Patterns of Innovation during the Industrial Revolution: a Reappraisal using a Composite Indicator of Patent Quality

Online Appendix

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A Appendix: The Bibliographic Composite Index (BCI) of patent quality

This Appendix contains a description of the sources of the BCI and some further robustness checks on the results reported in the paper.

A.1 Sources used for the construction of WRI, PAT_EM and INV_EM

The BCI is a composite index that integrates three different quality indicators: the Woodcroft Reference Index (WRI), Patent Eminence (PAT_EM) and Inventor Eminence (INV_EM).

The WRI is computed as the number of bibliographic references listed for each patent in Woodcroft (1862). Figure A1 and A2 shows the entries for two different patents (a technological breakthrough and an ordinary invention) in Woodcroft's volume.

16 REFERENCE INDEX OF PATENTS OF INVENTION.

Progressive Number.	REFERENCE.
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.

Figure A1: Entry in Woodcroft's *Reference Index of Patentees of Inventions, 1617-1852* (1862) for James Watt's patent of the separate condenser (1769)

Note: 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). The Index also notes of the Fire Engines Patent Act (1775) that extended the patent to 1800.

REFERENCE INDEX OF PATENTS OF INVENTION. 65

Progressive Number.	REFERENCE.
2544	Mechanics' Magazine, vol. 17, page 385; also vol. 20, page 98. Rolls Chapel Reports, 6th Report, page 151. Rolls Chapel.

Figure A2: Entry in Woodcroft's *Reference Index of Patentees of Inventions, 1617-1852* (1862) for William Watts' patent for making better small shots (1782)

Note: Not surprisingly, Watt's separate condenser received a much higher number of citations than the incremental improvements patented by William Watts.

Not surprisingly Watt's separate condenser is mentioned in a significantly higher number of references than the William Watts' invention for improvements in the production of small shots (making them "solid, round and smooth").

The Patent Eminence (PAT_EM) score is computed as the number of times each patent is mentioned in specialized reference volumes on the history of invention and engineering. The sources used for the construction of this variable are:

1. Baker, R. (1976): *New and Improved... Inventors and Inventions that Have Changed the Modern World*, London: British Library.
2. Carter, E. F. (1969): *Dictionary of Inventions and Discoveries*, London: F. Muller.
3. Desmond, K. (1987): *The Harwin chronology of inventions, innovations, discoveries: From pre-history to the present day*, London: Constable.
4. Inkster, I. (1991): *Science and technology in history: an approach to industrialisation*, London: Macmillan.
5. Bridgman, R. (2014): *1000 inventions and discoveries*, New York: Dorling Kindersley Ltd.
6. Bunch, B. H. and A. Hellemans (2004): *The History of Science and Technology*, New York: Houghton Mifflin.
7. Ochoa, G. and M. Corey (1997): *The Wilson chronology of science and technology*, New York: HW Wilson.
8. Dudley, L. (2012): *Mothers of innovation: How expanding social networks gave birth to the Industrial Revolution*, Newcastle upon Tyne: Cambridge Scholars Publishing.

9. Lilley, S. (1948): *Men, machines and history: a short history of tools and machines in relation to social progress*, London: Cobbett Press.

10. Challoner, J. (2016): *1001 inventions that changed the world*, Sydney: Pier 9.

Baker (1976) contains the patent number of the invention, so the matching procedure with the patent data is automatic. Carter (1976) reports whether the invention in question was patented or not. In all the other cases, the sources report the year and the inventor. It is relatively straightforward to match this information with the corresponding patent number using Woodcroft's *Alphabetical* and *Chronological* indices (1854a, 1854b). Figure A4 and A3 contains sample entries of these two publications.

256 CHRONOLOGICAL INDEX OF

RANSOME. 25th Oct. 1783.	**1392.** A grant unto ROBERT RANSOME, of the city of Norwich, ironfounder, of his new invented method of making and casting of iron & other metal plates, for the better and more secure covering of houses and other buildings, and which, from their durability, neatness, cheapness, and other properties, are far superior to tyles, slate, or lead, or any other substitute heretofore discovered; to hold to him, his exors, admors, & assigns, within England, Wales, & town of Berwick-upon-Tweed for the term of 14 years pursuant to the statute; with a clause to inroll the same within four calendar months from the date hereof. W. H. M. at Westmr, the 25th day of October, in the 24th year of the reign of King George the 3d, and in the year of our Lord, 1783. By writ, &c.
HATCHETT. 25th Oct. 1783.	**1393.** A grant unto JOHN HATCHETT, of his new invention for coaches and all other carriages, and bodies of them; to hold to him, his exors, admors, & assigns, within England, Wales, & town of Berwick-upon-Tweed for the term of 14 years pursuant to the statute; with a clause to inroll the same within four calendar months from the date hereof. W. H. M. at Westmr, the 25th day of October, in the year above. By writ, &.

Figure A3: Excerpt from Woodcroft's *Titles of Patents of Inventions Chronologically Arranged, 1617-1852* (1854)

All] ALPHABETICAL INDEX OF PATENTEES OF INVENTIONS. **[Amo**

Name of Patentee.	Progressive Number.	Date.	Subject-matter of Patent.
ALLPORT, SAMUEL - - -	12,608	14th May 1849	Manufacturing a part or parts of looms used in weaving.
ALLWRIGHT, JAMES - -	4637	14th Jan. 1822	Keyed musical instrument.
ALMONDE, OTTO C. VON -	8701	12th Nov. 1840	Production of mosaic work from wood.
ALPHEY, GODFREY - - -	2547	3rd Nov. 1801	Waterproofing hats and caps; also leather, cotton, linen, silks, stuffs, pasteboard, and other manufactures and substances, for the purpose of being worked up into shoes, boots, hats, bonnets, and other wearing-apparel.
ALPIN, THOMAS MC - -	13,055	23rd April 1850	Machinery for washing cotton, linen, and other fabrics.
ALSOP, ROBERT - - -	955	22nd March 1770	Loom-embroidery, manufactured in gold or silver, on silk ribbon and woollen, linen, cotton, or mohair.

Figure A4: Excerpt from Woodcroft's *Alphabetical Index of Patentees of Inventions, 1617-1852* (1854)

Table A1 shows the overlap in the coverage of the patent sample between the sources used for the construction of PAT_EM.

Table A1: Overlap between the sources used for Patent Eminence

	Source	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	Baker (1976)	150									
(2)	Carter (1978)	48	266								
(3)	Desmond (1987)	45	68	157							
(4)	Inkster (1991)	21	29	20	44						
(5)	Dudley (2012)	29	37	26	27	55					
(6)	Challoner (2009)	31	28	29	14	20	49				
(7)	Bridgman (2002)	22	26	24	16	18	18	38			
(8)	Bunch and Hellemans (2004)	39	52	31	19	27	23	23	93		
(9)	Ochoa and Corey (1997)	16	15	17	12	13	10	11	15	24	
(10)	Lilley (1948)	21	24	17	21	21	14	15	17	12	33

Note: This table shows the number of patents cited in every sources along with the number of these that are also mentioned in each of the other sources used. The diagonal cells contain the total number of patents in each of these lists, while cells outside the diagonal show the number of patents mentioned simultaneously in both sources.

Table A2 shows the patents with highest score of PAT_EM.

Table A2: Patents with the highest scores of Patent Eminence

Patent N°	Year	Inventor	Invention	Patent Eminence
542	1733	John Kay	Flying shuttle	10
913	1769	James Watt	Separate condenser	10
931	1769	Richard Arkwright	Water frame	10
962	1770	James Hargreaves	Spinning jenny	10
7390	1837	Charles Wheatstone	Telegraph	10
1063	1774	John Wilkinson	Boring machine	9
1351	1783	Henry Cort	Rolling of metals	9
1470	1785	Edmund Cartwright	Power loom	9
2599	1802	Andrew Vivian, Richard Trevithick	High pressure steam engine	9
1298	1781	Jonathan Hornblower	Compound steam engine	8
1565	1786	Edmund Cartwright	Power loom	8
1645	1788	Andrew Meikle	Threshing machine	8
2045	1795	Joseph Bramah	Bramah's lock	8
9382	1842	James Nasmyth	Steam hammer	8

The Inventor Eminence (INV_EM) score is computed as the number of times each inventor is mentioned in biographical dictionaries and other compilations of important inventors and historical figures. All the patents of the same inventor have the same score of INV_EM. The sources used for the construction of this variable are:

1. Matthew H. and B. Harrison (2004): *Oxford Dictionary of National Biography*, Oxford: Oxford University Press (www.oxforddnb.com).

2. Allen, R. (2009): *The British Industrial Revolution in Global Perspective*, Cambridge: Cambridge University Press.

3. Day, L. and I. McNeil (1996): *Biographical dictionary of the history of technology*, London: Routledge.

4. Abbott, D. (1985): *The Biographical Dictionary of Scientists, Engineers and Inventors*, London: F. Muller.

5. Murray, C. (2003): *Human accomplishment: The pursuit of excellence in the arts and sciences, 800 BC to 1950*, London: Harper Collins.

6. Benson, A. K. (2012): *Inventors and inventions. Great lives from history*, Pasadena: Salem Press.

7. De Galiana, T. and M. Rival (1996): *Dictionnaire des inventeurs et inventions*, Paris: Larousse.

8. Meisenzahl, R. R. and J. Mokyr (2012): "The rate and direction of invention in the British Industrial Revolution: Incentives and institutions," in *The rate and direction of inventive activity revisited*, ed. by J. Lerner and S. Stern, Chicago: University of Chicago Press, pp. 443-479.

9. Gergaud, O., M. Laouenan, and E. Wasmer (2016): "A Brief History of Human Time. Exploring a database of 'notable people'," *LIEPP Working Paper*, Sciences Po.

Table A3: Overlap between the sources used for Inventor Eminence

	Source	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	Oxford DNB	292								
(2)	Allen (2009)	45	77							
(3)	Day and McNeil (1996)	105	50	241						
(4)	Abbott (1985)	41	29	48	58					
(5)	Murray (2003)	32	29	35	28	55				
(6)	De Galiana (1996)	60	36	66	40	35	103			
(7)	Meisenzahl and Mokyr (2012)	153	55	178	45	39	75	538		
(8)	Benson (2012)	38	28	38	26	27	37	45	60	
(9)	Gergaud et al (2016)	86	22	66	29	25	45	84	36	135

Note: This table shows the number of inventors cited in every sources along with the number of these that are also mentioned in each of the other sources used. The diagonal cells contain the total number of inventors in each of these lists, while cells outside the diagonal show the number of inventors mentioned simultaneously in both sources.

It is relatively straightforward to match the inventors in these sources with the patentees listed in Woodcroft's *Alphabetical Index* (1854a). Whenever necessary, we have manually disambiguated the few uncertain cases using the information in the biography of the inventor in combination with the year of the patent, the description of the inventor and the residence of the patentees contained in Woodcroft's *Chronological Index* (1854b). Table A3 shows the overlap in terms of inventor coverage between the sources used for the construction of INV_EM.

Table A4 reports the inventors with the highest scores of INV_EM.

Table A4: Patents with the highest scores of Inventor Eminence

Inventor	Inventor Eminence
Andrew Vivian	9
Edmund Cartwright	9
Henry Bessemer	9
Henry Maudslay	9
James Hargreaves	9
James Nasmyth	9
James Watt	9
John Kay	9
Richard Arkwright	9
Richard Trevithick	9
Thomas Savery	9
William Murdock	9

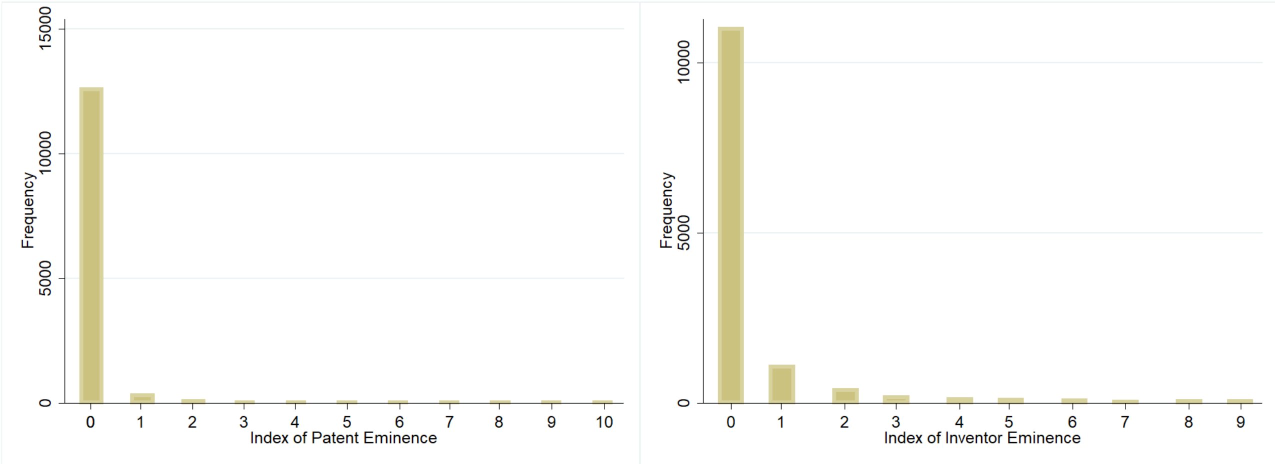
Table A5 examines the consistency of the sources used for the construction of INV_EM and PAT_EM by means of Kuder-Richardson 20 coefficients. The results are robust even when excluding one source at the time.

Table A5: Robustness of Kuder-Richardson 20 coefficients after excluding a source of Patent and Inventor Eminence at the time.

Patent Eminence		Inventor Eminence	
Source Excluded	KR20	Source Excluded	KR20
Baker (1976)	0.7632	Oxford DNB	0.8351
Carter (1978)	0.7864	Allen (2009)	0.8369
Desmond (1987)	0.7640	Day and McNeil (1996)	0.8173
Inkster (1991)	0.7569	Abbott (1985)	0.8326
Dudley (2012)	0.7490	Murray (2003)	0.8363
Challoner (2009)	0.7562	De Galiana (1996)	0.8290
Bridgman (2002)	0.7567	Meisenzahl and Mokyr (2012)	0.8568
Bunch and Hellemans (2004)	0.7526	Benson (2012)	0.8388
Ochoa and Corey (1997)	0.7666	Gergaud et al (2016)	0.8385
Lilley (1948)	0.7583		

Note: This table reports the Kuder-Richardson 20 coefficients for Patent and Inventor Eminence indicators after each of the sources used is excluded from its computation, one at the time. The table shows great stability of the coefficients, which when all sources are considered together are equal to 0.7792 and 0.8511 for Patent and Inventor Eminence, respectively.

Figure A5 displays the distributions of PAT_EM and INV_EM. Both distributions are very skewed, with the large bulk of patents having a score of zero and few selected patents with high scores.



(a) Patent Eminence

(b) Inventor Eminence

Figure A5: Distribution of the quality indicators Patent Eminence and Inventor Eminence.

FInally, Table A6 reports the descriptive statistics by sectors of WRI, PAT_EM and INV_EM.

Table A6: Descriptive statistics of quality indicators, detailed by sector of economic activity as defined by Nuvolari and Tartari (2011)

Industry	Patents	Woodcroft Reference Index					Patent Eminence					Inventor Eminence				
		Mean	Median	Std Dev	Min	Max	Mean	Median	Std Dev	Min	Max	Mean	Median	Std Dev	Min	Max
Agriculture	432	2.5717	2	1.3433	1	7	0.0856	0	0.5655	0	8	0.2152	0	0.8300	0	7
Carriages	812	2.8140	2	1.6593	1	15	0.0615	0	0.3384	0	4	0.3645	0	1.1752	0	9
Chemicals	1118	2.9758	3	1.6713	1	19	0.0286	0	0.2009	0	2	0.2504	0	0.9759	0	9
Clothing	322	2.3074	2	1.3814	1	13	0.0465	0	0.3879	0	6	0.2732	0	0.9952	0	6
Construction	640	2.8687	3	1.6238	1	16	0.025	0	0.2078	0	3	0.3078	0	1.1135	0	9
Engines	1637	2.7874	3	1.5135	1	21	0.0989	0	0.6136	0	10	0.5534	0	1.5464	0	9
Food	716	2.6955	2	1.6118	1	17	0.0488	0	0.3873	0	7	0.1955	0	0.8743	0	9
Furniture	659	2.4962	2	1.5021	1	18	0.0515	0	0.3313	0	4	0.1638	0	0.8124	0	9
Glass	123	2.8130	2	1.5436	1	9	0.0569	0	0.3213	0	3	0.5934	0	1.7547	0	9
Hardware	834	2.6163	2	1.5798	1	13	0.0611	0	0.3948	0	7	0.2170	0	0.8385	0	8
Instruments	598	2.5953	2	1.4642	1	13	0.1371	0	0.6833	0	10	0.5083	0	1.3815	0	8
Leather	218	2.6559	2	1.3799	1	9	0.0137	0	0.1511	0	2	0.1605	0	0.7840	0	6
Manufacturing	685	2.6087	2	1.6064	1	16	0.0701	0	0.3797	0	4	0.2919	0	1.0328	0	8
Medicines	288	2.1527	2	1.1404	1	10	0.0243	0	0.1754	0	2	0.1423	0	0.6443	0	7
Metallurgy	682	3.1568	3	1.9808	1	23	0.1114	0	0.6520	0	9	0.6436	0	1.6546	0	9
Military	252	2.4603	2	1.2944	1	11	0.1111	0	0.7221	0	9	0.4246	0	1.2264	0	7
Mining	81	2.9876	3	1.9202	1	14	0.0987	0	0.5149	0	4	0.4691	0	1.0849	0	5
Paper	480	2.9041	3	1.6648	1	14	0.1	0	0.4266	0	4	0.5812	0	1.3683	0	9
Pottery	277	2.8483	3	1.5738	1	12	0.0649	0	0.4030	0	4	0.2454	0	0.9465	0	9
Ships	590	2.8932	3	1.8280	1	17	0.0355	0	0.3302	0	7	0.3067	0	0.9935	0	9
Textiles	1626	2.5645	2	1.6636	1	19	0.0805	0	0.6451	0	10	0.5405	0	1.3496	0	9
Total sample	13070	2.7223	2	1.6161	1	23	0.0695	0	0.4797	0	10	0.3774	0	1.2031	0	9

A.2 The construction of BCI and some further robustness checks

Table A7 reports Spearman correlation coefficients among WRI, PAT_EM and INV_EM. The correlations are strongly significant, but the coefficients are rather low. The highest coefficient is between PAT_EM and INV_EM and is around 0.3. This suggests that the indicators provide relatively independent assessments of patent quality. In this context, integrating these three indicators in a composite quality index may lead to significant improvement of the signal-to-noise ratio (Lanjouw and Schankerman, 2004).

Table A7: Spearman's rank correlation coefficients of the raw quality indicators

	Woodcroft Reference Index	Patent Eminence	Inventor Eminence
Woodcroft Reference Index	1		
Patent Eminence	0.0710***	1	
Inventor Eminence	0.0645***	0.3001***	1

Note: *** denotes significance at 0.1% level.

In particular, some important innovations of the Industrial Revolution such as John Kay's flying shuttle, John Hadley's octant, James Hargreaves' spinning jenny, Henry Cort's puddling process and John Wilkinson's boring machine have relatively low scores of WRI*. Table A8 shows the scores of WRI* and BCI and the percentiles in which these patents are located in the distributions of the two indicators. Notably, all these inventions are in the top 0.5% patents when using the BCI.

Table A8: Scores of WRI* and BCI for some technological breakthroughs of the Industrial Revolution.

Patent N°	Inventor	Invention	N°Woodcroft Refs	WRI*	Percentile WRI*	BCI	Percentile BCI
542	John Kay	Flying shuttle	1	0.578	20	5.006	99.5
550	John Hadley	Octant	1	0.578	20	2.783	99.5
962	James Hargreaves	Spinning jenny	2	1.140	68	5.221	99.5
1063	John Wilkinson	Boring machine	2	1.165	69	4.700	99.5
1351	Henry Cort	Rolling of metals	2	1.072	67	4.525	99.5
1951	Samuel Bentham	Woodworking machinery	2	1.058	63	1.144	99

Table A9 compares the performance of BCI and WRI* in assessing patents on flawed designs in steam engineering (MacLeod et al. 2003; Dircks 1861). The comparison is carried out by means of Fligner-Policello of stochastic equality. Interestingly enough, in this case patents with flawed designs have significantly lower score of BCI, while WRI* is not able to tease them apart from the rest of the patent corpus.

Table A9: Fligner-Policello tests of stochastic equality: comparison of WRI* and BCI for flawed steam engineering patents.

	Perpetual Motion		"Impossible" Engines	
	BCI	WRI*	BCI	WRI*
Entire sample (1700-1850)				
Fligner-Policello statistics	-5.062***	-0.887	-2.765**	1.822

Note: *,**,*** denote significance at 5%, 1% and 0.1% level. Data for perpetual motion machines are taken from Dircks (1861) (23 patents), while the lists of 83 engines that were not technically feasible is the same employed by MacLeod et al. (2003). A negative sign of the Fligner-Policello statistics indicates that patents in the list considered are of lower average value than the excluded remainder. All the results hold if we employ Mann-Whitney-Wilcoxon median test.

Figure A6 contains a scatterplot that compares BCI and INV_EM. In this case, it is worth noting that several patents of "great inventors" are characterized by relatively low scores of BCI. This suggests that the BCI is correctly able to discriminate between important inventions and incremental improvements even when they were made by same inventor.

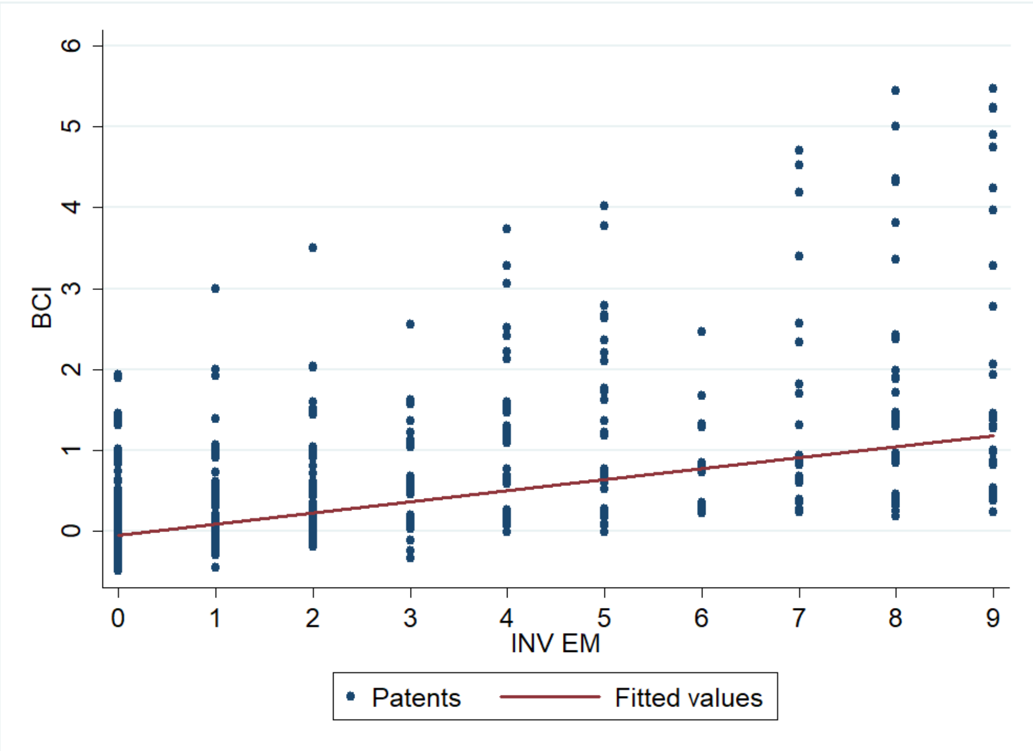


Figure A6: Scatterplot of BCI and INV_EM

Figure A7 contains a scatterplot that compares BCI and PAT_EM. The two measures are very consistent. As noted in the text, the main limit of PAT_EM is that is not very granular. The BCI shows more variation and allows a more fine-grained evaluation of microinventions.

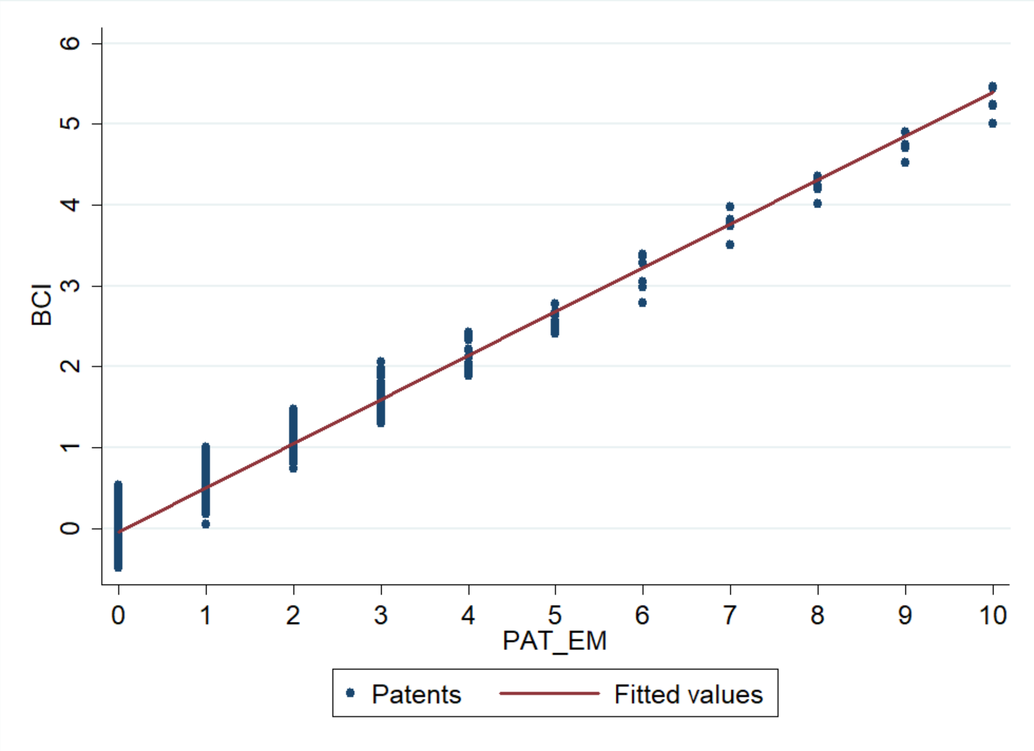


Figure A7: Scatterplot of BCI and PAT_EM

Table A10 contains a number of robustness checks on the construction of BCI. In particular, we experiment with different time and industry controls in the Poisson regressions for WRI, PAT_EM and INV_EM and examine the resulting set of the top 0.5% patents in the upper tail of the quality distributions (in the paper we use BCI as an ordinal variable). In all cases there is an almost complete overlap. This finding bolsters our confidence that we are selecting the subset of macroinventions for the period of the Industrial Revolution.

Table A11 contains a list of the top 0.5% patents in terms of BCI. Remarkably, the table shows technological breakthroughs spanning many different sectors of economic activity.

Table A10: Overlap between Top 0.5% patents when changing the time and industry controls used in the Poisson regression.

	(1)	(2)	(3)	(4)	(5)	(6)
(1)	65					
(2)	63	65				
(3)	62	63	65			
(4)	63	64	62	65		
(5)	62	63	62	63	65	
(6)	62	63	62	63	63	65

Note: This table shows the number of top 0.5% patents (65 patents) that overlap when the Bibliographic Composite Index is constructed using residuals of the raw proxies coming from different sets of regressions. In particular: (1) preferred specification, controls for time decade and industry (2) control for time windows of 50 years and industry (3) control for time windows of 25 years and industry (4) control for time decades only (5) control for industry only (6) no controls at all.

Table A11: Macroinventions (top 0.5% patents) according to the Bibliographic Composite Index.

Rank	Patent	Year	Patentee	Invention	Macroinvention/Technological breakthrough (references)	Notes
1	913	1769	James Watt	separate condenser for steam engines	Landes (1969, p. 102); Mokyr (1990, p. 85); Allen (2009, pp. 166-167)	
2	7390	1837	Charles Wheatstone	telegraph	Landes (1969, p. 284); Mokyr (1990, p. 123)	first telegraph put in commercial service
3	931	1768	Richard Arkwright	water frame	Landes (1969, p. 85): Mokyr (1990, p. 96); Allen (2009, pp. 195-201)	
4	962	1770	James Hargreaves	spinning jenny	Landes (1969, p. 85); Mokyr (1990, p. 96); Allen (2009, pp. 188-195)	
5	542	1733	John Kay	flying shuttle	Landes (1969, p. 84); Mokyr (1990, p. 77);	
6	2599	1802	Andrew Vivian, Richard Trevithick	high pressure steam engine	Landes (1969, p. 102); Mokyr (1990, p. 88); Allen (2009, pp. 166-167)	single cylinder high pressure engine
7	1470	1785	Edmund Cartwright	power loom	Landes (1969, p. 86); Mokyr (1990, p. 100)	
8	1063	1774	John Wilkinson	boring machine	Landes (1969, p. 103); Mokyr (1990, pp. 103-104);	machine that could bore cast iron cylinders
9	1351	1783	Henry Cort	rolling of metals	Landes (1969, p. 91); Mokyr (1990, p. 93);	
10	9382	1842	James Nasmyth	steam hammer	Landes (1969, p. 93); Mokyr (1990, p. 104)	industrial powered hammer used for shaping forgings
11	2045	1795	Joseph Bramah	hydraulic press	Trinder (2013, p. 74)	machine tool embodying Pascal's principle, with a wide range of industrial applications
12	1565	1786	Edmund Cartwright	power loom	Landes (1969, p. 86); Mokyr (1990, p. 100)	
13	1645	1788	Andrew Meikle	threshing machine		first successful design of threshing machine for removing husks from grain
14	1298	1781	Jonathan Hornblower	compound steam engine	Landes (1969, p. 103); Mokyr (1990, p. 88); Allen (2009, p. 167)	first compound design of steam working at low pressure (fuel efficiency similar to Watt's engine)
15	1876	1792	Edmund Cartwright	woolcombing machine	O'Brien (1997, p. 211)	machine used to arrange and lay parallel fibers of wool, crucial for the mechanization of this industry
16	1430	1784	Joseph Bramah	Bramah's lock		sophisticated lock (design similar to a modern tubular pin tumbler lock) famous for its resistance to picking. In 1790 Bramah issued a prize to anybody who could pick the lock. The prize was awarded only 61 years after, in 1851.
17	5701	1828	James Beaumont Neilson	hot blast furnace	Landes (1969, p. 92); Mokyr (1990, p. 95); Allen (2009, pp. 227-228)	
18	7104	1836	Francis Pettit Smith	screw propeller	Mokyr (1990, p. 128);	Pettit Smith's design was used in first successful screw propelled steamship, SS Archimedes (1839)

Table 11A (continued)

19	3372	1810	Peter Durand	preservation of food in tin cans	Mokyr (1990, p. 140)	first successful invention of preservation of food in tin cans
20	8842	1841	William Fox Talbot	calotype		early type of photographic process
21	3887	1815	George Stephenson	locomotive	Allen (2009, pp. 273-274)	
22	4804	1823	Charles Macintosh	waterproof cloth		waterproof cloth made of rubberised fabric
23	1321	1782	James Watt	double acting steam engine	Allen (2009, p. 171)	design with steam acting on both sides of the piston (important for rotary motion)
24	2772	1804	Arthur Woolf	high pressure compound engine	Landes (1969, p. 103); Mokyr (1990, pp.88-90); Allen (2009, p. 176)	compound engine using high pressure steam expansively
25	5990	1830	Edwin Budding	lawnmower		first machine using revolving blades to cut lawn
26	550	1734	John Hadley	octant		measuring instrument used in navigation
27	1306	1781	James Watt	rotary steam engine	Allen (2009, p. 171)	steam engine designed to deliver rotary motion
28	4136	1817	David Brewster	kaleidoskope		
29	4081	1816	Robert Stirling	Stirling air engine	Cardwell (1994, pp. 243-244)	heat engine working with expansion and compression of air and other gases
30	1420	1784	Henry Cort	iron puddling	Landes (1969, p. 91); Mokyr (1990, p. 93);	
31	6909	1835	Samuel Colt	revolver		first successful design of repeating handgun using revolving cylinder
32	722	1758	Jedidiah Strutt	stocking rib	Trinder (2013, p. 463)	mechanical knitting machine
33	380	1707	Abraham Darby	iron casting	Landes (1969, p. 89); Mokyr (1990, p. 93); Allen (2009, pp. 221-225)	process for smelting iron using coke
34	4067	1816	George Stephenson	half-lap joint for railways	Allen (2009, pp. 273-274)	joint for railway tracks
35	562	1738	Lewis Paul	spinning machine	Allen (2009, p. 197)	roller spinning machine
36	2196	1797	Joseph Bramah	beer pump		device for pumping beer out of casks, significant invention easing the selling of beer in the public houses
37	6159	1831	William Bickford	safety fuse		practical and reliable device for igniting gunpowder in mines
38	5803	1829	Charles Wheatstone	concertina		free-reed musical instrument
39	2708	1803	John Gamble	Foudrinier paper making machine	Mokyr (1990, pp. 106-107)	
40	5949	1830	Richard Roberts	self-acting mule	Landes (1969, p. 87); Mokyr (1990, p. 98); Allen (2009, p.208)	
41	636	1748	Lewis Paul	spinning machine	Allen (2009, p. 197)	roller spinning machine
42	939	1769	Josiah Wedgwood	new method for decorating earthenware	Mokyr (1990, p. 106)	

Table 11A (continued)

43	1111	1775	Richard Arkwright	carding machine	Allen (2009, p. 201)	
44	6733	1834	Joseph Hanson	Hansom cab		very successful horse-drawn carriage combining speed and safety
45	1105	1775	Alexander Cumming	flush toilet		first design of a flush toilet
46	5022	1824	John Apsdin	Portland cement		cement composition of very widespread use
47	1177	1778	Joseph Bramah	water closet		successful development of Cumming design, avoiding freezing of the water in cold weather
48	2202	1797	Edmund Cartwright	steam engine	O'Brien (1997, p. 231)	steam engine that may have been a source of inspiration for Robert Fulton's designs
49	6014	1830	Andrew Ure	thermostat		first bi-metallic thermostat
50	395	1714	Henry Mill	typewriter		early design of typewriting machine
51	3611	1812	Joseph Bramah	public water mains and high-pressure hydraulic mains		
52	3105	1808	William Newberry	machine for sawing wood		first bandsaw design
53	2652	1802	Joseph Bramah	making gun stocks		
54	6675	1834	Henry Shrapnel	firearms		innovative percussion lock for small arms
55	5138	1825	Richard Roberts	self-acting mule	Landes (1969, p. 87); Mokyr (1990, p. 98); Allen (2009, p.208)	
56	721	1758	John Dollond	lenses for telescopes	MacLeod (1988, p.70)	achromatic lenses for telescopes
57	8447	1840	George Richard Elkington	electroplating process		first commercial electroplating process
58	1478	1785	Joseph Bramah	screw propeller		early design of screw propeller
59	896	1768	Andrew Meikle	machine for dressing grain		
60	1112	1775	Jesse Ramsden	astronomic telescope		
61	734	1759	Jedidiah Strutt	Derby rib machine	Trinder (2013, p. 463)	mechanical knitting machine
62	10990	1845	Robert William Thomson	pneumatic tyre		first pneumatic tyre
63	3032	1807	Alexander John Forsyth	gun firing mechanism		percussion ignition for guns
64	3041	1807	William Cubbitt	self-regulating windmill sails	Trinder (2013, p. 47)	
65	1833	1791	John Barber	gas turbine		early design of gas turbine

Figure A8 shows the frequency of macroinventions in our data-base and the prediction of the Poisson model. The fit is remarkable, suggesting that the occurrence of macroinventions is consistent with a data-generating process in which serendipity play a significant part.

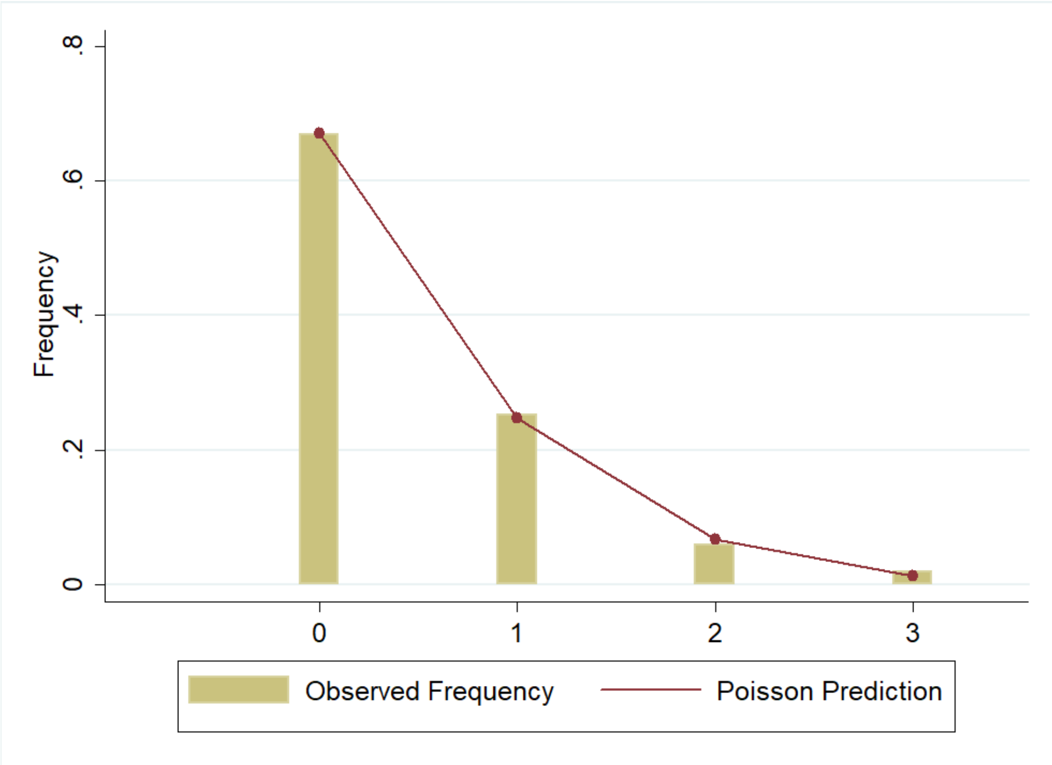


Figure A8: Frequency of years characterized by a certain number of macroinventions, actual vs predicted by the Poisson model.

Note: the unit of observation is the year and the graph shows the frequency of years with zero to three macroinventions. The Poisson model is estimated using a quadratic time trend.

One might be concerned that our results concerning the clustering behavior of macro and microinventions may be affected by the sizes of the samples. In particular, the relative low number of macroinventions may make difficult to discriminate between Poisson and Negative Binomial. Accordingly, we have carried out a simulation exercise to study the sensitivity of the overdispersion tests we have used in the paper with respect to the values of μ, the average number of events per unit of time for the cases of the Poisson and Negative Binomial distribution (Cameron and Trivedi, 1998). In the simulation, the test is formulated as a test of equidispersion, so if the underlying data generating process is a Poisson distribution it will not reject the null hypothesis, while this will be rejected if the data generating process is a Negative Binomial(Cameron and Trivedi, 2005). We perform the analysis with 100 cases for different values of μ ranging between 0 and 5, in increments of 0.05. The results are synthetically reported in Figures A9 and A10.

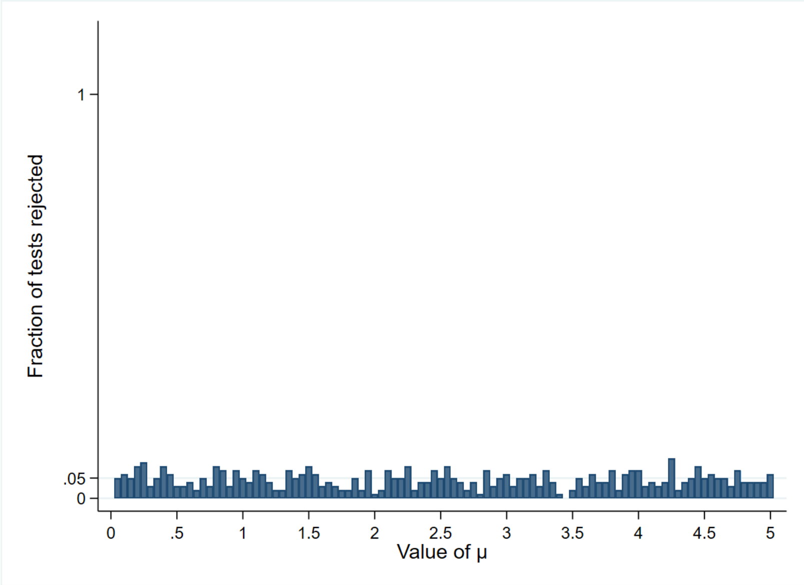


Figure A9: Fraction of cases rejected when the Data Generating Process is Poisson.

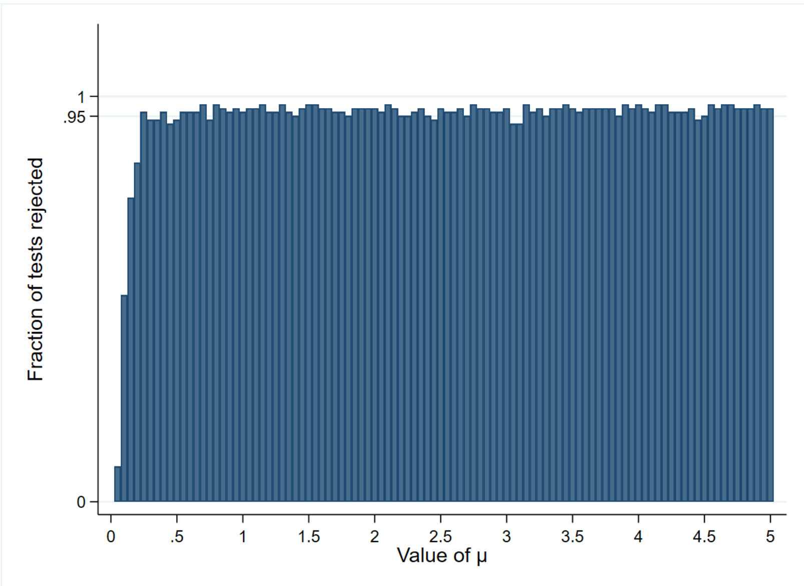


Figure A10: Fraction of cases rejected when the Data Generating Process is Negative Binomial.

In general, the test seems effective also at relatively low values of μ (so, in our case, also with low numbers of patents). Only for extremely low values of μ (< 0.3) the test does not seem effective in discriminating a Poisson data generating process from a Negative Binomial one. In our case, the relevant values of μ would be 0.43 (65 /150, i.e. 65 patents over 150 years) for the top 0.5% and 0.867 (130/150, i.e. 130 patents over 150 years) for the top 1%. This exercise confirms that our results are not simply due to the fact that macroinventions are relatively rare events (see also Sahal 1974, pp. 411-413 for a discussion).

Finally, we also tested the role of economic inducements on the rate of arrival of macro- and microinventions. We took the best models from Table 5 and Table 6 in the main text, and we included among the regressors the GDP index assembled by Broadberry et al. (2015). Interestingly enough, we find a significant correlation with GDP in the case of microinventions, but not for macroinventions (Table A12). This result is in line with previous evidence (Bottomley, 2014) and suggests that macroinventions' arrival is due to serendipitous strokes of genius and luck, as originally argued by Mokyr (1992).

Table A12: Regression results, Poisson and negative binomial models with arrival rate for microinventions as a function of time using the best model of Table 6.

DV:	Macroinventions		Microinventions	
Model:	Poisson		Neg Bin	
Time trend	0.0642***	0.0604*	0.0303***	0.0407***
	(0.0193)	(0.0324)	(0.0030)	(0.0047)
(Time trend)^2	-0.0003***	-0.0003	0.004**a	0.008***a
	(0.0001)	(0.0003)	(0.0016)a	(0.0045)a
GDP index		-0.0010		0.0029***
		(0.0057)		(0.0010)
Constant	YES	YES	YES	YES
Pseudo-R^2	0.097	0.097	0.291	0.295
Obs	151	151	151	151
LogL	-118.63	-118.61	-570.146	-566.424

Note: Note: *,**,*** denote significance at 10%, 5% and 1% level. The regressions without the GDP index are the best model of Table 6 for macroinventions and microinventions, respectively. GDP index is taken from Broadberry et al. (2015). Estimated coefficients are sometimes multiplied by the following factor: a=100.

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