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Inventive Activities, Patents and Early Industrialization. A Synthesis of Research Issues

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Abstract:
The aim of this paper is to provide an overview of recent research on the role of patent systems in the early phases of industrialization. Perhaps surprisingly, no consensus has been reached yet as to whether the emergence of modern patent systems exerted a favourable impact on inventive activities. However, the recent literature has shed light on a number of fundamental factors which affect the links between inventive activities and the patent system. The concluding section of the paper outlines some "history lessons" for the current debate on the role of Intellectual Property Rights in economic development.

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1. Introduction

Over the last two decades, intellectual property rights (IPR) have become a subject of growing discussion and debate both in industrialized and in developing countries. One of the chief reasons for this increasing attention has been without doubt the shift towards a strengthening of IPR regimes which has taken place in the global economy since the early 1980s. In fact, in the course of the 1960s and 1970s many developing countries were capable of withstanding political pressures for the implementation of stricter IPR regimes. However, with the early 1980s, IPR issues were more and more often raised by the US in the context of bilateral trade negotiations. This strategy of the US governments was essentially motivated by concerns over the deteriorating competitiveness of American industry, especially *vis a vis*, the newly industrializing countries. One of the culprits for this deterioration was identified in the imitation and reverse engineering of US products taking place in these economies. Hence, the campaign for the implementation of stronger IPR regimes (David, 1993, pp. 19-20, Scherer, 2006 and Granstrand, 2005, pp. 273-278).[1] Progressively, stronger IPR protection was included in the broad "package" of institutional reforms, which advanced industrial economies and international development organizations imposed on developing countries (Chang, 2002).

The TRIPS agreement can be regarded as a further stage in this process. Advanced industrial economies have insisted on the introduction of IPR issues within the framework of the WTO negotiations. The consequence is that failure to comply with the stricter standards of IPR protection defined in the agreements may result in trade retaliatory measures. Clearly, this amounts to a growing pressure towards stronger IPR regimes worldwide. As summarized, in the 1999 World Bank Report: “Stronger IPRs are a permanent feature of the new global economy” (World Bank, 1998, p. 36).

It should be noted that IPRs (and patent systems in particular) are especially tricky issues for industrial organization theory. This is due to the fact that many policy implications concerning the optimal design of a patent system (which in the literature are typically

[1] In his appraisal of the long-term, historical evolution of IPR systems, Granstrand (2005) significantly labels the phase beginning in the early 1980s as “the pro-patent era”.

addressed in terms of "duration", "height" and "breadth" of the patent) that can be derived from industrial organization models, are very sensitive to a number of specific assumptions concerning the specific set-up of the "patent race". Accordingly, this type of literature, at least so far, has not been able to produce a set of unequivocal and clear-cut policy prescriptions.[2] Further, one could argue that the majority of these “patent race” models rely on over-simplified and unrealistic hypotheses, which tend to misrepresent both the nature of innovative processes and the operation of markets for technology (Verspagen, 2003; Dosi, Marengo and Pasquali, 2006).[3]

Given this state of affairs, some interpreters have been tempted to shed further light on such intricate and controversial issues by looking at the historical evidence concerning the relationship between patent systems and inventive activities. Unfortunately, in many cases, the appraisal of historical contributions in this field has been rather superficial and inaccurate, leading to dangerous misapprehensions of the history lessons (if there are any) that could be drawn on the basis of our current knowledge of the industrialization of western economies (see Chang, 2001 for a critical discussion of this recent policy literature).

The aim of this paper is to provide a guide to recent research in economic history and history of technology, dealing with the connection between the patent system and inventive activities in the early phases of modern economic growth of Western economies.[4] In particular, we will focus on the British and US experience. The choice of Britain is motivated by the fact that it is of obvious interest to consider the role that the patent system played in the "making" of the “first industrial nation”. By contrast, the US

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[2] As noted iconoclastically by David (1993, p. 43), the current state of the art in the industrial organization approach to patents does not allow us to revise the well-known inconclusive assessments made by Penrose and Machlup during the 1950s: “If national patent did not exist, it would be difficult to make a conclusive case for introducing them; but the fact that they do exist shifts the burden of the proof and it is equally difficult to make a conclusive case for abolishing them” (Penrose, 1951, p. 40). See also Machlup (1958, p. 79-80).

[3] See Winter (1993) and Vallee and Yldizoglu (2006) for two studies of the relationship between patents and the pace of innovation based on evolutionary models that take explicitly on board the issue of the bounded rationality of the agents. Interestingly enough, both studies suggest that regimes of weak patent protection may yield faster rates of technical change.

[4] For a general overview of the long-run evolution of Intellectual Property Rights, we refer the reader to May and Sell (2006).

case has been selected, as representative of the country that first adopted what may be considered a truly modern patent system. As we shall see, in both cases, the historical record does not lend itself to straightforward and clear-cut interpretations. However, on the basis of the studies carried out over the last twenty years, it is possible to work out some *cautionary* notes on the centrality of a "strong" patent regime for a global economic development strategy.

2. Patent systems and industrialization: Britain

Rather surprisingly, the role of the patent system in the early phases of British industrialization did not become a subject of *systematic* historical investigation until the mid 1980s. Before that, the theme had been frequently touched upon in most of the works of synthesis providing general appraisals of the origins and nature of the industrialization of western economies. However, these judgments were based on the evaluation of the anecdotal experience of a handful of great inventors, such as Watt, Arkwright, and Crompton. Against this background, it should not come as a surprise that assessments of the patent system could be very different. Let us just consider two of the most authoritative works of synthesis on industrialization. North and Thomas (1973) gave the emergence and the progressive operationalization of the patent system a prominent place in their explanation of the rise of Britain as the "first industrial nation":[5]

> Innovation will be encouraged by modifying the institutional environment, so that the private rate of return approaches the social rate of return. Prizes and awards provide incentives for specific inventions, but do not provide a legal basis for ownership of intellectual property. The development of patent laws provides such protection....[B]y 1700...England had begun to protect private property in knowledge with its patent law. The stage was now set for the industrial revolution (North and Thomas, 1973, pp. 155-156).

In passing, we may note that North and Thomas' "economic incentive argument" is frequently put forward in the contemporary debate by proponents of strong patent protection (Chang, 2001). On the other hand, David Landes remarked that,

[5] See also North (1981), pp. 164-166.

A number of writers have laid stress on the incentive effect of patent legislation. I am inclined to doubt its significance (Landes, 1969, p. 64). [6]

The first contribution to consider in a systematic way the connection between the patent system and inventive activities during the British industrial revolution was Dutton's (1984). The available evidence, according to Dutton, suggests that the British patent system, although requiring the completion of cumbersome and costly bureaucratic procedures and granting a rather imperfect protection against infringements, was nevertheless capable of stimulating inventors' efforts. His judgment is essentially based on a wide-ranging examination of the contemporary literature on inventions, which seems to indicate that the prospect of the economic exploitation of a patent was explicitly considered by many inventors. Furthermore, Dutton also notices the existence of a group of "quasi professional inventors", that is individuals with several patents who took their profits through the sale or licensing of their IP. In Dutton's view, this suggests that the British industrial revolution was characterized by the emergence of a class of individuals systematically engaged in inventive activities with a view to reaping their economic fruits thanks to patent protection. This group of quasi-professional inventors constituted the backbone of an "infant invention industry". This process was coupled, at least from the early nineteenth century, with the emergence of an extensive "trade in invention". This means that patent rights became increasingly the object of market transactions (selling of patent rights, licensing, creation of commercial partnerships geared at the exploitation of patents). This expanding market for invention, providing a wide range of opportunities for the economic exploitation of inventive activities, reinforced the formation of the "specialist" invention industry. All in all, Dutton's conclusion is that the British patent system can be seen as having a strong stimulating effect on the rate of invention.

Sullivan (1989) appears to confirm Dutton's judgment by showing the existence of a structural break, in 1757, in the time series of total British patents. According to Sullivan, this discontinuity (which is neatly consistent with the traditional chronology of the British industrial revolution, ie 1760-1830) reflects an acceleration in the pace of invention

[6] In another "classic" reference work on British industrialization, Mathias (1969, p.34) noted that the impact of patent laws on innovation "have proved particularly intractable to analyze or to asses" and refrained from formulating a final balance.

taking place in the second half of the eighteenth century.[7] At least in part, this acceleration is accounted for by the progressive development of a body of case law related to the protection and enforcement of the rights of patentees. For example, the requirement to specify (normally within two to four months of the patent's enrolment) was introduced gradually during the first third of the eighteenth century; from 1734 it became standard. Although, initially demanded, it seems, to assist the law officers in discriminating between similar inventions, the specification was not normally scrutinized by any administrative department of government. As a result, many specifications remain vague and opaque (MacLeod, 1988, pp. 48-55). Increasingly, however, they became subjected to a very close examination when a prosecution for infringement reached the law courts. This process culminated in Lord Mansfield decision in the case of *Liardet vs Johnson* (1778) which stipulated that the specification should be sufficiently full and detailed to enable anyone, skilled in the art or trade to which the invention pertained, to understand and apply it without further experiment (MacLeod, 1988, p. 49, and Fisher (2003)). In other words, the time-lag between the enactment of the Statute of Monopolies in 1624 (which is commonly regarded as the first British patent law) and the acceleration of inventive activities is to be explained by the time needed for firmly establishing the rights of the patentees within the framework of the British legal system (Dutton, 1984, pp. 73-75; Sullivan, 1989, p. 435).

Christine MacLeod's evaluation of the British patent system in the early phases of the industrialization process is much more cautious (MacLeod, 1988). She draws attention to the frequently heterodox use of patents, which continued until (at least) the late eighteenth century. The most typical cases of this behaviour were the use of patents in support of specific government concessions and franchises or for advertising/certifying

[7] The existence of discontinuity around 1760 was also noted by Bowden (1925, pp. 12-14) and Ashton (1948, pp. 118-120). A recent analysis of the nature of the co-integration between the time series of patents and those of industrial output in various sectors for the period (1780-1851) performed by Greasley and Oxley (2006) reveals that the causality link run mostly *from* the dynamics of industrial output in a restricted number of key-sectors (cotton, iron and mining) *to* the series of aggregate patents. In Greasley and Oxley's interpretation, this result suggests that the rise of patenting was a *consequence* and not a *cause* of the acceleration of industrial output growth. A similar view, positing that the acceleration of industrial output led to a growth in the demand of patenting, was originally sketched by Ashton (1948). See also MacLeod (1988, ch. 8).

the specific qualities of a product. Thus, in several industries, and particularly in the medical field, patents were often employed as means for constructing product reputation. Finally we should also be aware of ‘vanity patenting’, when patents were taken by amateur, “gentlemen” inventors, who considered their engagement in scientific and technological activities as an enjoyable diversion. For these men, the granting of a patent was just a means for achieving a general public recognition for their inventive efforts, rather than the basis for the economic exploitation of a specific invention. Furthermore, MacLeod also notices that a large volume of inventive activities was undertaken outside the coverage of the patent system.[8] Broadly speaking, in the course of the eighteenth century the coverage of the patent system remained highly restricted both sectorally (limited to the newly emerging capital-intensive sectors) [9] and to commercially dynamic urban areas (chiefly, London, Birmingham, Bristol and Manchester). It would be wrong to assume that this concentration reflected the higher inventive activitiy of these sectors or locations, since emergent capitalism in their manufacturing industries probably increased their propensity to patent. In the period we are considering, particularly innovative and technologically sophisticated industries such as machine tools, mining and metallurgy, branches of chemicals, etc. remained characterized by a persistently low propensity to patent (MacLeod, 1988, ch. 6).

The foregoing discussion shows that the study of the role of the patent system is vitiated by the difficulties which are inherent in using patents as output indicators of inventive activities. The limitations of patent counts have been starkly summarized by Griliches (1990, p. 1669): "Not all inventions are patentable, not all inventions are patented and the inventions that are patented differ greatly in 'quality'...". This means that a proper

[8] Petra Moser (2005) research on the inventions presented at the Crystal Palace exhibition of 1851 provides an interesting snapshot on the large volume of inventive activities undertaken *outside* the patent systems in the first half of the nineteenth century. None of the British or American industries she considers had patenting rates (ie, the ratio between patented inventions and total inventions) higher than 50%. The highest value reported by Moser is 36.4% for the US machinery industry. Remarkably, differences in patenting rates across industries were similar in the US and Britain (countries that in 1851 were characterized by very different patent laws). This finding suggests that one of the major determinants of the patenting decisions of inventors lay in the differences in the technological characteristics of the innovations across industries (Moser, 2006).

[9] Sullivan (1990) has instead considered patenting activities in the period 1711-1850 as remarkably widespread across all economic sectors. In our view, a careful assessment of the very same data he sets out, reveals that patenting was instead heavily concentrated in a few key-sectors.

assessment of the links between patent laws and inventive activities requires to move beyond simple "patent counting", and provide an evaluation not only of the volume of inventive activities undertaken outside the coverage of patent protection, but also of the actual technological significance of patented inventions. [10]

In this sense, detailed examinations of the contents of patents for specific industries may provide us with important insights. [11] An exercise along these lines has been recently carried out by MacLeod et. al. (2003). They examined in detail a sample of 2,009 British patents in steam engineering, for the period 1800-1900, and found that 365 of these patents (corresponding to a sizable 18.1%) were granted to “perpetual motion” machines or other inventions which were not technically feasible. Interestingly enough, 217 of these impossible patents were granted in the period 1860-1900, that is well after the formulation of the principles of classic thermodynamics by Clausius and Kelvin in the early 1850s, which scientifically proved the impossibility of a perpetual motion engine.[12]

To sum up, historical research on the British case, seems to suggest that, at least to a degree, the patent system had a positive effect on inventive activities. This judgment is essentially substantiated by Dutton’s group of “quasi-professional” inventors. Notwithstanding this, given the amount of evidence pointing to the significance of non-patented technological progress, the relative contribution provided by the patent system to the general volume of inventive activities in this historical phase, remains a matter open for judgment. Furthermore, in our assessment, we should also not forget the detrimental impact on the rate of innovation of “blocking patents”:Scherer (1965) and Kanefsky (1978) considerthe negative impact of Watt ‘s separate condenser patent on innovation in steam engineering). In this respect, in the mid nineteenth century concerns

[10] In 1869, US Commissioner of Patents, Samuel S. Sparks suggested that only 10 per cent of all patents granted had some commercial value (Basalla, 1988, p.69).
[11] Other contributions (see Sullivan (1994) and Inkster (2003)), following the example of Shankerman and Pakes (1986), have instead made use of patent renewal data for assessing the relative value of patents during the nineteenth century.
[12] The findings of Macleod et al. (2003) also suggest a cautionary attitude towards the use of renewal data. In their study they find that many potentially valuable steam engineering patents were not renewed (this was most probably due to the limited financial resources of many patent holders). Vice versa, *even some technically impossible inventions* were kept in force for the full patent duration.

over the detrimental impact of “frivolous” patents (i.e. patents that were chiefly taken to harass manufacturers with preposterous demands for royalty payments under the threat of prosecution for infringements) on inventive activities were so serious, that, in 1851, several of the expert witnesses (including I.K. Brunel) called in front of the Select Committee of the House of Lords on the reform of patent laws had no hesitations in proposing the complete abolition of the patent system in order to avoid the problem (House of Lords, 1851).[13]

3. Patents systems and industrialization: the USA

It must be recognized that the first patent system working by what we might consider truly modern procedures was not the British, but the American, especially after the Patent reform of 1836 (Khan and Sokoloff, 2001).[14] Until the reform of 1852, the British patent system was characterized by a very restricted accessibility, due mostly to the high costs and the cumbersome administrative procedures involved in the process (Khan, 2005, p. 31).[15] On the other hand, in the United States, the patent application process was relatively smooth, involving few straightforward administrative procedures. The US patent fee was $30. For this reason, one could argue that the validity of North and Thomas’ hypothesis, linking the acceleration in the rate of innovation and the emergence of patent institutions, ought to be examined primarily in the case of the United States.

In a number of recent papers Sokoloff, Lamoreaux and Khan have tackled exactly this issue, examining the relationship between the patent system and inventive activities in the United States during the nineteenth century (see Khan and Sokoloff, 2001 for a general

[13] For an account of the patent controversy in Victorian Britain, see MacLeod (1996). On the views of Brunel concerning the negative impact of the patent system on the rate of innovation, see Buchanan (2002, pp.177-178) and Miller (2006).

[14] The patent reform of 1836 officially introduced the procedure of examination. It is also worth noting that, *until 1836, the US denied patent protection to foreign applicants* (Khan, 2005, p.57). Thus, although, the US patent system did not protect explicitly the “piracy” and “transfer” of foreign technologies, in several instances (in particular in the case of textile technologies) it was effectively employed for such purposes. This was typically done by patenting marginal improvements of European inventions. For a detailed case-study of the attempt of transferring Arkwright’s water-frame in the US using the coverage of a US patent, see Wallace and Jeremy (1977).

[15] The sensitivity of British patenting to fees was clearly shown in 1852, when the initial fee for a UK patent was reduced from approximately £350 (corresponding to $1,680, see Khan (2005, p.31)) to £25 and the number of patents leapt from 455 issued in 1851 to 2,187 in 1853; following a further reduction to £4 in 1883 the annual total of patents almost trebled from 5,993 in 1883 to 17,100 in 1884.

overview). Their contributions are based on an extensive quantitative analysis of the evidence collected from the patent records.

Sokoloff (1988) considers the patterns of patenting in the US over the period 1790-1846. Over time, patenting exhibits a cyclical behaviour around an upward trend which mirrors that of the major economic fluctuations. Geographically, patenting exhibits the tendency to cluster in areas located in the proximity of navigable waterways (which provided low cost access to major markets) and in urban centres. These results, in Sokoloff’s interpretation, suggest that patents and inventive activities were, in general, highly responsive to the expansion of markets. This influence of "market pulling" factors on patenting, in Sokoloff and Khan's view, indicates a general responsiveness "of inventive activity....to material incentives, as well as to the availability and security of property rights in technology" (Khan and Sokoloff, 2001, p. 240).

In a related contribution, Khan and Sokoloff (1990) examine the issue of the responsiveness of individual inventors to the economic inducements granted by the patent system over the period 1790-1846. They conclude that American inventors sought consistently to secure patent rights for their inventions and that patent protection permitted a fairly effective appropriation of economic returns stemming from inventive activities.

Khan and Sokoloff (1998) have compared the British and American patent systems. Undoubtedly, the British patent system before the 1852 reform was far less effective than the American in protecting the intellectual property rights of the patentee. Furthermore, as we have seen, administrative and monetary costs were considerably higher in Britain than in the United States, and this restrained access to the system. By the 1810s, the US surpassed Britain in patenting per capita, and it would remain higher in the US throughout the nineteenth century (Khan and Sokoloff, 2001, p. 238-239). This evidence, according to Khan and Sokoloff suggests that the rate of innovation was probably lower in early industrial Britain than in the United States. Obviously, this assessment is based on the assumption that patenting per capita reflects the relative volume of inventive activity. However, as Mokyr (2002, p. 295) has aptly remarked, the analysis of Sokoloff and his associates, does not appear consistent with the traditional view of economic historians and historians of technology, who have regarded the period 1790-1850 as a phase of firmly established British technological leadership. [16]

In other contributions, using data on the licensing and assigning behaviour of a large number of patentees, Lamoreax and Sokoloff (1996, 1999a, 1999b, 2001) argue that in the United States, during the nineteenth century, a solid market for technical innovations structured around the institution of the patent system progressively emerged. Through this well functioning "market for technology", individual inventors were able to sell to firms the new technical knowledge they had discovered. In the second half of the nineteenth century, the growth and consolidation of this market was also favoured by the emergence of a specialized class of intermediaries (patent agents and solicitors) which were able to "match" buyers and sellers in this market for patent rights, thereby lowering transaction costs substantially (Lamoreaux and Sokoloff, 2002). The existence of this type of market promoted a fruitful division of labour with "technologically creative individuals" (Lamoreaux and Sokoloff, 1999b, p.3) specializing in inventive activities, and firms in the production and commercialisation phases.[17] Hence, the coupled

[16] In this sense, the interpretation of Sokoloff and his associates is consistent with recent research contending that traditional accounts of industrialization may be in need of some revision with the United States "overtaking" Britain in an earlier period. For example, according to the recent estimates of Broadberry and Irwin (2006), the United States attained a substantial lead in labour productivity in industry over Britain as early as 1840. For a thorough discussion of the technology gap between Britain and the United States in the first half of the nineteenth century from the point of view of the history of technology arguing in favour of a British lead - especially in mechanical engineering - until about 1850s, see Musson (1981).

[17] More specifically, Sokoloff, Lamoreaux and Khan distinguish two phases characterizing the historical evolution of nineteenth century inventive activities in the United States (Lamoreaux and Sokoloff, 1996, pp. 12686-12687). The first phase covers approximately the period, 1790-1846. In this period, inventive activities are widely widespread across the entire population ("democratization of invention"). The rather simple nature of technology permitted ordinary citizens with common skills to be engaged in inventive activities. The second phase covers the period 1840-1920. In this period (due to the spread of mechanization and the increasing complexity of technology) inventions were primarily produced by individuals with technical backgrounds who were strongly committed to inventive activities. The market for technology reinforced this process of specialization.

development of the patent system and the market for technology determined a steady acceleration in the rate of innovation. [18]

An interesting example of the operation of this market for technology is provided in Lamoreaux and Sokoloff (2000), where they consider the case of the American glass industry. In this case too, they find evidence of the existence of a well-established market for technology operating through two channels: first, specialized trade journals disseminating general information and providing detailed descriptions of patent specifications; secondly, specialized patent agents who were able to act as intermediaries in the sale of patented technologies. In the same study, Lamoreaux and Sokoloff also notice that a number of locations with high patenting activities (in glass) were characterized by little glass production. In their view, this finding indicates that "learning by doing" and "localized knowledge spillovers" (two factors that have been prominently put forward to explain the connection between the localization of production and innovation) played a relatively minor role in the technological development of the industry. Geographical clusters of patenting in the American glass industry are instead accounted for by the existence of a more developed market for technology in those areas. Although Lamoreaux and Sokoloff acknowledge that it is hard to draw robust generalizations, they contend that, by combining the evidence of the glass industry with their findings for the economy as a whole, the proposition that the development of the patent system produced a tidy and fruitful division of labour between innovation and production appears to be confirmed.

As should be clear from this concise summary of their contributions, Lamoreaux, Sokoloff and Khan have elaborated a complex account of technical change in the course of US industrialization, which is in many respects similar to the one originally proposed for Britain by Dutton. It is worth stressing again that their interpretation, more or less explicitly, downplays the role of learning by doing and of knowledge spillovers in nineteenth-century technical advances.

[18] For an extensive treatment of the relationship between markets for technologies and the division of innovative labour, see Arora, Fosfuri and Gambardella (2001). The research findings of Lamoreaux, Sokoloff and Khan are discussed on pp. 23-27.

4. The "Great inventors" approach

The contributions of Sokoloff, Khan and Lamoreaux that we have discussed so far are based on the systematic analysis of patent records. In several instances, their analysis of the connection between the patent system and inventive activities, relies on patent counts as a synthetic indicator of the volume of inventive activities.[19] Recognizing the general limitations of this type of inquiry, Khan and Sokoloff have tried to provide additional evidence on the nature and scope of inventive activities, by means of what may be labeled the "great inventors approach" (Khan and Sokoloff, 1993, Khan and Sokoloff, 2004, see also Khan, 2005, ch. 7).

In a nutshell, the great inventor approach consists in a prosopographical investigation[20] of American "great inventors" active in the period 1790-1930.

Khan and Sokoloff's sample is drawn from a number of American biographical dictionaries, by identifying all the individuals to whom at least one major invention was ascribed.[21] Their systematic investigation of this sample of "great inventors" shows that these inventors typically engaged in inventive activities with a view to *explicitly* reaping economic returns by means of patents. In general, throughout their lives, they tended to obtain a number of diverse patents and to employ the whole range of options allowed by their patent holding (direct production, assignment or sale of patent rights, licensing) for appropriating the economic returns of their inventive activities. Overall, it would appear that there was no fundamental distinction between the behaviour of the "great inventors" and that of the much larger population of US patentees: the inventive activities of both groups were very similar in terms of their general responsiveness to market inducements. Indeed, what distinguished the "great inventors" was their "entrepreneurial abilities".

[19] Sokoloff (1992) finds a positive significant link between total factor productivity and the number of patents per capita by US county over the period 1820-1860, which he interprets as providing support to the use of nineteenth-century US patent counts as good indicators of the volume of inventive activities. For a critical assessment of this exercise, see Atack (1992).

[20] Prosopography is a technical term which in historical scholarship indicates the study of the common background characteristics of a selected group of individuals.

[21] Khan and Sokoloff 's samples of US inventors comprise 160 individuals for the period 1790-1865 and 409 individuals (408 men and one woman) for the period 1790-1930: see respectively Khan and Sokoloff (1993) and Khan and Sokoloff (2004).

They were actually more, not less, finely attuned than the average patentee to economic incentives.

Khan and Sokoloff's conclusion is that their "great inventors" prosopography has provided a synthetic, but accurate, record of the major contours of inventive activity during the nineteenth century, which corroborates the evidence from the patent records (Khan and Sokoloff, 2001).

MacLeod and Nuvolari (2006) have recently raised concerns over the "great inventors" exercise. The critical issue is that Khan and Sokoloff treat the selection of their "great inventors" as unproblematic. They state only that, "The sample comprises virtually all the best-known antebellum inventors who were first active in the field of innovation between 1790 and 1846". Their "main source . . . was volumes 1 to 10 of the Dictionary of American Biography. This was supplemented by Who Was Who in America, Historical Volume, 1607-1896 and The National Cyclopaedia of American Biography; additional details were obtained from a number of biographical sources."(Khan and Sokoloff, 1993, p. 290). On reflection, it is clear that the use of these iconic works of collective biography is unlikely to provide a random or representative sample of inventors. Consequently, a detailed inquiry into the criteria governing the selection of entries in such historical reference works should be a compulsory research step in this type of exercises. MacLeod and Nuvolari (2006) investigate in detail this issue, by considering the representation of inventive activities during the British industrial revolution in the first edition of the *Dictionary of National Biography (DNB)* (1885-1900). They construct a sample of "great" British inventors, following a methodology similar to the one adopted by Khan and Sokoloff (i.e. they select all individuals alive in the period 1650-1850, who are credited with at least one invention in their *DNB* entry). The analysis of the inventive activities of the 383 "great" British inventors identified by MacLeod and Nuvolari suggests the existence in the *DNB* of a strong bias towards inventors active in very specific technological fields, such as steam engineering, navigation, railways, etc. (mostly those associated with the grand narrative of the British industrial revolution and imperial advance). Other technologies and industries, such as consumption goods, food and drink production, etc., that recent historical scholarship has shown to be of great economic and technological significance (see Bruland, 2004) did not receive adequate attention by the compilers of the *DNB.* In broader terms, this raises doubts concerning the interpretation that Khan and Sokoloff would like to attach to “great” inventors’ evidence. MacLeod and Nuvolari’s conclusion is that, when used as a source in the field of history of technology, biographical dictionaries might actually reveal more about the lenses through which scholars and contemporaries have looked at and judged specific inventions or technologies, rather than about the actual contours of technical progress in a specific historical period. [22]

5. The significance of collective invention

Following the seminal contribution of Bob Allen, recent research is increasingly drawing attention to the critical importance of *collective invention settings* as critical institutional support for inventive activities during the early phases of industrialization (Allen, 1983). In collective invention settings, competing firms freely release to one another *pertinent* technical information on the construction details and the performance of the technologies they have just introduced.[23] Allen has noticed this type of behaviour in the iron industry of Cleveland (UK) over the period 1850-1875. In the Cleveland district, iron producers freely disclosed to their competitors technical information concerning the construction details and the performance of the blast furnaces they had erected. In the words of Allen,

> ....if a firm constructed a new plant[more specifically, a blast furnace] of novel design and that plant proved to have lower costs than other plants, these facts were made available to other firms in the industry and to potential entrants. The next firm constructing a new plant built on the experience of the first by introducing and extending the design change that had proved profitable. The operating characteristics of the second plant would then also be made available to potential investors. In this way fruitful lines of technical advance were identified and pursued (Allen, 1983, p.2).

Information was normally released through both formal channels (presentations at meetings of engineering societies and publications of design details in technical journals)

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[22] MacLeod and Nuvolari (2006) find that more than 39% of their sample of "great" British inventors extracted from the *Dictionary of National Biography* never took a patent. Thus, in case one is not troubled by the limitations of this type of source, this finding provides another indication of the large volume of inventive activity taking place outside the coverage of the patent system during the early phases of British industrialization.

[23] There is an interesting historical parallel between nineteenth century collective invention and contemporary open source software development (see Nuvolari, 2005 for a further elaboration).

and informal ones (such as visits to plants, conversations, etc.). Additionally, new technical knowledge was usually not protected by patents, so that competing firms could *liberally* make use of the released information when they came to erect a new plant. [24] As a consequence of the proliferation of these "voluntary" knowledge spillovers, in the period considered, the height of the furnaces and the blast temperature increased steadily by means of a series of small but continuous rises. Increases in furnace height and in the blast temperature brought about lower fuel consumption and lower production costs. On the basis of his findings, Allen suggests that the pattern of technical change emerging from collective invention settings is dominated by incremental innovations.

Another important case of nineteenth century collective invention has been identified by Nuvolari (2004). In this case, the technology developed collectively was the steam pumping engines which were used for draining Cornish copper and tin mines. In the wake of their disappointing experience with Watt's patent for the separate condenser (its tight enforcement having led to a stagnation of inventive activities during the 1780s and 1790s), Cornish steam engineers typically preferred not take a patent for their inventions. Accordingly, the share of patents in steam engineering for the period 1813-1852 fell to under one per cent of the national total of all patents.[25] Yet, in the same period, Cornwall assumed the technological leadership of British steam engineering, with the introduction and development of the high-pressure engines. It is also important to note that in 1812 Cornish mining engineers and entrepreneurs launched a monthly journal called *Lean's Engine Reporter* with the explicit intention of facilitating the discovery and rapid dissemination of best-practice techniques.

[24] Note that Allen's notion of "collective invention" does not refer to the exchange of information between users and producers studied by Lundvall (1988). In fact, Allen is describing an exchange of information among *competing* entities. "Collective invention" also differs from "know-how trading" described by von Hippel (1987). In "know-how trading", engineers "trade" proprietary know-how in the sense the information is exchanged on a bilateral basis (non-participants to the transaction in question are excluded). Within collective invention, *all* the competing firms of the industry have free access to the potentially proprietary know-how, see von Hippel (1987), pp. 296-297. Cowan and Jonard (2003) have recently proposed a model which analyzes the properties of knowledge diffusion in collective invention settings.

[25] In the period 1698-1812, Cornwall's share in the national total was about 10 per cent, which was the second highest share , after London, see Nuvolari (2004, p. 358).

As with the Cleveland blast furnaces described by Allen, the emergence of a collective invention regime was favoured by a specific set of conditions. First, the “empirical” nature of inventive activities (in this period there was no established theory of the functioning of the steam engine) made it particularly fruitful to extrapolate the best design options from the systematic collection and analysis of information concerning variation in the design and performance of a large number of engines. Secondly, the structure of the Cornish mining industry (where mine entrepreneurs usually held shares in several different mines) favoured the search for improvements in the average performance of pumping engines (the rapid dissemination of best-practice techniques was clearly the most direct way for raising average performance). At the same time, the systematic publication of the performance of the engines allowed the best engineers to demonstrate their engineering skills and improve their professional reputations and career prospects.

Although not as systematic as in the "collective invention settings" identified in Cornwall and Cleveland, a similar ethos seems to have pervaded the nascent civil engineering profession, which was responsible for many of the innovations in transport that we commonly identify with the industrial revolution. Very little of the problem-solving activity that underpinned the engineering of bridges, tunnels, cuttings, embankments, etc.-- whether for roads, canals or railways-is reflected in the patent records. Rather, civil engineers tended to share and publish their solutions, with a view to enhancing their professional reputations (MacLeod, 1988, pp. 104-5). An analogous disregard for the privatisation of intellectual property is also discernible among other innovative groups of this period, such as some of the early developers of machine tools (others members of this group, however, practised secrecy) and the first generation of West Riding textile engineers (Cookson, 1997, pp. 8-9)

It would be wrong to assume that collective invention was just a British phenomenon. In his account of the development of the high pressure engine for the western steamboats in the United States, during the early nineteenth century, Louis Hunter has also emphasized the significance of various flows of incremental innovations (Hunter, 1949, pp. 121-180).

In the light of the present discussion this passage from Hunter's contribution is particularly intriguing:

> Though the men who developed the machinery of the western steamboat possessed much ingenuity and inventive skill, the record shows that they had little awareness of or use for the patent system. Of more than six hundreds patents relating to steam engines issued in this country down to 1847 only some forty were taken out in the names of men living in towns and cities of the western rivers. Few even of this small number had any practical significance. In view of the marked western preference for steam over water power and the extensive development of steam-engine manufacturing in the West, these are surprising figures. How is this meager showing to be explained and interpreted ? Does it reflect a distaste for patents as a species of monopoly uncongenial to the democratic ways of the West, an attitude sharpened by the attempts of Fulton and Evans to collect royalties from steamboatmen ? Or, were western mechanics so accustomed to think in terms of mere utility that they failed to grasp the exploitative possibilities of the products of their ingenuity ? Or, did mechanical innovation in this field proceed by such small increments as to present few points which could readily be seized upon by a potential patentee ? Perhaps each of these suggestions – and especially the last - holds a measure of the truth. At all events the fact remains that, so far as can be determined, no significant part of the engine, propelling mechanism, or boilers during the period of the steamboat's development to maturity was claimed and patented as a distinctive and original development (Hunter, 1949, pp. 175-176).

This passage seems clearly to reveal the existence of another collective invention setting in early nineteenth-century steam engineering. Interestingly enough, Hunter suggests that the litigation of the patents taken by Robert Fulton and Oliver Evans (mirroring the conflict between Boulton and Watt and Cornish engineers) may help account for the negative attitude of western mechanics towards patents (see Hunter, 1949, p. 10 and pp. 124-126 for a short overview of these litigation cases). Again, the dynamics of technological change in western steamboats was characterized by the steady accumulation of many minor changes and alterations to the design of the physical characteristics of the steaming, which determined improvements in carrying capacity, increases of speed, reduction of cargo collection times, etc. The cumulative impact of these improvements led to a rate of productivity growth which was without parallel in the transport technology of the period (Mak and Walton, 1972). [26] The detailed study of paper-making in Berkshire (US) by McGaw (1987) seems also to point to the existence of

[26] "The available evidence suggests that the increase of steamboat productivity (on inland rivers), 1815-1860, exceeded that of any other major transportation medium for a period of similar length in the nineteenth century" (Mak and Walton, 1972, p.623).

another American collective invention setting.[27] Finally, Foray and Hilaire-Perez (2006) suggest that it also characterized the highly successful silk industry of Lyon.

As a final consideration, it is important not to dismiss these cases of collective invention as "curious exceptions". It is worth stressing, once more, that key-technologies that lay at the heart of the industrialization process, such as high pressure steam engines, steamboats, iron production techniques, etc. were at times developed in a collective invention fashion, and consequently *outside* the coverage of the patent system.

6. Other institutional arrangements supporting inventive activities.

David (1993) has suggested that, in capitalist economies, the institutional arrangements supporting inventive activities may be summarized in terms of three P's, namely Property Rights (or patents), Patronage and Procurement. In this respect, our recognition of the historical literature suggests that, so far, historical research has focused primarily on the patent system. We believe that is important that historians in their future research efforts devote attention also to the other two P's. Here we will limit ourselves to some considerations which suggest that these alternative institutional arrangements to patent protection may have played an important role in supporting inventive activities in specific technological fields in the early phases of industrialization.

Let us consider first the case of public procurement, The famous block-making machinery (a complex of machines which permitted the full mechanization of the production of pulley-blocks for the Royal Navy ships) was developed by Marc Brunel and Henry Maudslay at the Portsmouth Dockyards, following a contract of public procurement with the Admiralty (Rolt, 1957, pp. 32-33 and Coad, 2005). Another famous case of successful public support for the development of a specific invention, is the "Congreve" rocket which was developed at the Royal Arsenal in Woolwich by William Congreve (Stearn, 2004).

[27] The interpretation of the McGaw study as another possible case of collective invention in the sense of Allen has been first suggested by Cowan and Jonard (2003).

In some cases, procurement for certain technological advances was implemented by means of prizes and competitions.[28] Perhaps one of the most successful cases of this form of public procurement is the Longitude Act of 1714. The Act established a handsome prize of £ 20,000 for a method for determining the longitude (which was one of the most taxing problems of oceanic navigation). The prize was finally assigned in 1775 to John Harrison for his "perfect clock" after a prolonged struggle. Be this as it may, Harrison's clock is nowadays recognized as one of the most fundamental breakthroughs in marine instrumentation (King, 2004).

Paul David ‘s contributions (see, e.g., David, 2004) have made clear that public patronage became, from the sixteenth century onwards, the most important form of support of “scientific” research. However, it should be recognized that during the eighteenth and the nineteenth century, some forms of public patronage also covered technological activities. For example, we can surely consider in this light the public support provided by the Treasury to Charles Babbage’s pioneering efforts to construct a mechanical calculating engine, although evidently the project cannot be regarded as fully crowned with success (Swade, 2004). [29]

Another important case of effective patronage of invention has been identified by Griffiths, Hunt and O'Brien (1992) and Hilaire-Perez (2000, pp. 190-209) in the Royal Society of Arts. In the second half of the eighteenth century the Society promoted inventive activities in a wide range of industries by means of prizes. It should be noted, that, in the interest of dissemination, the Society would have not normally assigned a prize to an invention which was patented. Griffiths, Hunt and O'Brien (1992) find that a large volume of inventive activities in the textile industries can be linked directly with the prize competitions of the Society. [30] We should also not forget that, in some special

[28] According to Boehm and Silberston (1967, pp. 25-26) from 1750 to 1825 there were at least eight Acts of Parliament instituting various forms of rewards for specific type of inventions (most of them in the field of navigation instruments)

[29] Another example of a risky (and ultimately unsuccessful) technological project that received financial backing (a grant of £200) from the Admiralty is the “gaz engine” of Marc and I.K. Brunel, see Buchanan (2002, pp. 20-22).

[30] In France, direct public patronage and procurement of invention was much stronger than in Britain (Hilaire-Perez, 2002).

cases, Parliament also established rewards for inventors "post-facto".[31] It was calculated that by 1815 more than £77,000 had been distributed in this form (Bohem and Silberston, 1967, p. 26).

7. Directions for further research

As this survey of recent contributions has shown, considerable progress has been made in the analysis of the role played by patent systems during the early phases of industrialization. However, it is also clear that important issues are still in need of further investigation. In this section, we would like to flag up what seem to us to be the most fruitful directions for further research.

a) It is vital to connect research on the emergence of patent systems with recent research on the nature of inventive activities in the pre-industrial revolution Western societies (1500-1750). In this respect, Epstein (1998) has taken a revisionist stance and argued that, contrary to the traditional view, some features of the guild system may have represented an effective mean for encouraging both invention and diffusion in a context where technological knowledge was chiefly tacit and empirical and costs of transmission were high (see, however, Ogilive (2005) for some cautionary notes on this argument). Similarly, Belfanti (2004) argues that early patents and guilds were two instruments of technology policy which were used consciously in tandem by mercantilist states during the sixteenth and seventeenth centuries. These perspectives open the possibility of shedding new light on the processes of transformation/adaptation undergone by patents (changing their nature from an instrument for stimulating technology transfer to a device for encouraging domestic innovation) during the early phases of industrialization (David, 1993). In this respect, the recent contributions of Epstein and Belfanti suggest that this transition was an element of a broader process of historical change which involved other forms of IPRs and a

[31] Recipients of this type of reward comprise: Samuel Cromton, inventor of the spinning mule and Edward Jenner, inventor of the smallpox vaccine, Edmund Cartwright, inventor of the power-loom, and Henry and Sealy Fourdrinier, importers of the paper-making machine.

concomitant of re-definition of the notions of authorship, invention and creativity.[32]

b) Increasing attention should be paid to the role of invention conducted outside the coverage of patent protection. This involves making further progress with the collective invention research agenda (identification of other circumstances in which the phenomenon took place and analysis of the various sets of conditions which led to its emergence and disappearance in different historical circumstances). We also need, however, to go beyond that. As noted by Nelson (1992), in every industry there is always a component of technological change which is publicly shared. From this perspective, collective invention processes can be seen as representing one extreme of a much wider spectrum. Hence it is important to study and compare in detail the patterns of patented and unpatented inventive activities in a variety of industrial contexts.

c) It is also important to combine the use of patents as indicators of inventive activities, with indicators constructed on the basis of other historical sources. The work of Petra Moser (2005, 2006) has shown the potentialities of the ingenious use of exhibition data. For many industries, there is a rich contemporary engineering literature which could be used for constructing lists of inventions (covering both patented and non-patented ones) and also for an assessment of their technological and economic significance. [33]

8. Concluding remarks.

Our survey of historical research suggest that accounts of industrialization that are based on simple and general causal mechanisms linking the emergence of patent systems and markets for technology with an acceleration of inventive activities may be unwarranted. Following Mokyr (2002), it might be assumed that the origins of western industrialization

[32] See Biagioli (2006) for a challenging account of the changing use of patents for protecting invention in scientific instruments in the early-modern period.

[33] Schmookler (1966) made use of lists of "important inventions". Of course, depending on the nature of the historical sources employed, these lists have various pitfalls, the most prominent is clearly their somewhat "subjective" character. Still, if properly handled, we believe that they may represent a useful complement to patent data. It is also worth remarking, that several key-insights into the nature of modern innovative processes elaborated during the 1970s and 1980s - for example Pavitt's taxonomy (Pavitt, 1984) were based on the analysis of this type of data.

lay in a revolution in the procedures for the accumulation and dissemination of 'useful knowledge' taking place in the eighteenth and in the early nineteenth century. However, it would be wrong to assume that the emergence of patent systems played a critical or determinant role in such a transition. The evidence discussed in this paper has shown that the institutional arrangements supporting inventive activities in this historical phase were extremely variegated and sophisticated. Further, a large volume of inventive activities was undertaken outside the coverage of patent protection. It is worth remarking once more that this type of inventive activity provided a fundamental contribution to the development of some of the key-technologies of early industrialization. In other words, the roots of western industrialization seem to have been wider and deeper than the emergence of modern patent systems. When the recent debate on IPR and economic development is considered in this light, one cannot avoid the impression that excessive emphasis has been put on the implementation of strong IPR regimes and that a more sobering and pragmatic approach to innovation policies is in order. [34]

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[34] Even Khan, who sees a potential role for a strengthening of patent protection in developing countries in enhancing the opportunities of relative disadvantaged individuals (Khan, 2005, p. 314) is extremely cautious on the issue of global harmonization towards higher standards of IPR protection: "[The]...analysis of the evolution of intellectual property regimes in Europe and in the United States raises questions about the desirability of applying the same system to all places at all times. Indeed, the major lesson that one derives from this aspect of the economic history of Europe and America is that intellectual property rights best promoted the progress of science and arts when the evolved in tandem with other institutions and in accordance with the needs and interests of social and economic development in each nation. In short, the historical record suggests that appropriate policies towards intellectual property are not independent of the level of development nor of the overall institutional environment" (Khan, 2002, p. 58).

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