure 1. In this paper we use the second edition published in 1862 (Woodcroft, 1862). The patent in question (patent 913) is the one granted in 1769 to James Watt for the separate condenser. The entry gives references to technical and legal literature where the patent is mentioned, while the last line of the table indicates in which office the specification was lodged (in this case Rolls Chapel). Figure 2 provides the example of another entry. This is for a patent (patent 2544) covering an improvement in the Newcomen engine developed by William Symington. This was surely a valuable invention, but whose economic and technological significance was relatively minor in comparison to Watt's separate condenser.[5] For this patent, as one would have expected, the *Reference Index* contains a much lower number of references.

Figure 1 and 2 around here

Table 1 contains a list of all publications that were referenced more than 10 times in Woodcroft's *Reference Index* over the period 1617-1841. Overall, the publications used in the compilation of Woodcroft's *Reference Index* can be classified in three broad categories: i) publications reporting latest developments in science and technology (in particular those embodied in patents recently granted), ii) engineering journals and books containing discussion of merits and limitations of specific technical solutions, iii) legal commentaries on patent laws and cases.

The first category contains specialized journals edited by patent agents that published regularly selections of patent specifications.[6] This specialized literature represented an important channel of information fuelling the emergence of the market for patented inventions identified by Dutton (1984) in the first half of the nineteenth century. The first important publication of this kind was the *Repertory of Arts and Manufactures*, first published in 1794. In the 1820s two noteworthy new journals that published regularly selections of patent specifications were launched: the *London Journal of Arts and Sciences* edited by William Newton, and the *Register of Arts and Sciences* first issued in 1824, that had similar editorial scope. Finally, *The Inventors' Advocate and Patentee Recorder* first issued in 1839 was also an important publication with the same purposes.

The second category contains engineering journals and books that did not limit themselves to summarize the contents of patents, but discussed in more depth the merits and limitations of the technical solutions contained in some patented inventions. This is the case of journals such as *The Engineer's and Mechanic's Encyclopedia*, *Mechanics' Magazine* and *The Artizan*.

University College. In 1852 with the passing of the Patent Law Amendment Act, Woodcroft was appointed assistant to the Patent Office Commissioners. He was in charge of the publication of all the specifications of patents for the period 1617-1852 together with the relative series of indexes. On Woodcroft's life and achievements, see Hewish, (1982) and Harrison (2006, pp.55-66).

[3] The *Reference Index* was a component of a larger set of indexes that were published on requests of the Patent Office Commissioners after the patent reform of 1852. The aim of these indexes was to increase the accessibility of patent specifications. Together with the *Reference Index,* Bennet Woodcroft and his team of clerks published an *Alphabetical Index of Patentees,* a *Chronological Index of Patents* and a *Subject Index of Patents.* The publication of these indexes was followed by a further attempt to summarize and classify by subject all the existing patent specifications by publishing a series of volumes *Abridgments of Patent Specifications*. Each of these volumes contained a succinct description of all the patent specifications pertaining to a specific technological subject.

[4] There first edition of the *Reference Index* was published in 1855. A second edition based on a slightly more extensive number of references was published in 1862. In this paper we use this second edition.

[5] On Symington's improved Newcomen engine design, see Harvey and Downs-Rose (1974).

[6] See Harrison (2006, pp. 224-226) for an overview of the publishing activities of some early patent agents.

Technical treatises covering specific technology fields such as Ure's *Cotton Manufacture* and Stuart's *History of the Steam Engine* also belong to this second category.

Table 1 around here

The third category comprises publications that were clearly more aimed to be digests of patent cases, such as the famous patent treatises by Carpmael, Holroyd and Webster. However, even in these publications, legal considerations were often interwoven with technical discussions. Overall, table 1 indicates that the bulk of the publications used in the compilation of the *Reference Index* is largely of technical nature (either specialized journals publishing systematically selections of patent specifications or more elaborated technical commentaries of specific patents). The extension of this publishing activity suggests that a considerable amount of the technical information embodied in patent specifications was actually placed in the public domain by virtue of the growth of this specialized literature that reported and discussed the contents of patents (Mokyr, 2009, p. 409; Moser, 2010).

Our basic assumption is that the relative "visibility" of each patent in Woodcroft's *Reference Index* provides a reasonable proxy for its relative technical and economic significance (only patents of non-trivial economic value are likely to be extensively discussed in the technical literature or at the centre of litigations). Thus, we propose that the number of references listed in Woodcroft's *Reference Index* can serve as a reasonable proxy of the economic value or "quality" of the patent in question.[7] In particular, our approach is to assign to each patent a score that is equal to the number of references listed in Woodcroft's *Reference Index.* In our sample, this indicator has a lower bound of 0 (patents with no references and for which the index contains only information concerning the public office in which the specification was lodged) . We will refer to this variable as Woodcroft Reference Index (WRI).[8] Nuvolari and Tartari (2011) contains a preliminary exploration of the potential of this proxy as an indicator of patent quality.

This method is, at least in principle, analogous to the use of patent citations as measures of patent quality in the recent economics of innovation literature. However we should take into account that due to the expansion of the specialized literature discussing patent specifications, the average number of references per patent is not constant, but it displays an increasing trend. In other words, more recent patents tend to be mentioned in a higher number of references. Therefore, if one were to use simply the number of references as indicator of patent quality when comparing patents granted in different years, he could obtain results that are possibly biased by the variations over time in the number of references per patent. Further, it is also likely that the number of references would be affected by the type of technology covered in the patent. Note, however, that this type of problem is indeed present in modern patent data. Also in this case the propensity to cite other patents is not constant over time. For example, the computerization of patent databases during the 1980s enhanced the search of prior art for inventors and patent examiners leading to an increase in the average number of citations per patent (Hall et al., 2002, p. 418-419). In this paper, we will deal with this problem using time and industry dummies for controlling for these systematic sources of variation of the variable WRI.

The second proxy for quality is based on the relative visibility of each patent in reference books on the history of technology and invention. This approach is similar to the one adopted originally by Schmookler (1966) who compiled lists of "important inventions" for a number of industries on

[7] The *Reference Index* volume was prepared in the early 1850s. This means that Woodcroft and his team of clerks, due to lack of hindsight, may have faced more difficulties in preparing accurate and complete list of references for the most recent patents. In order to minimize this problem, in this paper we restrict our analysis to the period 1617-1841. This means that each patent in our sample can at least enjoy a period of ten years for becoming "fully visible" in the technical and legal literature.

[8] Thus, going back to the examples of figure 1 and figure 2, patent 913 is assigned a WRI score of 20 and patent 2544 a WRI score of 2.

the basis of a scrutiny of specialized historical and engineering references. In our case we use four different sources:

i) Baker (1976): Baker's patent list was meant to include the "most important" patents granted in Britain over the period 1691-1971. An initial selection was originally compiled by the staff of the enquiry desk of the British patent office in the early 1970s. This selection was extended by Baker through an extensive search in the technical and historical literature (Baker, 1976, pp. 7-25). Baker's list of important patents has been employed by Kleinknecht (1987) and Silverberg and Verspagen (2003) for testing the Schumpeterian hypothesis of the existence of temporal clusterings of radical innovations.
ii) Carter (1978): this is a catalogue of major inventions and scientific discoveries (paying specific attention to patents)
iii) Desmond (1987): another catalogue of major inventions, innovations and scientific discoveries distilled from reference works of history of technology
iv) Inkster (1991, pp. 304-306): a list of major inventions taking place in Britain in the period 1700-1870. The selection has been carried out giving particular consideration to the economic impact of the inventions.

Our second proxy variable, which we term "patent reputation" is constructed by giving to each patent a score of 4 if it is included in all sources, a score of three if it is included in three sources, etc. Table 2 reports the patents that have reached the max. score of the patent reputation variable. Not surprisingly the table contains all the most famous technological breakthroughs of the industrial revolution.

Table 2

The third proxy variable is based on the relative visibility of the inventor/patentee in biographical dictionaries and other similar sources. Khan and Sokoloff (1993) have first used inclusion in biographical dictionaries as a method for identifying "great inventors" (ie, those responsible for the most historically significant inventions) in the US case. More recently Khan and Sokoloff (2008) have carried a comparative study of American and British "great inventors" using the same method. Khan and Sokoloff (2008) have constructed their British sample of "great inventors" using the 2004 edition of the *Dictionary of National Biography* (DNB). In this case, we rely on the following four sources

i) The 2004 edition of the *Oxford Dictionary of National Biography* (www.oxforddnb.com)
ii) Allen (2009): Allen (2009, pp. 242-271) has also recently constructed a list of British "great inventors" with a specific focus on the economic significance of the inventions they produced. Allen's first list of "great inventors" has been constructed by considering all the inventors active in Britain between 1660 and 1800 mentioned in Singer's *History of Technology*. The list has been integrated also considering Mokyr (1990) and Mantoux (1928).
iii) Day and McNeil (1996): this is a biographical dictionary with a specific focus on the history of technology
iv) Abbott (1985): another biographical dictionary with a focus on history of technology.

This third proxy variable, which we term "inventor reputation" is constructed in an analogous way to "patent reputation". If an inventor is included in all four sources, all his-her patents are assigned a score of four, if an inventor is included in three sources a score of three, etc. Table 3 contains the inventor mentioned in all four sources. Again there are no particular surprises as the table seems to contain all the most famous inventors of the industrial revolution without noteworthy omissions.

Table 3

3. THE CONSTRUCTION OF THE COMPOSITE PATENT QUALITY INDEX

We construct our composite indicator of patent quality following the approach developed by Lanjouw and Schankerman (2004). First we control for systematic temporal and industrial effects that may affect the variation of our three individual indicators of patent quality. Since our three proxy variables WRI, "patent reputation" and "invention reputation" are count variables characterized by "overdispersion", we perform this adjustment by running three negative binomial regressions in which WRI, "patent reputation" and "invention reputation" are the dependent variables and the covariates are industry and time dummies. [9] From these regressions we then extract the residuals. The intuition is that these residuals will capture the share of the variance attributable to the intrinsic quality of the patent, after having eliminated the effects related to time and industry which instead do not reflect "real" quality, but simply some artificial variations of each indicator over time and across industries. These adjustment procedure is analogous to the one that is frequently carried out in the case of modern patents (Hall et al., 2002). Table 4 reports the Spearman's correlation coefficients among the residuals of these regressions. All correlation coefficients are significant at 1% level, but it is interesting to notice that among "patent reputation" and "invention reputation" there is a stronger degree of correlation (0.4) than that existing between these variables and WRI. Overall this may perhaps suggest that our indicators are capturing two different dimension of patent quality. In particular, WRI is probably capturing patent quality as perceived by contemporaries whereas "patent reputation" and "inventor reputation" may instead provide a perception of quality that reflects also the benefit of hindsight.

Table 4 around here

We then carry out a factor analysis on the residuals of the three regressions to extract a composite indicator of patent quality. We use the principal factor estimation procedure which has been shown to be relatively robust to different assumptions on the distribution of the data. The results of the factor analysis are presented in table 5. The Kaiser criterion suggests that only one factor with eigenvalue>1 should be retained. This factor explains 50.3% of the total variance. Interestingly enough, the loadings on this factor are higher for the indicators constructed using modern sources than the loadings of the Woodcroft Reference Index. Furthermore, it is also worth noting that WRI is also characterized by a high degree of uniqueness (0.739) which suggests that the relationship between patent quality and this indicator may be affected by a significant amount of noise. In this sense, this new composite indicator of patent quality may probably be considered as a useful improvement on the quality indicators developed using exclusively WRI in Nuvolari and Tartari (2011).

Table 5 around here

Table 6 reports the ranking of the top quality patents measured with this composite indicator of patent quality. The list of patents seems, at least, *prima facie*, to offer a very plausible selection of the most important patents of the industrial revolution period.

Table 6 around here

[9] We have used the following time cohorts 1617-1701,1702-1721,1722-1741,1742-1761,1762-1781,1782-1801,1802-1811,1812-1821,1822-1831,1832-1841, 1832-1841 is the base reference. Nuvolari and Tartari (2011) have examined the use of different time cohorts for carrying "fixed effects" adjustments of the WRI variable. The results were not affected by robust to the choice of alternative time periods. For the industry dummies, we use a classification of 21 industries inspired by Moser (2010). The base reference is "textiles".

4. THE DISTRIBUTION OF HIGH QUALITY PATENTS OVER TIME AND ACROSS INDUSTRIES

What are the implications of our composite indicator of patent quality for the debate concerning the timing and scope of the industrial revolution ? Figure 3 charts the cumulative distribution of patents of different quality over time. The thin lines represent the cumulative distribution of patents that are in the top 0.5% and 1% percentiles in terms of their quality scores measured using WRI*. The thick line represents the cumulative distribution of the total number of patents. Figure 3 may be interpreted as comparing the evolution over time of the stock of knowledge embodied in patented macroinventions (the top percentiles) and in patented microinventions (the total number of patents). Figure 3 shows that the cumulative distribution of high quality patents tends to "anticipate" the cumulative distribution of the total patents. In particular, the cumulative distribution of the top 0.5% percentile reaches a level of 50% in 1788, whereas the cumulative distribution of total patents reaches a level of 50% only in 1823, that 35 years later. It is instructive to compare this time profile with the estimates of productivity growth produced by Crafts and Harley. According to Crafts' most recent estimates, total factor productivity growth was negligible in the period 1760-1780. It increased to 0.3 % per year in the period 1780-1831 and from there to 0.75 % per year in 1831-1873 (Crafts, 2004, p. 522). It is relatively straightforward to put forward an explanation that can accounts for the temporal patterns of figure 3: the classical take-off period (1760-1801) should be regarded as the phase in which several macroinventions in the sense of Mokyr (1990) emerged. In this interpretation, the time profile of the high quality patents in figure 3 (in particular the top 0.5%) is capturing the time dynamics of these macro inventions. However, the impact of these macroinventions on productivity growth became fully manifest only after a stream of microinventions (possibly represented in figure 4 by the cumulative distribution of total patents) improved their technological performance and cost effectiveness. In this way, the distribution over time of high quality patents may be reconciled with the dynamics of productivity growth posited in Crafts and Harley (1992) revisionist account.

Figure 3 around here

Turning our attention to the scope of technical change, table 8 shows the concentration of patents of different quality across industries over the period 1700-1841 measured using the Herfindahl index and concentration ratios.[10] Patents in the top percentiles of the quality scores (top 0.5%, top 1%) exhibit a remarkably higher degree of concentration than patents of lower quality (top 50% and the total patent sample). Overall, table 8 suggests that, although total patents were relatively widespread across industries as pointed out by Sullivan (1990), technological blockbusters (patents of very high quality) were remarkably more localized. This result, in our view, provides an interesting hint for reconciling the Crafts-Harvey view with the patent evidence. Interestingly enough, the industrial sectors where the top quality patents are "textiles", "engines" and "metallurgy". In this case the pattern is similar for both composite indicators of patent quality.

Table 7 around here

5. CONCLUDING REMARKS

In this paper we have proposed a new composite indicator of the quality of English patents in the period 1617-1841 based on the combination of both historical and modern sources. Our findings

[10] The Herfindahl index was computed as $H = \sum s_i^2$ where s_i is the share of patents of given quality in industry i. The higher the value of H the higher the degree of concentration: in this formulation, the index ranges from 1/21 (≅ 0.048) when patents are evenly distributed across industries, to 1 when all patents are concentrated in one single industry. It is also instructive to consider the equivalent number (1/H) that indicates the number of industries with equal size corresponding to the level H of concentration. The C3 concentration ratio is the sum of the shares of the three industries with the largest shares.

indicate that this new quality indicator has some very interesting potential for helping us to shed further light on some of the ongoing debates on the timing and scope of innovation during the industrial revolution. Our composite indicator presents the advantage of being of relatively easy computation and it seems capable to provide a reasonable proxy for the economic value of patents, which can fruitfully complement simple patent counts as indicator of innovation in this historical period. In particular, it has been frequently pointed out that the patent evidence lends support to a traditional view of the industrial revolution as a dramatic acceleration of technical change taking place in the second half of the eighteenth century and affecting simultaneously many sectors (Sullivan, 1989, 1990; Temin, 2000, p. 845). Our composite indicator of patent quality seems instead to offer a way of reconciling the patent evidence with the "revisionist view" put forward by Crafts and Harley (1992). Concerning the timing of the industrial revolution, our findings seem in line with a traditional chronology and confirm that the second half of the eighteenth century (1762-1801) was the critical historical phase with a clustering of critical technical breakthroughs (top quality patents). However, it is important to take into account that the full impact of these macro "prototype" inventions on productivity growth became visible only after a phase of adaptation, improvement and refinement by means of streams of microinventions. Thus the time profile of high quality patents that we have reconstructed using our composite indicator appears to be consistent with the dynamics of productivity growth estimated by Crafts and Harley (1992). In terms of the scope of the change, our findings indicate that, although total patents were relatively widespread, top-quality patents (ie, those covering technological blockbusters) were much more concentrated across industries. If we regard productivity growth as an outcome of the sustained improvement and extension (also to other industrial applications) of these macroinventions, our results indicate that the patent records evidence may indeed be consistent with a view of the industrial revolution as a process driven by a few revolutionary industrial innovations localized in a relatively circumscribed segment of the economy.

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FIGURE 1: ENTRY IN WOODCROFT'S *REFERENCE INDEX* FOR JAMES WATT'S PATENT (PATENT 913) OF THE SEPARATE CONDENSER

16 **REFERENCE INDEX OF PATENTS OF INVENTION.**

Progressive Number.	REFERENCE.
910	Rolls Chapel Reports, 6th Report, page 136. Rolls Chapel.
911	No Specification :—Letters Patent printed.
912	Petty Bag.
913	Repertory of Arts, vol. 1, page 217. Mechanics' Magazine, vol. 1, page 4. Practical Mechanics' Journal, vol. 1, page 285. Register of Arts and Sciences, vol. 4, pages 24 and 346. Engineers' and Mechanics' Encyclopædia, vol. 2, page 725. Webster's Reports, vol. 1, page 31 (note p.), page 56 (note), and pages 230, 282, and 285. Webster's Patent Law, page 46 (also page 127 cases 30, 31, and 32); and Supplement pages 2, 18, and 20. Webster's Letters Patent, pages 6, 17, and 20. Blackstone's Reports, vol. 2, page 463. Carpmael's Reports on Patent Cases, vol. 1, pages 117, 155, and 156. Davies on Patents, pages 155, 162, and 221. Collier's Law of Patents, pages 71, 75, 83, 90, 94, 100, 128, 139, and 181. Parliamentary Report, 1829 (*Patent Law*), pages 187, 189, and 190. Vesey, junr.'s, Reports, vol. 3, page 140. Holroyd on Patents, pages 35, 48, and 55. Durnford and East's Term Reports, vol. 8, page 95. Patentees' Manual, page 8. Billing on Patents, pages 20, 22, 23, 26, 27, 28, 29, 31, 32, 48, 82, 89, 90, and 145. Rolls Chapel Reports, 6th Report, page 160. Extended by Act of Parliament for 25 years. (*See* No. 913*.) Rolls Chapel.
913*	Act of Parliament for extending No. 913 for 25 years.
914	Rolls Chapel Reports, 6th Report, page 136. Rolls Chapel.

FIGURE 2: ENTRY IN WOODCROFT'S *REFERENCE INDEX* FOR WILLIAM SYMINGTON'S PATENT (PATENT 2544) OF AN IMPROVED NEWCOMEN ENGINE DESIGN

2538 & 2539	Petty Bag.
2540	Repertory of Arts, vol. 16, page 79. Petty Bag.
2541 to 2543	Petty Bag.
2544	Mechanics' Magazine, vol. 17, page 385; also vol. 20, page 98. Rolls Chapel Reports, 6th Report, page 151. Rolls Chapel.
2545	Repertory of Arts, vol. 1 (*second series*), page 257. Rolls Chapel Reports, 6th Report, page 200. Rolls Chapel.

TABLE 1: PUBLICATIONS WITH MOST REFERENCES IN WOODCROFT'S *REFERENCE INDEX*

Publication s	**Total**
London Journal of Arts and Sciences (Newton's; London, 1820)	3085
Repertory of Arts and Manufactures (5th series, London, 1794)	3392
Rolls Chapel Reports, 6th, 7th and 8th	2311
Mechanic's Magazine (London, 1823)	1138
Inventors' Advocate and Patentees' Recorder (London, 1839)	939
Register of Arts and Sciences (2nd series, London, 1824)	873
Engineers' and Mechanics' Encyclopaedia (by Luke Hebert, London, 1836)	491
Carpmael's Patent Cases (Reports)	131
Webster's (Reports)	132
Webster's Patent Law (a Treatise)	106
Billing on Patents (a Treatise)	100
Engineers' and Architects' Journal (London, 1837)	154
Law Journal (Reports)	60
Parliamentary, 1829 Patent Law (Reports)	58
Artizan. A Monthly Journal of Operative Arts (London, 1843)	47
Patentees Manual (by Henry Johnson, London, 1853)	37
Ure's Cotton Manufacture (London, 1836)	45
Websters Letters Patent (London, 1848)	34
Patent Journal and Inventor's Magazine (London, 1846)	41
Holroyd's on Patents (a Treatise)	31
Jurist (Reports)	31
Law Times (Reports)	29
Davies on Patents (Reports)	25
Practical Mechanics' Journal (Glasgow, 1848)	26
Stuart's History of the Steam Engine (London, 1825)	18
Moore's Privy Council Cases (Reports)	16
Transactions of the Society of Arts	15
Meeson and Welsby's (Reports)	13
Ure's Philosophy of Manufactures (London, 1835)	11

TABLE 2: PATENTS WITH MAX.SCORE (4) OF PATENT REPUTATION

Number	Year	Patentee	Invention
356	1698	Thomas Savery	steam engine (Newcomen)
542	1733	John Kay	flying shuttle
913	1769	James Watt	separate condenser
931	1769	Richard Arkwright	water frame
962	1770	James Hargreaves	spinning jenny
1063	1774	John Wilkinson	boring machine
1351	1783	Henry Cort	iron making
1470	1785	Edmund Cartwright	power loom
1565	1786	Edmund Cartwright	power loom
1876	1792	Edmund Cartwright	power loom
2045	1795	Joseph Bramah	hydraulic engine
2599	1802	Andrew Vivian	high pressure steam engine
5701	1828	James Beaumont Neilson	blast furnace
7390	1837	Charles Wheatstone	Telegraph

TABLE 3: INVENTORS WITH MAX. SCORE (4) OF INVENTOR REPUTATION

Inventor
Bryan Donkin
Edmund Cartwright
Henry Cort
Henry Maudslay
James Hargreaves
James Watt
John Kay
John Smeaton
Joseph Bramah
Josiah Wedgwood
Richard Arkwright
Richard Trevithick
Thomas Newcomen
Thomas Savery
William Murdock

TABLE 4: SPEARMAN'S RANK CORRELATION MATRIX OF PATENT VALUE INDICATORS

	WRI	Inventor Reputation	Patent Reputation
WRI	1		
Inventor Reputation	0.076***	1	
Patent Reputation	0.0499***	0.4111***	1

NOTE:***,**, * indicate significance levels of 1%,5% and 10% respectively

TABLE 5: FACTOR ANALYSIS OF PATENT VALUE INDICATORS

	Factor loadings	Uniqueness
WRI	0.5109	0.7390
Inventor Reputation	0.7701	0.4070
Patent Reputation	0.8093	0.3451

NOTE: one factor with eigenvalue >1 was retained (explaining 50.3% of the total variance); extraction method: principal component factors.

TABLE 6: RANKINGS OF TOP QUALITY PATENTS (ESTIMATED WITH FACTOR ANALYSIS)

Rank	Patent number	Year	Patentee	Invention
1	913	1769	James Watt	separate condenser
2	1876	1792	Edmund Cartwright	power loom/carding engine
3	356	1698	Thomas Savery	steam engine (Newcomen)
4	2599	1802	Andrew Vivian	steam engine (high pressure)/Trevithick
5	7390	1837	Charles Wheatstone	Telegraph
6	2045	1795	Joseph Bramah	hydraulic press
7	5701	1828	James Beaumont Neilson	blast fornace
8	931	1769	Richard Arkwright	water frame
9	1470	1785	Edmund Cartwright	power loom
10	962	1770	James Hargraves	spinning jenny
11	1565	1786	Edmund Cartwright	power loom
12	1351	1783	Henry Cort	iron making
13	1063	1774	John Wilkinson	boring machine
14	2708	1803	John Gamble	paper making machine (Fourdrinier)
15	542	1733	John Kay	flying shuttle
16	4804	1823	Charles MacIntosh	water proof cloth
17	1430	1784	Joseph Bramah	Bramah's lock
18	1306	1781	James Watt	steam engine (rotative motion)
19	2652	1802	Joseph Bramah	wood planing machinery
20	562	1738	Lewis Paul	spinning machine
21	1747	1790	Edmund Cartwright	carding machine
22	636	1748	Lewis Paul	machine for carding wool, cotton and silk
23	1177	1778	Joseph Bramah	new watercloset
24	1478	1785	Joseph Bramah	hydraulic engine
25	8842	1841	William Henry Fox Talbot	Photography
26	1111	1775	Richard Arkwright	water frame/combing engine
27	1420	1784	Henry Cort	iron making
28	2209	1798	Charles Tennant	chlorine bleaching
29	3887	1815	George Stephenson	Locomotive
30	1645	1788	Andrew Meikle	threshing machine

FIGURE 3: CUMULATIVE DISTRIBUTION OF PATENTS OF DIFFERENT QUALITY (ESTIMATED WITH FACTOR ANALYSIS)

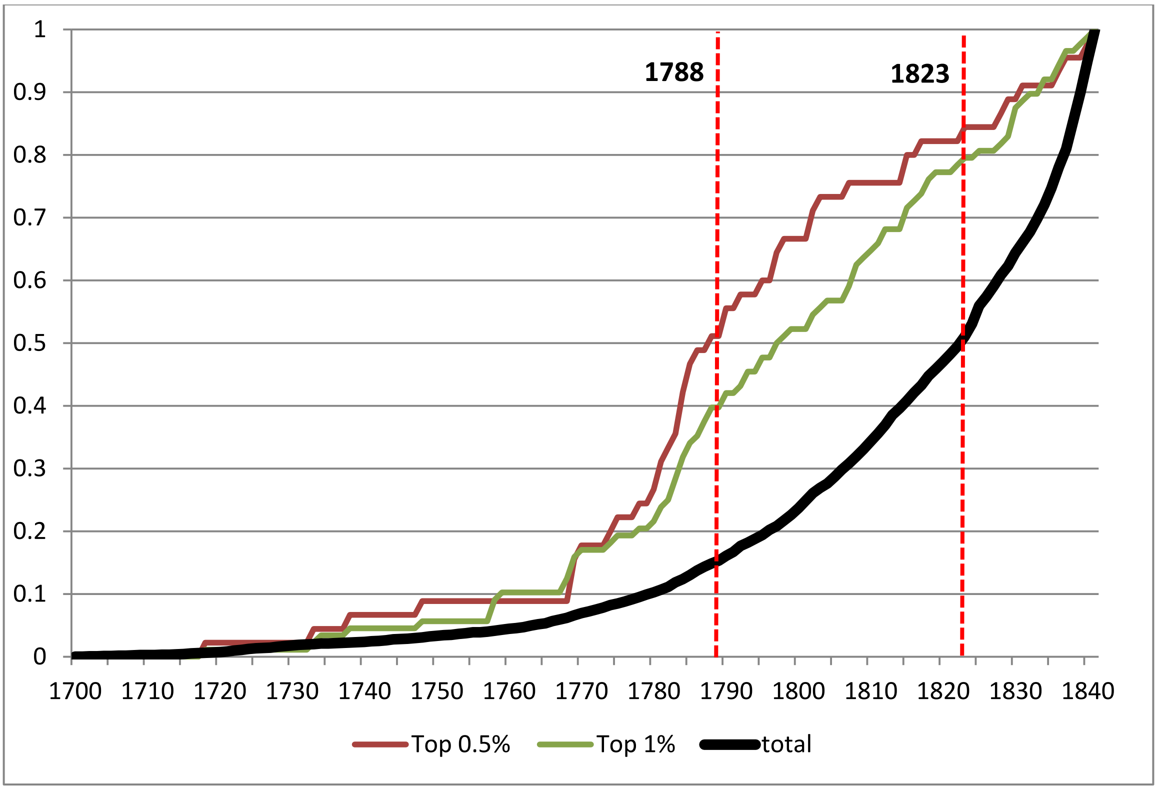

TABLE 7: CONCENTRATION ACROSS SECTORS OF PATENTS OF DIFFERENT QUALITY, 1700-1841

Patent quality estimated with factor analysis						
	Top 0.5%	Top 1%	Top 5%	Top 10 %	Top 50%	Total
Herfindahl	0.154	0.115	0.093	0.078	0.067	0.070
Equivalent number	6.511	8.701	10.774	12.891	14.857	14.375
C3	0.600	0.500	0.435	0.363	0.309	0.338
Sectors with highest shares						
1	Textiles	Textiles	Engines	Engines	Textiles	Engines
2	Engines	Engines	Textiles	Textiles	Chemicals	Textiles
3	Metallurgy	Metallurgy	Metallurgy	Metallurgy	Engines	Chemicals