Patenting in Scotland and Ireland during the industrial revolution, 1700-1851

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Introduction

The English patent system during the industrial revolution has been the subject of several monographs and multiple articles, unlike the the related patent administrations in Ireland and Scotland which have been almost entirely neglected.[1] This paper constitutes the first step towards a systematic analysis of the economic effects of patenting in these two countries. The first part of the essay describes the contours of patent administration in the two countries, with specific reference to their English counterpart. This section will establish that the legal requirements and costs of obtaining and enforcing patents were substantially the same throughout the United Kingdom. This was largely because Scotland and Ireland followed English practice. The second part of the paper describes the compilation of the Scottish and Irish patent indexes. These have been specially constructed for this paper. The third part presents a statistical analysis of these indexes. It shall argue that these patent indices mirrors the 'orthodox' chronology of industrial development in Ireland and Scotland. It shall also argue that the three patent series indicate that patentees and inventors were responsive to the economic opportunities of invention during the industrial revolution. The fourth part will test this contention by using the three patent indices in conjunction with an established quality indicator to look at the behaviour of patentees.

Section 1

The British patent 'system': Patent administration before reform

Modern day patent systems are generally characterised by a centralised office staffed by

1 There is a complete absence of any work relating to patents for inventions in Ireland during this period. There is one essay that includes a discussion of Scots patent law. H.L, MacQueen, 'Intellectual Property and the Common Law in Scotland c.1700-c.1850' in Lionel Bently, Catherine Ng, & Giuseppina D'Agostino, (eds.) The Common law of Intellectual Property, Essays in honour of Professor David Vaver, (Oxford, 2010)

professionals responsible for the awarding, recording and administering of patents. Before the Patent Law Amendment Act in 1852 there was no such equivalent to a centralised bureaucracy in any part of the United Kingdom. Rather patents for invention were administered by a plethora of separate offices and officials through which the petitioner had to navigate to secure patent protection.

Further, there was not one patent system responsible for the United Kingdom: rather there were three semi-autonomous administrations. One was responsible for England and Wales, the second Scotland and the third Ireland. Within certain time restrictions it was possible for an inventor to obtain patent protection within any combination of the three jurisdictions.

The origins of the patent system were medieval, letters patent being an administrative tool by which the monarch made grants. The English patent rolls (a register of the grants) survive from 1201.[2] Similarly, the Scottish 'Great Seal Register' survives from 1315.[3] The bureaucratic structure of patenting in England was barely changed between the 1535 passing of the Clerks of the Signet and Privy Seal Act and 1852. The intention of the 1535 act was not to provide an efficient and expeditious service. Rather it was designed to include as many offices as possible in the petition procedure, to secure more fees for the unsalaried officers, explaining the immensely convoluted petition process in England.[4] The relative absence of reform meant the offices dealing with patent petitions were still being allocated by means of patronage and patrimony rather than merit until 1852. For example, the office of Clerk of Inventions in the Patent Office of the Attorney-General stayed in the Poole family for over 70 years.[5] To obtain an English patent, a petition had to pass through the following stages.

1st stage. The petition and sworn affidavit of the petitioner is submitted to the office of the Secretary of State for the Home Office. The petition provided the title of the proposed patent, the name of the proposed patentee(s) and whether the petitioner was the original inventor, or an importer of the invention.

2nd stage. Once the petition was signed by the Secretary of State, the petitioner (or his agent) took the petition to the chambers of one of the law officers. It was here that the law officers (theoretically) examined the petition and made their report. However, in the absence of any caveat opposition, from around 1760 the petition was passed as a matter of course.[6]

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2 Patent Rolls, London, National Archives (N.A.), C66/1 to C66/5726

3 Great Seal Register, Edinburgh, National Archives of Scotland, C1/1 to C2/270

4 For a full outline of the English petiton process see Christine MacLeod, Inventing the Industrial Revolution, The English patent system, 1660-1800, (Cambridge, 1988), p.40

5 James Poole, was Clerk of Inventions from 1776. His son Moses, inherited the position in 1817, and held it until 1852. Number of Letters Patent for Inventions, sealed in each of the Ten Years, ending 31 December 1847, together with the fees paid, (Parl. Papers, 1849, XLV), p.52

6 A caveat was a form entered by interested parties, usually with the law officers, requesting notification of any patents relating to a particular technological area. Upon receipt they could choose to oppose the grant of the patent, and in England this occurred regularly. Of 5993 petitions that reached the law officers between 1838 and 1847, 384 were either stopped, altered or forced to restart the petition process as a result of caveat opposition. This represents 6.4% of all petitions. Although there are no exact figures available, caveat oppositions were less frequent in Scotland and unusual in Ireland. This is because English patents were normally obtained before an Irish or Scottish counterpart, and if the petition was contestable, most potential objections would have been exhausted after the English caveat oppostions had been heard. Also the English law officers, in deciding caveat oppositions in their jurisdiction would, where necessary, consult their Irish and Scottish counterparts. Number of Letters Patent for Inventions, sealed in each of the Ten Years, ending 31 December 1847, together with the fees paid, (Parl. Papers, 1849, XLV), p.7-8

3rd stage. The report of the law officer is returned to the Home Office to receive the King's (or from 1837 the Queen's) Warrant. The warrant is signed by the monarch and countersigned by the Secretary of State.

4th stage. The warrant is then taken to the Patent Bill Office of the law officer. Here the Bill for the patent is prepared by the engrossing clerk of the Office.

5th stage. The Bill is now taken back to the Secretary of State for the Home Office (for the third time). Here it is to receive the royal signature (for the second time) and receive the sign manual. With the sign manual affixed the bill is now entitled the 'The King's bill'.

6th stage. The King's bill is taken to the Signet Office. Here the clerks of the Signet must prepare and issue the Signet bill to the Lord Privy Seal.

7th stage. The Signet bill is taken to the Privy Seal Office to obtain the Privy Seal Bill.

8th stage. The Privy Seal bill is now taken to the Letters Patent Office (not to be confused with the Patent Bill Office mentioned in stage 4). It is here that the letters patent are prepared, sealed and enrolled.

9th stage. The Letters patent are taken to the Lord Chancellor to receive the Great Seal. There is a public seal day on Friday every week but, for an additional fee, the bill may be sealed any other day. Once sealed, the patent and Great Seal are put into a case and delivered to the petitioner.

10th stage. At the final stage the patentee must submit a detailed description of his patented invention, entitled the specification. As mentioned above the amount of time the patentee had in which to submit his specification depended on where he (during this period it was almost invariably a he) had stated it was intention to obtain a patent. The specification could be enrolled in one of three Chancery offices, the Enrolment Office, the Petty Bag Office or the Rolls Chapel.

By the mid-nineteenth century most contemporaries regarded the petition process as far too lengthy and inefficient One engineer complained to an 1851 Committee, 'I think the present patent law, as regards the granting of patents' is about as disgraceful a state as it can be'.[7]

The legislative basis for Scottish and Irish patents of inventions is less clear, especially as there does not appear to be any legislation relating to either system after the two Acts of Union.[8] It is likely though that Irish and Scottish administrations were influenced by practices in England. The most important development in the English petition process was probably the introduction of the specification, the detailed description of the patented invention submitted after the patent had been awarded. Although there is some dispute regarding the timing of the 'first' specification, there were very few before 1735, after which they appear to have become standard practice. Although there were very few patents awarded in this period in Scotland and Ireland, it appears that specifications were also adopted in both quite quickly. The last Scottish patent without a specification was awarded in 1736.[9] Similarly from 1728 Irish patents were awarded on the condition that a specification was entered with Irish Chancery.[10]

The patent systems in Ireland and Scotland were administered by a similarly 'amateur' and

7 Minutes of Evidence taken before the Select Committee of the House of Lords appointed to consider the Bill to extend the provisions of the Design Act, 1850, and to give protection from Piracy to persons exhibiting Inventions in the Exhibition of 1851, (Parl. Papers, 1851, XVIII), p.25

8 The Acts of Union with Scotland took effect in 1707. The Acts of Union with Ireland took effect in 1801

9 Scottish patents and specifications, 1712-1812, Edinburgh, National Archives of Scotland, CE3, fol.1

10 State Papers, London, National Archives (N.A.), SP36/5 fol.259

labyrinthine bureaucracy. To secure a patent in Scotland, the petition had to pass through seven distinct stages:

1st stage. Petition and declaration submitted to the Secretary of State for the Home Office in London.
2nd stage. Petition is referred to the Lord Advocate of Scotland (the chief legal advisor to the government on Scottish legal matters).
3rd stage. The report of the Lord Advocate.
4th stage. Report is taken to the Home Office where the King's Warrant is prepared, directing preparation of the the patent.
5th stage. Patent is prepared in the office of the Director of the Chancery.
6th stage. Carries to the Keeper of the Great Seal, to have the seal affixed.
7th stage. Specification had to be lodged at Scottish Chancery.[11]

To secure a patent in Ireland, an inventor had to go through a similar process again.

1st stage. Petition submitted to the Lord-Lieutenant of Ireland, the regents personal representative in Ireland.
2nd stage. The petition was referred to the Attorney-General or Solicitor-General of Ireland to report.
3rd stage. On receipt of the Attorney-General of Ireland's report a draft of a King's letter is prepared and forwarded to the Home Office in London.
4th stage. The King's letter, consisting of the authority to grant the patent, is signed by the monarch and countersigned by the Secretary of State.
5th stage. This is entered at the Signet Office, sealed with the Signet, and returned to the Lord-Lieutenant.
6th stage. On receipt of the King's letter, a warrant is prepared for the Lord-Lieutenant's signature, directed to the Attorney-General or Solicitor-General of Ireland authorising him to draw up a fiant (or warrant) containing a grant from the King.
7th stage. The fiant was submitted to the Lord-Lieutenant for his signature, and the Privy Seal affixed.
8th stage. The fiant was forwarded to the Clerk of the Crown, who prepares the necessary document thereon, that is passed under the Great Seal of Ireland.
9th stage. The specification is entered at the Irish Court of Chancery.[12]

Although there are some minor differences between the three petition procedures, the essential steps were the same. Firstly, the substantive examination of the petition was (in theory) undertaken by the chief law officer(s) of the country. Secondly, every petition at some stage required the monarch's signature. Thirdly, the specification was to be deposited in the offices of the court of equity. In the first half of the nineteenth century it was reckoned to take about 1 month to secure an English patent, a few weeks longer in Ireland and about a week less in Scotland.

Although the bureaucracy appears foreboding, it was normally of little practical significance to the

11 Report of the Committee (appointed by the Lords of the Treasury) on the Signet and Privy Seal Offices, (Parl. Papers, 1849, XXII), p.xii
12 Ibid, p.xii

inventor, since most employed an agent to obtain the patent on their behalf. Patent agents were working in London from the mid-eighteenth century and by 1849 it was regarded as unusual for a petitioner not to employ one. In evidence to a parliamentary committee, Thomas Ruscoe, chief clerk of the Great Seal Patent Office, observed 'there are but few patents passed by the patentees themselves'.[13] By 1849 a number of London patent agencies maintained Dublin and Edinburgh offices and it is likely the majority of inventors employed the services of patent agents there as well.[14] Unlike in England, however, in obtaining a Scottish or Irish patent, the inventor was never required to attend their petition in person. Doubtless this meant there were more English patentees in Scotland and Ireland than would otherwise have been the case.

There was, however, no escaping the tremendous cost of maintaining this labyrinth. In 1846 the minimum amount payable in official fees for an English patent was £95. In modern terms this equates to around £70,000 calculated as a multiple of average earnings.[15] In real terms the cost of these official fees remained stable over 130 years. The diary of a patentee from 1723 suggests that the official fees then amounted to £62, around £90,000 today.[16] In Scotland the fees were slightly lower, and again remained fairly stable over time. In 1829 Moses Poole quoted a figure of £66.[17] In 1849 official fees were slightly less at £63.

However, patentees had to pay a great deal more than just the official fees. Firstly, they had to pay fees for patent agents. These amounted to 10 guineas for every individual English, Scottish or Irish patent. Secondly, a patentee had to pay fees to enter their specification. This varied considerably according to the length of the instrument entered.[18] In 1826 in Scotland, the most expensive specification entered to date had been £33, exclusive of the £5 stamp duty, whereas the cheapest had been £1 7s.[19] Thus another £25 has to be added to the cost of a Scottish patent (£10 for a patent agent and about £15 for entering the specification according to length) in addition to the £65 charged in ordinary fees. This gives a total figure of £90, in

13 Committee on the Signet and Privy Seal Offices, (Parl. Papers), p.26

14 Ibid, p.58

15 There are several methods of translating historical monetary values, into a modern-day comparitor. The one used here, 'average earnings' (the average weekly wage) calculates the value of the good or service as a multiple of the average contemporary wage. So for 2009, the figure of £70,000, has the same ratio to average earnings in 2009, as £95 did to average earnings in 1846. This measure is useful for indicating the relative affordability of a commodity or good in terms of labour. Lawrence H. Officer, "Purchasing Power of British Pounds from 1264 to Present," MeasuringWorth, 2011. URL: www.measuringworth.com/ppowerus/

16 This however excludes the expenses of travelling , lodgings and entertainment incurred by a patentee who had to travel to London (before the advent of patent agents). In total the patentee spent £128 19s. 5d. or as a multiple of average earnings, around £192,000 A. A. Gomme, 'Patent Practice in the 18th Century: The Diary of Samuel Taylor, threadmaker and inventor, 1722-1723', Journal of the Patent Office, 19 (1937), 209-224

17 The full cost reported by Poole for a Scottish patent was £79 10s. 5d, but this figure included other coosts such as patent agency fees. To make the figure reported in the text comparable wth the quote from the 1849 Committee these costs were excluded. Report from the Select Committee on state of law and practice relative to patents for inventions, (Parl. Papers, 1829, III), p.87.

18 There was one ancillary expense to entering the specification which could be considerable. If the patentee ever sought to enforce their patent in legal action, any opponents would carefully scrutinise the accuracy and sufficiency of their specification. Many patentees lost legal actions, because of the insufficiency of their specifications. To avoid this eventuality, patentees generally employed legal and technical assistance in the preparation of the specification. In an 1829 Select Committee one witness stated that he had known the professional charges relating to the preparation of the specification to be as high as £200 – more than twice the official fees. The average was around £20. However, Scottish or Irish patents almost always had an English equivalent, which was normally obtained first. Because the same description could be entered for the different national patents, so long that the patented inventions were the same, professional fees in preparing the specification only had to be incurred in England. Ibid, p.17

19 Expenses incurred in taking out a patent in Scotland, (Parl. Papers, 1826, XXIII)

modern terms £70,000. Again, though, this figure should be regarded as the bare minimum, particularly as no effort has been made to account for extra fees, gratuities and/or the costs of facing caveat opposition.

Patent protection cost slightly more to obtain in Ireland than in England or Scotland. With official fees of around £115, and the specification and agent fees, the total cost was around £140, £105,000 today. This means that, at a minimum, a specified patent for the entire United Kingdom, cost around £365 (£135 for England including consultancy fees for the specification, then £90 for Scotland and £140 for Ireland). For an equivalent, this would around £300,000 today, a significant sum. Including all the ancillary costs, perhaps a more accurate estimate of the cost is the £500 to £600 claimed by Richard Roberts before an 1851 Select Committee.[20]

The costs and process of obtaining a patent were broadly the same in all three countries. Although protecting intellectual property was expensive, it was not particularly onerous. Indeed for a provincial inventor, obtaining an Irish or Scottish patent was probably easier than an English one. There was less chance of facing caveat opposition, and nor did they have to travel to submit the specification Establishing these similarities is essential for the statistical analysis of the three patent series outlined in section three. If Scottish patents had cost £1 compared to £115 in Ireland, it would be difficult to reliably attribute differences in the number of patents awarded to anything other than the large price differential. However, it is also important to consider possible differences in law before seeking to establish comparisons between the three countries. There are two halves to this problem. Firstly, it is important that legal issues of authorship, novelty and patentability were adjudicated in the same way in the three jurisdictions. For example, if novelty requirements were less strictly enforced in Ireland than in Scotland, there would be more patents in Ireland than if Scottish standards of novelty were enforced. The second half relates to the problem of the legal status of a patent or invention in another part of the United Kingdom. Was it, for example, possible to patent an invention in Ireland that had already been used in England?

Evidence regarding the first problem appears straightforward: both Scotland and Ireland deferred to English patent law, presumably because there were far more court cases there. With regard to Scotland, Hector MacQueen notes that decisions in Scottish courts, 'make clear the continuing sense that...the law was essentially a unity north and south of the border'.[21] He cites the example of manufactory inspections being allowed within the terms of an interdict (the Scottish equivalent of an injunction) in accordance with English practice.[22] This conclusion is supported by Select Committee evidence. In 1849 the patent agent Frederick William Campin, declared 'Scotch judges are invariably guided by English decisions in cases of patents'.[23] Also, although the records of Irish patent cases are sparse, there does not appear to be any material difference between Irish and English patent law.[24]

20 Report and Minutes of Evidence taken before the Select Committee of the House of Lords appointed to consider of the Bills for the amendment of the Law touching Letters Patent for Inventions with Appendix and Index, (Parl. Papers, 1851, XVIII), p.193

21 MacQueen, 'Intellectual Property and the Common Law in Scotland', p.25

22 Ibid, p.28

23 Select Committee of the House of Lords (Parl. Papers), p.109

24 This however, is based on only two court cases. The two cases are *Baxter* v *Combe* (1851). P. A. Hayward, Hayward's patent cases, 1600-1883: A compilation of the English cases for those years, (13 vols., Abingdon, 1987), Vol.VI, pp.11 and

Evidence regarding the legal status of a patent or invention in another part of the United Kingdom is slightly more problematic. Within certain time restrictions it was possible to obtain a patent for an invention in any combination of the three countries. When submitting the initial petition the inventor had to state whether it was their intention to apply for a patent anywhere else in the United Kingdom. If the initial application stated that only an English patent was sought, then two months were awarded to prepare the specification. Four months were awarded if a patent was applied for in another country, and six months for all three.[25] The additional time was awarded to help inventors obtain their patents. This was because the law provided that publication (an act of which, submitting the specification constituted) in any one of the three countries constituted a publication in all of them barring any subsequent patent.

The law however, was applied inconsistently. Before 1800, it was commonly accepted that prior use in one part of the Union constituted publication in another part. In *Roebuck* v *Stirling* (1774) the plaintiff had sought to maintain his patent on the grounds that as the patent bore only the seal of Scotland, only prior use in Scotland could annul it. This argument was refuted by the defendants who 'maintained that the whole United Kingdom being subject to the same rules, regulations, and restrictions in matters of trade'.[26] Defence argument was upheld both by the Lord Ordinary in Scotland, and on appeal in the House of Lords.[27] This ruling was, however, reversed by *Haworth* v *Hardcastle* (1834) where the legality of the patent was affirmed as 'the use of the machinery in Scotland before the patent, could not invalidate the English patent'.[28] There was no precedent for this decision, and it was again contested in the courts. In 1842 *Brown* v *Annandale* came on appeal from the Scottish courts to the House of Lords. Here it was held by Lord Campbell 'that the law was quite correctly laid down by this house in the year 1774'.[29] Nonetheless the issue still proved contentious. In *Brown* v *Kidston & Waters* (1852) the Lord Ordinary's initial decision to award an interdict had to be overturned at the Second Division, even though the Scottish patent had been obtained 10 months after the English - and so 4 months after the English specification had been entered.[30]

The ambiguous wording of the patent itself also raised the spectre of 'legal' infringement. While the part of the patent reciting the actual grant conferred the right to 'vend' the invention, the prohibitory part of the patent (that part which details the exclusion operating on other parties) made no mention of vending. This could be seen to imply that it was legal to manufacture or use the invention in a part of the kingdom where a patent was not in force, and sell (vend) it where the patent was in force. However, it was expressly decided in the case of the *Universities of Oxford and Cambridge* v *Richardson* (1803), that where a (copyright) patent is in force in England but not Ireland, 'if any of the King's subjects buy an article in Ireland, he cannot bring it

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Carmichael v *Combe* (1851). Ibid, Vol.6 p.216

25 It appears that this system was being abused by the end of the period, with virtually all petitioners claiming they intended also to apply for patents in Scotland and Ireland when only a fraction actually did. Of 440 patents awarded in 1840, only 14 were not given six months to enter the specification. Bennet Woodcroft, Chronological Index of patents, 1617-1852, (London, 1854)

26 William Carpmael, Law reports of patent cases. (3 vols, London, 1843), Vol.1, p.48

27 Hayward, Patent Cases, I, p.177

28 Ibid, II, p.384

29 Ibid, IV, p.24

30 MacQueen, 'Intellectual Property and the Common Law in Scotland', p.26

here, where there is a patent for it, for the purpose of trading'.[31] This decision appears to have been accepted law with regard to patents for inventions as well and was quoted in contemporary patent treatises.[32]

This section has established the close similarities between the English, Scottish and Irish patent systems. Although theoretically autonomous, in practice Scotland and Ireland followed the English lead in patent law and administration. This was shown by the analogous petition procedures and the swift adoption of the English specification in Ireland and Scotland, as a condition of the patent grant. It is likely that this English pre-dominance is due to there having been far more patents awarded there than in Scotland and Ireland (as will be established in Section 3) and because there were many more reported court cases relating to patents.

Section 2

Constructing the patent index

This English pre-dominance also means greater efforts were made to catalogue its patent grants. After the passing of the Patent Law Amendment Act in 1852 four indices of pre-reform English patents were published. These provide information on patent date, subject matter, patentee name, residency and references to the patent in contemporary technical literature.

Indexes for pre-reform Scottish and Irish patents were not published. For both, however, there are hand-written indices surviving in the British Library, providing information similar to that of the English indexes, listing patentee name, date of grant and subject matter. Although its likely that these indices were produced as part of the same cataloguing effort that produced the four English indexes, there is no indication as to when they were produced nor as to authorship. Neither do they appear on the British Library Integrated Catalogue. Clearly it was necessary to check their accuracy. In the case of Scotland it was possible to check the British Library indices with the King's Warrant Books held in the National Archives.[33] The books contain transcripts of the King's Warrant authorising the award of the Seal of Scotland. It is reasonable to assume that the Warrant Books closely match the 'actual' patent series, as the warrant could only be obtained after the favourable report of the Lord Advocate. It is apparent from the warrant books that from before 1793, the British Library index is incomplete. The BL index contains only 37 patents from before 1793, yet the warrant book records 113 warrants for patents for inventions. Because the warrant could only be obtained after the Lord Advocate had made his report, and after caveat opposition had been defeated, it is simply not credible that so many petitioners would have failed to secure the patent after obtaining the King's Warrant. So for before 1793 the British Library Index is supplemented by the Warrant Books. Encouragingly of the 37 pre-1793 patents listed in the BL index, all are recorded in the Warrant Books. Thereafter the large majority of

31 E. Holroyd, The law and practice for inventions, (London, 1830), p.177
32 Ibid, p.177
33 These were produced at the 4th stage of the Scottish petition process, as described on page 3. Scottish Warrant Books, London, National Archives (N.A.), HO106/1 to HO106/11. Pre 1774 Warrants are in SP54

warrants appear in the BL index, meaning the BL index can be regarded as complete thereafter. The small discrepancy can probably be attributed to petitioners' failing to secure the Seal. Accordingly, after 1792 only the BL Index is used.[34]

The British Library patent index for Ireland is also incomplete. Firstly, it only lists patents for which specifications were entered. This leads to an underestimate of the total number of patents granted in Ireland as compared with Scotland and England, where all patents to have received the Seal are counted. Secondly, it appears also to be an underestimate of the number of patents awarded during the eighteenth century, listing only 7. Fortunately, there is a contemporary Home Office document listing Irish patents for invention from before 1827.[35] This lists 58 patents for the eighteenth century. Again the 7 patents listed in the British Library Index all appear in the Home Office paper. Also, because it includes all patents (not just patents with specifications), it has been used as the main source for pre-1827 Irish patents for inventions. After 1826 the specification index has been used.

It is possible to estimate how many patents are excluded from this specification index by comparing it with the Home Office paper. Of 350 patents listed between 1800 and 1826 in the Home Office paper, 322 appear in the specification index. This means 28 patents were awarded for which no specification was entered – or just under 9% of the specification total. If we assume this proportion of unspecified to specified patents was the same between 1827 and 1851, then a total number of specified patents of 1175 implies there were around 1280 patents awarded in total. Although this represents only a small underestimate, it would have been preferable to use the original patent rolls. These however, were destroyed during the Anglo-Irish war in 1921.

After collecting the data, I began to match the Irish and Scottish patents with their English equivalents. Generally Scottish and/or Irish patents were obtained under the same name, similar patent title and (due to the specification requirement) within six months of the English patent, making the large majority of matches simple.[36] For example the English patent granted to Thomas Dunn for a 'Turntable to be used on railways', on the 13th of March 1845, (English patent no. 10556) was matched with the patent granted in Scotland to a Thomas Dunn for 'Certain improvements in or applicable to turn tables to be used on or in connection with Railway', granted on the 4th of April 1845 and with the Irish specification entered by Thomas Dunn for 'turntables for railways' on 19th of November 1845.

There were a number of cases where there was some ambiguity in the match. For example, as with the Irish patent granted to Benjamin Batley for a 'New method of curing and preserving herrings' granted on the 15th of November 1800. This was matched with the English patent taken out by Benjamin Batley awarded

34 Between 1793 and 1808, only 18 out of 184 warrants do not appear in the BL Index, less than 10% of the total. Scottish Warrant Books, London, National Archives (N.A.), HO106/2 to HO106/3

35 This was derived directly from the original Irish patent rolls. These have now been destroyed. Return to Parliament from the Rolls Office of the titles and dates of patents granted in Ireland for manufactures and inventions, London, National Archives (N.A.), HO42/218

36 For post 1826 Irish patents the potential range between English and Irish matches was increased to 12 months, as only the date of the Irish specification was recorded. This could be entered 12 months after the English patent was obtained because, 6 months were generally awarded for entering the specification after the grant of the Irish patent, which itself could be obtained up to 6 months after the English patent.

on the 11th of September 1800 (no.2441) for 'Curing and preserving herrings and sprats', rather than the patent awarded to him on 25th January 1801 (no.2465) for 'Curing and preserving herrings, sprats, and other fish'. In this instance and in other cases of ambiguity, the match was normally made with the English patent with a date preceding the Scottish or Irish grant, as English patents were normally obtained before either. This is apparent from evidence in the parliamentary papers. Before an 1849 Parliamentary Select Committee, for example, one prominent patent agent claimed that even Scottish or Irish inventors 'almost invariably come or write to London first'.[37]

There were also cases where there was not an exact match in the information between the English patent and a Scottish or Irish patent, but where it was reasonable to suppose a match could be made. For example, an English patent awarded to James Mayer, for a 'machine for cutting splints for matches' on 4th December 1839 (no.8297) was matched with an Irish specification entered by Antonio J Mayer for 'cutting splints for matches' on the 24th September 1840.

There were also a small number of patents (3 in Ireland, 23 in Scotland) where no precise match could be made although it was likely that there was an English equivalent. This occurred where an individual, normally a patent agent, was responsible for a large number of patents with similar subjects in a short period of time.

After the matching process there remained a number of patents that could not be matched with an English equivalent. This is most likely because there was no English patent obtained for that invention, and patent protection was only obtained in Scotland and/or Ireland.

Section 3

The British patent series

The first section of this paper described the administrative and legal aspects of patenting in Scotland and Ireland. It established the close similarities between the patent systems of the three countries. Because the costs and requirements of obtaining and enforcing patents were broadly the same in Ireland, Scotland and England, patents within the three jurisdictions may be legitimately regarded as statistically comparable. The second section outlined the compilation of the English, Scottish and Irish patent indexes. The only discrepancy in the three series is that after 1826, the Irish index only lists patents with which a specification was later submitted. This section presents an analysis of the three patent series, interpreting Scottish and Irish patent numbers as an indicator of the commercial opportunity for new technology.

The first historian to analyse the English patent series of the period was Richard Sullivan. He argued that the contemporary patent count could be regarded as an indicator of the resources committed to (patentable) inventive activity.[38] Accordingly, he claims the acceleration in the growth in English patenting

37 Committee on the Signet and Privy Seal Offices, (Parl. Papers), p.30

38 R. J. Sullivan, 'The revolution of ideas: Widespread patenting and invention during the English Industrial Revolution', The Journal of Economic History, 50, (1990), p.351

around the late 1750's indicates an acceleration in the growth of resources committed to inventive activity.[39] This in turn is interpreted as marking the beginning of the industrial revolution. Sullivan, however, has been criticised for assuming that the propensity to patent inventions did not vary over time and between industries, and that most inventions that could be patented were. Certainly, this assumption looks questionable, when one considers the infeasibly low level of inventive activity indicated by the annual patent totals, during the first half of the eighteenth century.[40]

Of particular importance in this respect is the work of Petra Moser, who has demonstrated that a substantial proportion of invention was never patented, and that this proportion varied between industries. Moser undertook an empirical study of the exhibits in the 1851 Great Exhibition at Crystal Palace. She found that there were considerable disparities in the patenting rates of different exhibits. For example, only 5.1% of all British exhibits in chemicals were patented, whereas 29.8% of manufacturing machinery exhibits had been patented. Moser's data is corroborated by O'Brien et al's work on British textile inventions.[41] Tracing 174 key textile inventions during the eighteenth century they found that 44% were patented.[42] However, they employed a broader definition of textile inventions than that employed by Moser, including developments in both textile manufacturing machinery and dyeing (the latter categorised as chemicals in Moser's sectoral classification). The figure of 44% thus masks wide differences in patenting rates in different types of textile invention. Once the different types of textile invention are accounted for, O'Brien et al found similar results to those of Moser. The patent rates for dyes were noticeably low, while there was a much higher propensity to patent machinery.[43]

Because the propensity to patent varies, patent numbers do not provide a straightforward indicator of inventive. This is not to suggest that the increase in patent numbers during this period, is not *partly* accounted for by increases in levels of inventive activity, but rather that they do not *fully* account for these changes. Other factors must affect the propensity to patent new developments, given that the patent series does not accurately measure changes in inventive activity. While not rejecting the possible role of increases in the underlying level of inventive activity, Christine MacLeod also suggests that economic factors played an important role in the increasing propensity to patent.[44] She notes in particular that increasing disposable incomes led to more 'consumer' patents.[45] Similarly, growing investment in capital equipment led to the

39 R.J. Sullivan, 'England's "Age of Invention": The acceleration of patents and patentable invention during the Industrial Revolution', Explorations in Economic History, 26 (1989), p.425

40 James Harrison, Encouraging innovation in the eighteenth and nineteenth centuries: The Society of Arts and patents, 1754-1904, (Gunnislake, 2006), p.14

41 T. Griffiths, P. Hunt, & P. K. O'Brien, 'Inventive activity in the British textile industry, 1700-1800', Journal of Economic History, 52, (1992), 881-906

42 Ibid, p.885

43 Ibid, p.888

44 MacLeod also notes there were other factors increasing the accessibility of the patent system to petitioners, for example better transport links to London and increasing knowledge of the existence of the patent system due to growth in numbers and new publications. It is unlikely that either factor was important in regard to Scotland and Ireland. Concerning transport links, as mentioned in the first section there was no need to travel to Edinburgh or Dublin to secure a Scottish or Irish patent. Its also unlikely that increasing knowledge of the potential of the patent system was important, as the rapid growth of English patents and commerical publication of specifications pre-dated rapid growth in the Scottish and Irish patent systems. MacLeod, Inventing the Industrial Revolution, p.145

45 Ibid, p.149

development of a specialist capital goods sector, for which the value of patent protection increased with their output. MacLeod argues that these developments led to a 'first-strike' mentality: that it was necessary to patent one's improvements, to pre-empt another party's independently patenting them and fore-stalling its exploitation by the first inventor. Although MacLeod presents something of a hotch-potch of possible factors, there does appear to be one underlying claim: changes in the economy made it more valuable to protect one's own intellectual property.

Some of these complicating factors can be side-stepped in the cases of the Irish and Scottish patent series. From 1700 to 1851 there were 13514 patents awarded in England, 3879 in Scotland, and 1525 in Ireland. Almost all inventions for which patents were obtained in Scotland and Ireland were also patented in England. From 1750 to 1851 there were only 151 Scottish patents that did not have an English counterpart, about 4% of the total number of patents awarded. The comparable figure for Ireland was 66, again ≈4% of the total patents awarded.[46]

These figures have an important implication for how we consider the relationship between the three patent populations. Although the three populations might have been relatively independent, in practice it is more useful to think of all patents originating in England that were then subsequently extended to Scotland and/or Ireland. This is confirmed by an analysis of residency information in the three patent series. In Ireland from 1800 to 1851 84% of first named patentees gave their residency in England, whereas only 6% gave Ireland. The remainder were either from Scotland (7%) or from abroad (3%). Similarly, in Scotland 88% of first named patentees came from England, 10% from Scotland, 2% from Ireland and less than 1% from abroad. This presents an opportunity. Patent indices are normally a 'noisy' indicator, responsive to changes in the economy, institutional changes and levels of inventive activity. However, because the large majority of inventions that were patented in these countries were not developed there, underlying levels of inventive activity can be factored out. Similarly, there were no significant changes in the patent system of any country before the Patent Law Amendment Act in 1852.

This means that changes in the number of patents in Scotland and Ireland were attributable to changes in the economic opportunity of protecting intellectual property. This inference is supported by modern data. In their work on European patenting, Nicolas van Zeebroeck and Bruno van Pottelsberghe established a strong correlation between the number of patents filed for each country in the European Patent Office and the size of that country's GDP.[47]

There are three factors that would influence a party's decision to extend a patent to Scotland or Ireland (besides affordability), the first the perceived quality of the invention. Generally speaking, the more valuable the invention, the more extensive the protection we would expect the inventor to invest in. Secondly, we would expect the decision to extend a patent to be influenced by the market for the invention in that particular country. Economic growth would increase the expected market for most inventions and so would be expected to lead to an increase in patenting. The third factor that would influence an individual's

46 There were 14 patents that were obtained in both Scotland and Ireland, but not England

47 Bruno Van Pottelsbeghe de la Potterie, & Nicolas Van Zeebroeck, 'A brief history of space and time: the scope-yar index as a patent value indicator based on families and renewals', Scientometrics, 75 (2008), p.324

propensity to patent in a particular country would be the extent of their personal and business connections in that country. This third factor probably increased in importance with improving communications and market integration between the three countries. This would have acted to increase the propensity to extend patent protection to Scotland and Ireland. These developments, however, were themselves bound up with changes in the economy.

The reasoning behind these two factors are exploited in a form of modern patent analysis called 'family size analysis'. Van Zeebroeck summarises the rationale for this analysis thus, 'given the costs required to file and enforce patents in multiple countries, only those with sufficient expected value to their owners will be extended abroad': in effect that patent quality can be inferred from the number of jurisdictions in which patent protection is obtained.[48] In a test of various methods of estimating patent value against a dataset where value assessments had come directly from a survey of the patent holders, Harhoff, Scherer and Vopel found that 'family size, the number of jurisdictions for which patent protection was granted carries the expected positive sign and is highly significant' in relation to the patent's empirical value.[49] This claim will be explored in the fourth section

Van Zeebroeck also argues that family size analysis can also be used to 'denote an expected market for the patented technology', i.e. that an analysis of the differences in the distribution of patents over time and between industries can illuminate the perceived relative opportunities for new technologies in different countries.[50] It is this second claim which will be explored in the rest of this section with reference to Scotland and Ireland. If we want, however, to attribute differences in their respective patent indices to changes in their economy, it is necessary briefly to outline a chronology of industrial development in Scotland and Ireland.

In comparison with the rest of Europe, Ireland remained poor throughout the first half of the nineteenth century. Standard consumables such as tea and sugar were rarely found in Irish households. Despite this poverty there was widespread rapid population growth, increasing from about 5 million in 1800 to 6.8 million just 20 years later.[51] This probably contributed to the widespread decline in standards of living reported by the Poor Inquiry of 1835-6.[52] Irish industry stagnated during this period, as the percentage of the population in manufacturing activities declined. The 1821 census recorded 41.2% of the labour-force engaged in manufacturing or trade. In 1841 this figure had declined to 33.6%, although with overall increases in the population size, the absolute number in manufacturing was constant.[53] After 1841, however, absloute numbers in manufacturing collapsed. Geary estimates that 400,000 jobs were lost during the 1840's in textiles due to the introduction of wet-spinning.[54] Overall it is likely that manufacturing output remained

48 Nicolas Van Zeebroeck, 'The puzzle of patent value indicators', Economics of Innovation and new technology, 20, (2011), p.36

49 Dietmar Harhoff, Frederic Scherer, & Katrin, Vopel, 'Citations, family size, opposition and the value of patent rights', Research Policy, 32 (2003), p.1358

50 Van Zeebroeck, 'Puzzle of patent value', p.36

51 Cormac Ó Gráda, Ireland, a new economic history, 1780-1939, (Oxford, 1994), p.6

52 The Poor Inquiry suggested that standards of living were declining in 30 of the 32 counties. Joel Mokyr, Why Ireland starved: A quantiative and analytical history of the Irish economy, 1800-1850, (Oxford, 1983), p.12

53 Frank Geary, 'The Act of Union, British-Irish trade and pre-Famine deindustrialisation', Economic History Review, 48 (1995), p.83

54 Frank Geary, 'Deindustrialisation in Ireland to 1851: some evidence from the census', Economic History Review, 51, (1998), p.521

constant during the first half of the nineteenth century, despite the (overall) increases in the potential labour supply.

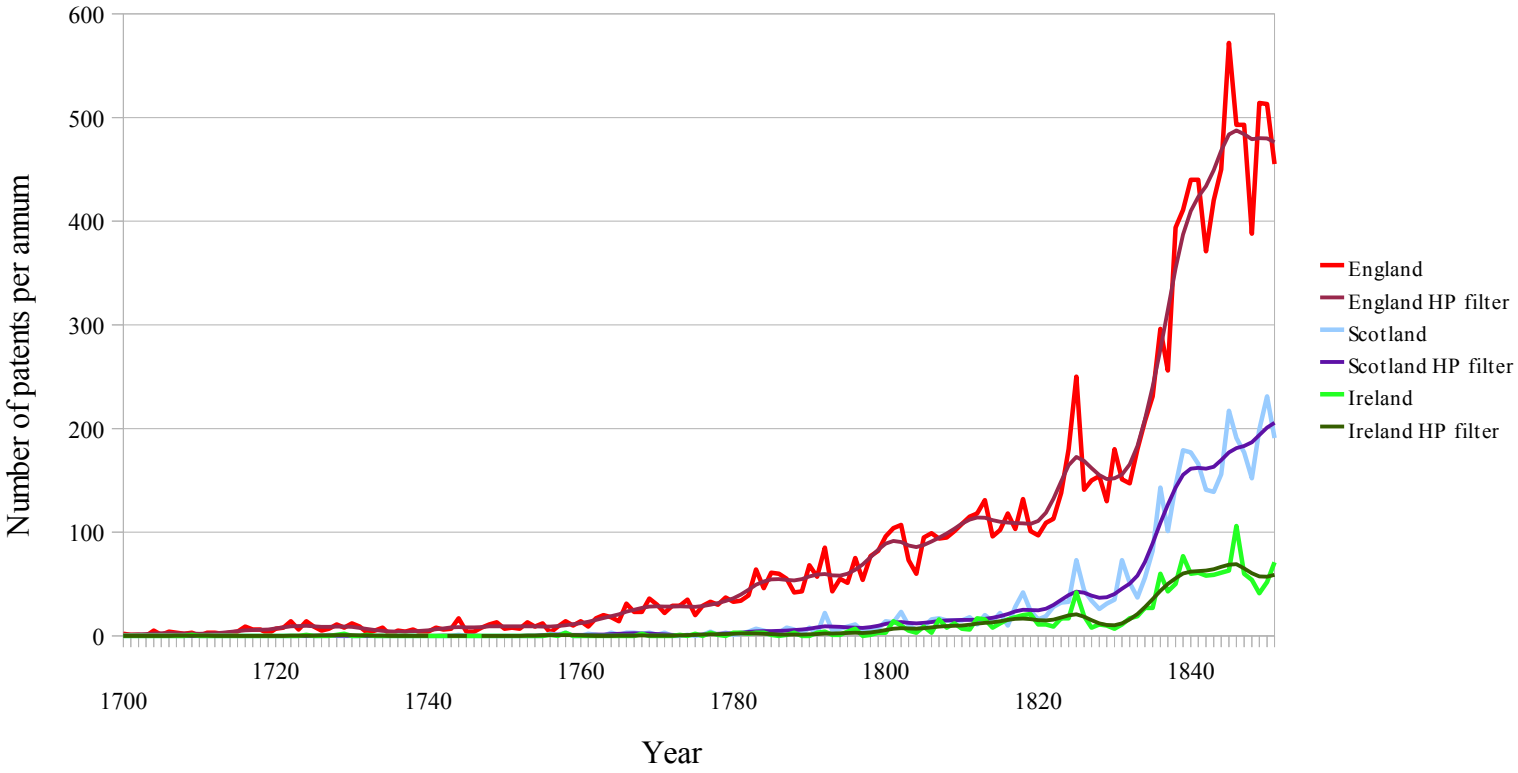
In contrast, Scotland saw rapid industrialisation that by 1851 had wrought changes that were every bit as transformative as anything that had happened in England.[55] In the eighteenth century Scotland was poor compared with England. From 1765-95, the wages of carpenters in Aberdeen or Edinburgh, never reached two-thirds of the level of carpenters in Manchester or Exeter.[56] However, the Scottish textile industry began to grow rapidly towards the end of the eighteenth century. From 1781-86 to 1799-1804, annual imports of cotton grew 17 fold.[57] Initially, however, manufacturing growth was largely confined to the textile sector. Before 1830 it may have accounted for 90% of Scottish manufacturing employment.[58] After 1830, however, there was an abrupt diversification of Scottish manufacturing into other 'revolutionary' sectors. Especially important was Neilson's invention of the hot blast process. Scottish iron output grew from 37,500 tons in 1830 to 700,000 tons in 1849.[59] Crafts estimates of the proportion of male workers in 'revolutionised industry' in Britain in 1841 show 3 out of 8 Scottish regions had 30% or more of their adult male labour force in these revolutionised sectors, compared to 4 out of 43 in England.[60]

Although this is not the place for an extended discussion of why Scotland enjoyed such success while Ireland suffered stagnation, one factor ought at least be mentioned: the importance of natural deposits of iron and coal. Whatley claims that in Scotland coal and iron was essential to industrial growth, with real incomes declining until sufficient supplies of coal began to be mined to feed industrial growth.[61] By contrast Ó Gráda notes of Ireland that by 1830 coal prices had forced the abandonment of energy-hungry industries such as glass-making, sugar-refining and salt production.[62]

This brief summary of relevant Scottish and Irish economic history, suggests that we should expect divergent patterns in their respective patent series. In particular we would expect to see many more patents in Scotland than Ireland. This is because Scotland's rapid economic development made the protection of new inventions more valuable than in Ireland. The graph below shows the annual number of patents awarded in each of the three countries between 1700 and 1851. The light-coloured lines indicates the annual total of patents awarded for each of the three country's. Because there is considerable fluctuation in annual totals, the Hawley-Prescott filter has been used to dampen short-term fluctuations and clarify the longer-term trends. These are shown by the darker lines.

55 C. A. Whatley, The Industrial Revolution in Scotland, (Cambridge, 1997), p.7
56 T. M. Devine, 'Scotland', in Roderick Floud, and Paul Johnson., The Cambridge Economic History of Britain, Volume I, Industrialisation, 1700-1860, (Cambridge, 2004) p.395
57 Whatley, Industrial Revolution in Scotland, p.25
58 Devine, 'Scotland', p.399
59 Ibid, p.400
60 N. F. R. Crafts, British Economic Growth during the industrial revolution, (Oxford, 1985), p.4-5
61 Ibid, p.52
62 Ó Gráda, Ireland, a new economic history, p.316

Fig.1 British patents, 1700-1851



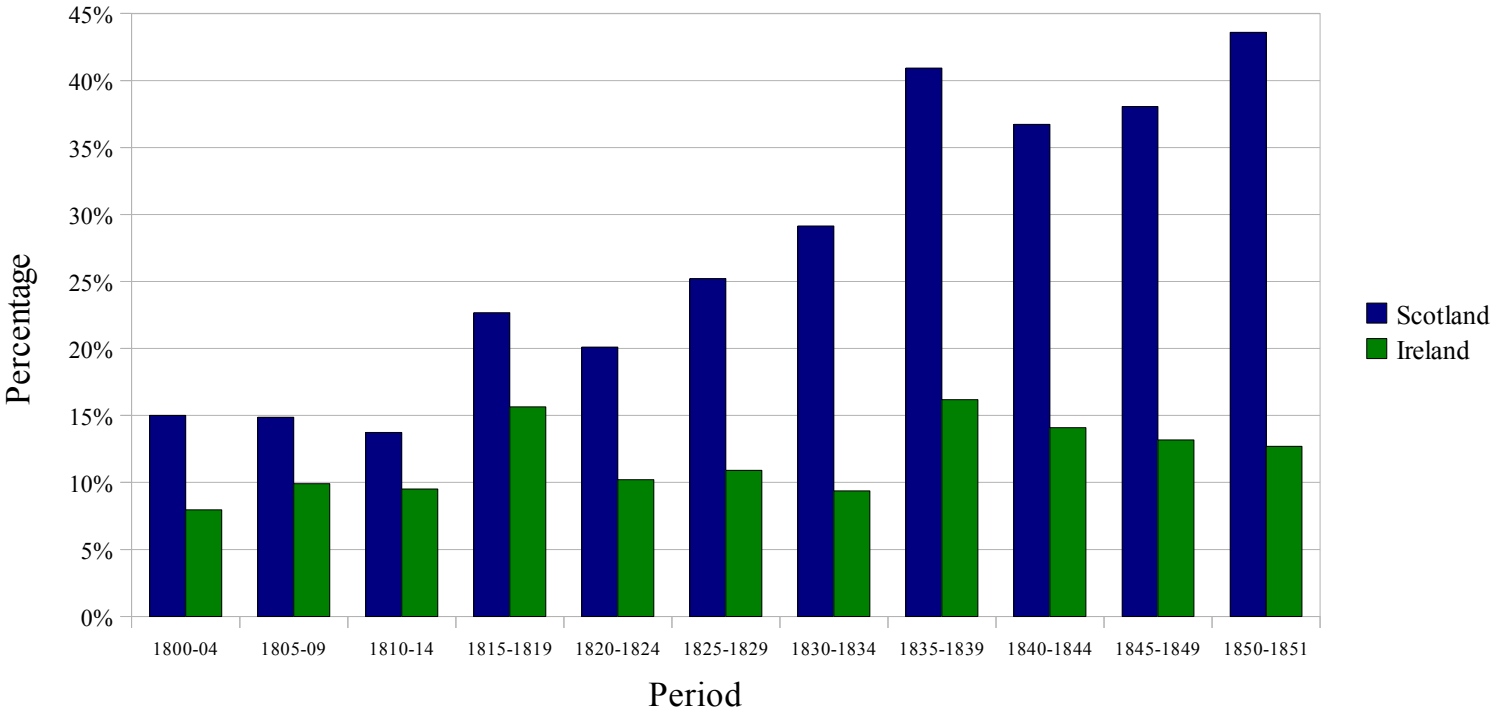
The growth pattern in patenting in all three countries is remarkable. Before 1760 there were very few patents awarded anywhere in the United Kingdom. After, around 1760 however, annual English patent numbers begin to take-off. In 1750 only 7 English patents were awarded; yet by 1799, 82. This steady growth continued until a second 'boom' starting in the 1830's.[63] This pattern is closely matched by the Irish and Scottish patent series, with steady growth after 1800 (from almost nothing), and then a marked acceleration during the 1830s. From around 1820, there are significantly more patents obtained in Scotland than in Ireland. Between 1820 and 1851 3375 Scottish patents were awarded, compared with only 1239 in Ireland. Some of this difference is attributable to the absence of unspecified Irish patents after 1827, and lower patents fees in Scotland. However, the difference is too large to be wholly accounted for by these factors. There is one important difference in the two patterns of growth. After a burst of growth in the 1830's, Scottish patenting continues to grow, while Irish (and after 1845 even English) numbers stagnate.

These results corroborate the 'orthodox' chronology of economic development in both countries. However, as discussed above, the majority of Scottish and Irish patents may be regarded as extensions of an English equivalent. It is thus important to consider the extent to which growth in Scottish and Irish patenting

63 Although Sullivan located what he regarded to be a 'break-point' in trend growth of patent numbers in the second half of the 1750's, no attention has been paid to what appears to be a new, higher, regime of trend growth in patenting after around 1830. This second break-point could be correlated with the development of the railways, in a manner analogous to the relationship between canal construction and growth in patenting highlighted by Sokoloff. Sokoloff argues that canals, by increasing access indivudals and firms had to markets, led to an increase in the return to invention (and patenting) by increasing the number of units that could be produced, to which the adavance could be applied. In the English case, without further research, this can only be a speculation. Kenneth Sokoloff, 'Inventive Activity in Early Industrial America: Evidence From Patent Records, 1790-1846', The Journal of Economic History, 48, (1988), 813-850

was driven by growth in the English patent series. If the propensity to extend patent protection to Scotland remained constant, this would imply there was no Scottish industrial 'catch-up'. The bar graph below shows the total of Scottish and Irish patents awarded in five year periods as a percentage of the total awarded in England (1850-1851 is also included).

Fig.2 Scottish and Irish patent totals as a percentage of English, 1801-1851



This series shows Scottish patent totals catching up with those of England, increasing from a low of 13.6% in 1810-1814, to an average of 39% between 1835-1851. This establishes that the propensity to extend patent protection to Scotland almost triples in about 30 years. By contrast, there is no significant change in the percentage of English patents extended to Ireland. This pattern may be attributed to the stagnation of Irish industry.

The difference between Scotland and Ireland becomes starker, when we look at per capita patenting. The following table presents the number of patents per million population in each census year from 1801. Because the annual patent totals fluctuate so much a 'patent average' for each year is calculated. The patent average is the mean of the annual number of patents awarded in each of the nine years 'surrounding' and including the census year. For example, the patent average for 1801 is calculated by dividing the total number of patents granted between 1797 and 1805 by nine. The population totals are derived from census data, except for Ireland 1801 and 1811 which are estimates from the Public Record Office of Northern Ireland.

Table.1 Patents by population, 1801-1851

Ireland

Year	Population	Patent Average	Patents per million population
1801	5.4	5	0.93
1811	6	10.11	1.69
1821	6.8	17.89	2.63
1831	7.77	19.44	2.5
1841	8.18	59.11	7.23
1851	6.55	54.67	8.34

Scotland

Year	Population	Patent Average	Patents per million population
1801	1.61	9.89	6.14
1811	1.81	14.67	8.12
1821	2.09	32	15.3
1831	2.36	47.33	20.02
1841	2.62	157.89	60.26
1851	2.89	207	71.65

It can be seen that Scotland had significantly more patents by population, than Ireland. Even before the famine decimated Irish population, the 1841 figure for Ireland was 7 patents per million population per annum. The equivalent figure for Scotland was 60. By 1851 Scotland's per capita patenting was over eight times that of Ireland.

In the aggregate numbers then there appears to be a strong correlation between economic development, the market for technology and patenting rates. With the onset of widespread industrialisation in Scotland during the 1830's there was a tripling in patents per million population. By this measure there was similar growth in Ireland – but this was from a much lower starting point. However, if there was a close correlation between patenting and economic development, there has also to be a sectoral analysis of patenting. The work of Moser, discussed above, emphasised the difficulties in using patent statistics to analyse the sectoral distribution of inventive activity, as the propensity to patent varied widely between sectors. However, we need only concern ourselves with the *relative* sectoral distribution of patents between the three countries. In particular, Crafts' work on the adult male share of labour in 'revolutionary' industrial sectors, such as textiles, metallurgy and engines, suggests that patenting in Scotland should have been heavily concentrated in those sectors.

There does remain one problem with this analysis. Alessandro Nuvolari has established that higher-quality inventions tended to be concentrated in particular sectors, especially chemicals, construction, glass, metals and paper.[64] As it is likely that there is a higher propensity to extend patent protection of more valuable inventions (a proposition that is explored in the final section), there is a danger that the results of a sectoral analysis will be skewed towards those sectors with a higher proportion of high-quality inventions.

64 Higher quality is defined here by reference to his WRI* measure. These five sectors all had average WRI* scores of in excess of 1.1. Alessandro Nuvolari, and Valentina Tartari, 'Bennet Woodcroft and the value of English patents, 1617-1841', Explorations in Economic History, 48, (2011), p.109

Because of this the sectoral distribution of patents awarded in all three countries, 'British' (and theoretically the population with the highest average quality of patents) is also presented for comparison.

The first stage of a sectoral analysis of patents was to classify the patents by sector. For the sectoral classifications I have used Nuvolari's classifications from his 2011 article.[65] This divides all patents into 21 sectors. However, the analysis excludes the small number of patents that were not obtained in England, but in Scotland and/or Ireland. It also excludes patents obtained from after 1841, as Nuvolari's classifications end in that year. The table below presents sectoral concentration statistics for the four patent populations (England, Scotland, Ireland and 'British'). The first row for each population gives the total number of patents in each sector between 1800 and 1841. The second row gives the percentage of all patents accounted for by that sector. The third row gives the concentration statistic for each sector, the fraction of patents in that sector squared. At the bottom of the third row is the sum of the concentration statistics, the Herfindahl Index. Finally, below this, is a figure showing 1 divided by the Herfindahl Index. This equates to the number of sectors there would have to be for there to be an equal distribution between them, as denoted by the sum of the squares. So if there were an equal distribution between the 21 sectors, we should expect the sum of the squares to be 0.0476 (1/21). This figure represents a measure of how sectorally concentrated the patent population was, with a higher value denoting a more equal distribution. Nowhere, however, is this result obtained; for example the Herfindhal index score for England was 14.31.

Table.2 Sectoral Concentration, 1750-1841

	England	% of English patents	Concentration	Scotland	% of Scottish patents	Concentration	Ireland	% of Irish patents	Concentration	British	% British patents	Concentration
Agriculture	264	3.09%	0.00095	30	1.55%	0.00024	15	1.70%	0.00029	13	1.72%	0.00029
Carriages	481	5.62%	0.00316	70	3.62%	0.00131	31	3.51%	0.00124	21	2.77%	0.00077
Chemicals	705	8.24%	0.00679	243	12.57%	0.01580	136	15.42%	0.02378	117	15.46%	0.02389
Clothing	181	2.12%	0.00045	31	1.60%	0.00026	13	1.47%	0.00022	11	1.45%	0.00021
Construction	376	4.40%	0.00193	47	2.43%	0.00059	31	3.51%	0.00124	22	2.91%	0.00084
Engines	1095	12.80%	0.01639	288	14.90%	0.02220	104	11.79%	0.01390	88	11.62%	0.01351
Food	455	5.32%	0.00283	122	6.31%	0.00398	75	8.50%	0.00723	66	8.72%	0.00760
Furniture	460	5.38%	0.00289	38	1.97%	0.00039	21	2.38%	0.00057	18	2.38%	0.00057
Glass	72	0.84%	0.00007	18	0.93%	0.00009	9	1.02%	0.00010	8	1.06%	0.00011
Hardware	602	7.04%	0.00495	73	3.78%	0.00143	37	4.20%	0.00176	28	3.70%	0.00137
Instruments	391	4.57%	0.00209	37	1.91%	0.00037	21	2.38%	0.00057	17	2.25%	0.00050
Leather	151	1.77%	0.00031	35	1.81%	0.00033	18	2.04%	0.00042	16	2.11%	0.00045
Manufacturing	433	5.06%	0.00256	94	4.86%	0.00236	48	5.44%	0.00296	39	5.15%	0.00265
Medicines	221	2.58%	0.00067	12	0.62%	0.00004	6	0.68%	0.00005	5	0.66%	0.00004
Metallurgy	410	4.79%	0.00230	119	6.16%	0.00379	46	5.22%	0.00272	42	5.55%	0.00308
Military	205	2.40%	0.00057	21	1.09%	0.00012	9	1.02%	0.00010	8	1.06%	0.00011
Mining	49	0.57%	0.00003	7	0.36%	0.00001	4	0.45%	0.00002	1	0.13%	0.00000
Paper	322	3.76%	0.00142	102	5.28%	0.00278	38	4.31%	0.00186	36	4.76%	0.00226
Pottery	145	1.70%	0.00029	23	1.19%	0.00014	8	0.91%	0.00008	7	0.92%	0.00009
Ships	432	5.05%	0.00255	116	6.00%	0.00360	51	5.78%	0.00334	44	5.81%	0.00338
Textiles	1104	12.91%	0.01666	407	21.06%	0.04433	161	18.25%	0.03332	150	19.82%	0.03926
	8554	100%		1933	100%		882	100%		757	100%	
Herfindahl Index			0.06987			0.10416			0.09576			0.10100
			14.31			9.60			10.44			9.90

These results indicate that sectors with higher average quality inventions were more likely to have

65 Ibid, p.112

patent protection extended to Scotland and/or Ireland. Of Nuvolari's five high quality sectors, highlighted with a yellow background, four had higher concentrations in the British population than in England (the odd-one-out being construction). Despite this trend towards greater concentration in the high value sectors, the (lower quality) population of Scottish patents have a higher Herfindhal index score (0.104 or 9.6 sector equivalent) than the much more restricted, higher quality, population of 'British patents' (0.101 or 9.9). This means that even when accounting for the tendency of smaller (higher quality) populations to have a higher sectoral concentration, Scotland has a higher concentration than either England or Ireland.

In which sectors were Scottish patents concentrated? It would seem likely that they would be predominately in heavy 'revolutionised' industry. For comparison Crafts's definition of revolutionised industry, referred to earlier, is adopted. Crafts figures for employment in the 'revolutionised industry' in 1841 used Lee's employment categories, of chemicals, metal manufacture, mechanical engineering, instrument engineering, vehicles, textiles and transport.[66] Although the sectoral classification used by Lee (and Crafts) differs from that used to classify these patents, here the revolutionised industries are taken to equate to chemicals, metallurgy, engines, textiles and ships. These sectors are highlighted with a green border.

It can be seen that in Scotland four of these five sectors (engines, metallurgy, ships and textiles), accounted for a higher percentage of the overall number of patents than in any of the three other populations. Similarly, the fifth sector (chemicals) accounted for a higher share of patents in Scotland than in England. The combined share of these 'revolutionary' patents was 43.8% in England, compared to 60.7% in Scotland.

Section 4

Patents and the market

The previous section established the relationship between the commercial opportunity for technology, industrial development and the patent index in Scotland and Ireland. In Scotland, rapid industrial development, especially after 1830, increased the commercial opportunity for protecting intellectual property there. By contrast, the industrial stagnation of Ireland meant there was no change in the underlying propensity to extend patent protection there.

These results suggest that inventors could and did make informed decisions on the value of extending patent protection to Scotland and/or Ireland. The responsiveness of inventors to economic opportunity is an important historiographical point, and needs further investigation. Allen argues that the key inventions of the industrial revolution were invented and adopted in England, because they produced sufficient income to pay for their development and adoption.[67] Of particular importance was England's (initially) unique factor prices. In England energy and capital was very cheap relative to labour costs, biasing

66 Crafts, British Economic Growth, p.5

67 Robert. Allen, 'The industrial revolution in miniature: the spinning jenny in Britain, France, and India', Journal of Economic History, 69 (2009), p.903

technological change towards increasing the capital-labour ratio.[68] This labour-saving technology was ultimately the progenitor of the industrial revolution However, this interpretation is critically dependent on the assumption that inventors were sufficiently attuned to specific economic opportunities. This section will outline another test of this proposition, looking at the three patent indices in conjunction with an established quality indicator.

One way of modelling the potential value of patent protection is with the following equation, proposed by Clarissa Long:

(1) $$V^P = r^P - (c^P_o + c^P_d + c^P_e) - r^T - u$$

Here V^P signifies the private value of patent protection. It is equal to the expected rents over the lifetime of the patent (r^P), minus the costs of obtaining, defining and enforcing the rights ($c^P_o + c^P_d + c^P_e$), and minus the opportunity of trade secret protection ($r^T - u$). r^P includes the full gamut of potential income - monopolistic profits from working the patent, licensing its use, assigning shares and so on. $r^T - U$ signifies the net rents obtainable from a trade secret plus the value of the undisclosed technology.[69]

The costs of obtaining patent rights will increase with the number of countries in which it is obtained. This was established in the first section. The cost of a patent for England alone was £135, for England and Scotland, £225 and all three countries, £365. However, the costs of defining and enforcing a patent will also increase with its geographical scope, as there will be more potential infringements to police and perhaps prosecute. To compensate for the extra costs, the expected patent rents to be obtained will also have to increase. Because of these additional costs, if patentees were responsive to market forces, it would be expected that those with inventions of a more marginal quality would chose not to extend their patents to Scotland and/or Ireland. Another way to put it, we should expect those inventions extended to Scotland and/or Ireland to have a higher average quality than those only protected in England.

We can test for this using Alessandro Nuvolari's WRI* (Woodcroft Reference Index) indicator of patent quality. After the Patent Law Amendment Act of 1852, four indices of English pre-reform patents were produced. One, the *Reference Index*, provided references to each patent in the contemporary technical literature. Nuvolari used the number of references listed in the Reference Index as an indicator of the quality of the patent. Because the average number of references received by patents varied over time, Nuvolari adjusted for the period in which the patent was granted, producing a time-adjusted WRI* indicator. Nuvolari tested the reliability of the WRI* indicator by comparing the quality of four populations of 'important patents', as defined elsewhere in the historiography, with the full population of patents. This was done by employing the Fligner-Policello test, a non-parametric test of stochastic equality. The Fligner-Policello test reveals the probability that a random patent selected from the population of 'important patents' will have a higher quality as measured by WRI*, than a random patent selected from the rest of the sample. Nuvolari found that in all cases, relating to the four populations of important patents, the hypothesis of stochastic

68 Robert Allen, The British industrial revolution in global perspective, (Cambridge, 2009), p.140
69 Clarissa Long, 'Patent Signals', University of Chicago Law Review, 69 (2002), p.638-9

equality could be rejected at the significance level of 1%.[70] This means that the WRI* indicator may be regarded as a robust indicator of patent quality.

Nuvolari allotted all English patents awarded between 1700 and 1841 a WRI* score. Because Scottish and Irish matches had already been established (where possible) with English patents, it was possible to measure and compare the WRI* score of three different populations. The first was the population of patents where protection was only obtained in England ('popE'). The second was the population of English patents where protection was extended to Scotland ('popES') and the third where protection was extended to Scotland and Ireland ('popESI'). Because there were so few patents obtained in Ireland and Scotland during the eighteenth century these populations were limited to where the English patent had been granted between 1800 and 1841. As in Nuvolari's paper the Fligner-Policello test was employed to test the hypothesis of stochastic parity in the quality of patents between the three populations. Three comparisons were made firstly between popE and popES, secondly between popE and popESI and finally between popES and popESI. To check for the robustness of the results the Mann-Whitney statistic, a similar test for assessing the medians between two samples was also calculated.

Table.3 Patent quality, 1800-1841

	Number	Median Adj WRI*	Mean Adj WRI*
England (popE)	6410	0.7978	0.9403
England & Scotland (popES)	1933	1.0912	1.1694
England, Scotland & Ireland (popESI)	757	1.0912	1.2809
Fligner Policello statistic		Significance	
popE v popES	7.600	***	
popE v popESI	6.611	***	
popES v popESI	1.271	0.1019	
Mann-Whitney Statistic			
popE v popES	-7.41	***	
popE v popESI	-6.494	***	
popES v popESI	-1.921	0.0548	

The first part of the table states the basic statistics for the three populations. As expected English patents have a lower mean and median WRI* than both popES and popESI. Similarly, popESI has a higher mean WRI* than popES, although it has the same median WRI*. The second part of the table shows the Fligner-Policello statistic for the three comparisons This indicates that the hypothesis of parity of quality between the popE and popES can be rejected at a significance level of 1% - i.e. that there is a significant probability that a patent randomly chosen from popES will have a larger WRI* score than a patent from popE. Similarly, the hypothesis of parity of quality between the popE and popESI can also be rejected at a

70 Nuvolari & Tartari, 'Value of English patents', p.106

significance level of 1%. However, in the comparison between popES and popESI, although it appears that there is a greater chance a patent randomly chosen from popESI will have a larger WRI* score than a patent from popES, this result is not significant. The robustness of these results is confirmed by the Mann-Whitney test.

That patentees tended to obtain more extensive patent protection, in accordance with the greater value of the invention suggests that inventors were sensitive to potential economic opportunities in their decision-making. This corroborates the conclusion from the 3rd section, that inventors were closely attuned to the economic opportunities afforded by their inventions. This is not to suggest that *all* individual inventors were 'rational' in estimating the value of their invention and acting accordingly. The perennial example of irrationality are the patents obtained for perpetual motion devices, and these appear even in the high quality population of patents obtained in all three kingdoms.[71] Rather the results relate suggest that for the *majority* of inventors, such commercial considerations were important.

Conclusion

This is the first analysis of any type of the Scottish and Irish patent systems. The first section outlined the administrative and legal characteristics of the two patent systems, establishing the close similarities with their English counterpart. Although patents were expensive to obtain; the petition was a relatively simple process for an inventor who hired an agent to act on his behalf (as the majority did) especially as there was no attendance requirement in Edinburgh or Dublin. This has two implications. Firstly, obtaining a patent in either country was not especially difficult for an English patentee – meaning that many did. Although the role patenting had in spreading English technology to Scotland and Ireland is not directly discussed in this paper, any future treatment of patenting in this period would have to broach the subject.[72] Secondly, it made statistical comparison between the three patent series possible. The direct comparability of individual patents between the three countries was confirmed by the matching process that found 96% of Scottish and Irish patents had a direct English equivalent.

The third section analysed the growth and sectoral breakdown of patents in the three countries. There are two reasons why the Scottish and Irish patent series offer a relatively 'clean' source for studying the relationship between technology, economic development and the market. Firstly, their patent administration and costs were similar to those of England, making comparison robust. Secondly, because the majority of patents obtained in these countries were not the result of domestic inventive activities, but were originally

71 For example, the English patent awarded to William Parkes for his 'perpetual motion machine' in 1801, (Woodcroft number 2535), was extended to Scotland and Ireland in 1802.

72 Without further work the economic consequences of patenting in Scotland and Ireland can only be speculated upon. On the negative side, because of the widespread diffusion of patent specifications in contemporary mechanical literature, the free working of new technology in Scotland and Ireland was stymmied by allowing English inventors easy access to patent protection. However, patent protection was presumably obtained because the patentee wanted to work the invention there themselves. This structure of patenting would also have encouraged the efforts of Scottish and Irish inventors by providing easy access to patent protection in the much larger English economy. There would probably also have been specific cases where access to patent s in Scotland and Ireland encouraged the efforts of English inventors.

from England, we can be reasonably sure that changes in patenting in these countries were (largely) the result of changes in the economic opportunity for new technology.

The patent series of Scotland and Ireland provides an important new time series for measuring economic development in both countries. In the relative absence of statistical indices concerning the development of the Scottish economy, the growth in industrial patents provides an important quantitative support for the traditional chronology of Scottish industrial development.[73] Similarly, the consistently low propensity to extend patent protection to Ireland reflects industrial stagnation. Also, although inferring levels of inventive activity from the patent index is fraught with interpretative danger, it is telling that there were more Scots than Irish obtained patent protection in Ireland.

It appears then that there was a close relationship between economic opportunity, patenting and technology. It was necessary to statistically test this contention. The final section did this by comparing the quality of patents in three different populations. The result obtained, that inventions with patent protection extended to Scotland and/or Ireland tended to be of a higher quality than those only protected in England, supported this hypothesis. Demonstrating the sensitivity of inventors to economic opportunities is an important historiographical point. Bob Allen argues that factor prices were the key determinent in producing the technology of the industrial revolution.[74] In particular, high labour prices, along with low energy and capital costs generated the demand for new labour-saving technology. However, Allen's finding relies on the premise that inventors and inventive activity were responsive to these economic stimuli. This work indicates that they were.

Finally, these results indicate the importance of patents in encouraging inventive activities during the industrial revolution. Inventors cum patentees were strongly influenced by the market opportunity of their inventions. If patents had not provided an effective opportunity for appropriating returns to inventive activity, then inventors would simply not have chosen to patent their inventions. That many did, particularly in important industrial sectors (as shown by the work of Moser) suggests that, by providing inventors with an effective method of appropriating returns from inventive activity, the patent system encouraged inventive activity.

73 On lack of national statistical evidence relating to Scottish economic development see Whatley, Industrial Revolution in Scotland, p.4

74 Robert. Allen, 'Why the industrial revolution was British: commerce, induced invention, and the scientific revolution', Economic History Review, 64 (2011), p.361

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