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PROLIFIC INVENTORS: WHO ARE THEY AND WHERE DO THEY LOCATE? EVIDENCE FROM A FIVE COUNTRIES US PATENTING DATA SET

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Prolific inventors: who are they and where do they locate? Evidence from a five countries US patenting data set[1].

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The prolific (serial) inventors set up the core of the paper. Prolific inventors tend to have a high productivity in terms of inventions (patents) having in general more economic value. The capacity to produce a lot of inventions (patents) is termed "prolificness". We want to deepen our knowledge about the size of their population, some of their main characteristics, the factors that explain the number patents applied. We exploit a rich data set built onto information available released by the US Patent and Trade Mark Office (USPTO) for the five more important countries as far as technological activities are concerned: Great-Britain, France, USA, Germany, Japan over a long time period (1975-2002). We give insights upon the size of the population of prolific inventors and provide new information about some of their characteristics. We carry out an empirical study in order to explain the prolific inventor patents distribution. We suggest models for estimating the effects of the main variable explaining their productivity. Binomial regressions explaining the inventor productivity after controlling for patent duration and time concentration (among others factors) show that interfirm and international mobility and technological variety (at the inventor level) affects positively the inventor productivity. But there is simultaneity. The overall results suggest that the same factors impact positively productivity with no difference across countries (with exceptions).

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Introduction: Prolificness and the black box of knowledge creation.

The starting point of our research on prolific inventors is founded upon the empirical evidence drawn from two studies. First and foremost the study by Gambardella et al. (2005) using the PATVAL survey (7000 patents). The authors note that the characteristics of the inventor, in particular *his past number of patents is the main determinant* of the private value of invention *more important* than the characteristics of the organization in which he is employed[2.] Secondly Gay et al. (2008) research confirms this remarkable result. By using a data set of patents granted by the US Patent Office to French, German and British inventors over a long period of time (1975 to 1999) they estimate a relationship explaining the citations received by each patent[3]. Prolific inventors tend to produce inventions that have more economic value[4]. We term this relation "prolificness" and define it as the capacity to produce a lot of patents, which have, in general and on average, more value. Prolificness tends to lay out the effects of the accumulation of patents on the value of inventions. To put it simply, it is a dynamic process of increasing returns. This paper is a first step to increase our understanding of these prolific inventors across five countries. We want to deepen our knowledge about the size of their population, some of their main characteristics, the factors that explain the number patents applied. Our definition of prolific inventor and of its role in technological creation shall be better understood once inserted in a larger framework. Two frameworks appear as good candidates: the Theory of localized technological change recently developed by Antonelli (2008) and the Model of dynamic creation given by Nonaka et al. (2000). Let us start with the analysis carried out by Antonelli (2008). The main point here is the following: knowledge creation is a collective process and the production of knowledge is viewed as the result of both knowledge transaction and cooperative interaction of learning agents who undertake complementary research activity. These interacting agents are embedded in a network of relations (for instance in a regional space) that allow them to accumulate experience and competence. We claim that prolific inventors play a crucial role in this process by matching the dispersed and fragmented bits of knowledge. They likely act as

[2] In other terms past quantity of patents => current quality of patents.
[3] These empirical analyses, which reveal the importance of prolific inventors, are consistent with the evolutionary analysis of the key factors to successful innovation. For instance Archibugi and Lundvall (2001) emphasize that successful innovation requests a strong corporate knowledge base including an R&D capacity and a *well-trained workforce*. In the same vein Nelson (2006) argues that the process of technological catching-up is pushed to a considerable extent by effective learning and human capital growth.
[4] Mariani and Romanelli (2007) claim that the relationship between quantity and quality is not direct but indirect: when an inventor produces a lot of inventions, the probability of a technological hit increases.

knowledge integrators in the process of communication and transmission of knowledge (Antonelli C., 2001; Gay et al., 2008). The outcome of these interactions is localised technological knowledge. It is primarily the result of the valorisation of past experience and the stock of accumulated knowledge. Also, the competences of prolific inventors as key individuals are the backbone of this learning process. But the internal (internal to the firm) knowledge is not sufficient for producing new bits of knowledge. A lot of scholars have emphasized that productive organizations have to absorb knowledge from outside (from users, suppliers, competitors, public academic institutions, others technical agencies) through different types of channels and mechanisms (markets transaction included). The capacity of absorption is mainly driven by the internal capacity of learning: the more the organization knows internally, the more it can absorb external knowledge. We argue that prolific inventors are crucial for increasing learning capacity and, as a consequence, organizational absorptive capacity. To put it simply our basic idea is that the prolific inventors stand at the core of the process of localised technological change. Nonaka et al. (2000) suggest a complementary analysis. By entering more deeply into the black box of knowledge-creating process, their analysis offers richer insights. Nonaka and his colleagues argue that tasks of top and middle managers tend to lead to knowledge-creating process into the firm. In particular they remark the crucial importance of knowledge producers who are at the intersection of vertical and horizontal flows of information in the organisation (Nonaka et al., 2000). To us, prolific inventors seem to be within R&D department "the leaders that provide the knowledge vision, develop and promote the sharing of knowledge assets" (Nonaka et al., 2000). Thus, we consider prolific inventors as crucial actors of the internal process of knowledge creation within the firm. The aim of this paper is to improve our knowledge and understanding of the "scale and scope" of the population of prolific inventors, such as revealed by patents data. No matter what the system of patent is, a patent document gives inventors' names and further information about them. We exploit extensively and intensively the richness of the information available released by the US Patent and Trade Mark Office (USPTO) for the five more important countries as far as technological activities are concerned: Great-Britain, France, USA, Germany, Japan. We give some insights upon the size of the population of prolific inventors and provide information about some of their characteristics. The paper is organized as follows. Section 1 sets out precursor and previous studies that deal with our topic. Section 2 explains how we have built up our data set. Section 3 describes the data we used and focuses on the prolific inventor population size and some of their main characteristics. With respect to these characteristics, we put the emphasis on their professional mobility (inter-firms mobility). In section 4 we carry out an empirical study in order to explain the prolific inventor patents distribution. Subsequently, we suggest a model (and variables) and comment on the estimation results. In the conclusion we portray some lessons and implications for the process of knowledge governance and the Economics of talented individuals.

1. Prolific inventors: what we learn from precursors and previous studies

In the literature there are three basic references. First and foremost, the well-known seminal study by Lotka (1926). Lotka observes that the number of highly productive scientists was a relatively small fraction of all scientists. After acknowledging the existence of a highly prolific inventors population, he suggests a law for laying out their distribution. Secondly, the study by Levine (1986) analyses the statistical distribution of a bulk of patents from a sample of 7392 inventors who received 9 patents or more during the 1975-1984 time period. He observes that the frequency distribution of patent output per inventor reveals "an approximately logarithmic decline". He performs a patent citations analysis on a random sample of 45 prolific inventors and finds no statistically significant difference as far as the average citations across the range of inventor patent outputs is concerned. The interpretation is the following: the value of patent (patent quality) does not decrease when the quantity of patent per inventor increases. This point is particularly important as Levine does not show that the quality of invention *increases* when the productivity of prolific inventors (quantity of patent) increases. Thirdly, the Narin and Breitzman (1995) interesting paper onto "highly prolific inventors". They investigate 4 companies in the sector of semiconductors and perform an inventor's name unification (onto 3000 inventors). Every inventor is given credit for the whole invention regardless the number of co-inventors (Narin and Breitzman, 1995: 510). They emphasises the key role of a few researchers that "seems to be a law of nature": "One, two or three individuals are really driving their laboratory….companies should make effort to retain and nurture these key contributors". In sum they emphasize that highly prolific inventors' technological tasks are crucial for the invention process and are of a strategic importance for the firms. Narin and Breitzman (1995) paper constitutes the first modern study that deals with prolific inventors, even with the limited sample of inventors and patents[5].

We find in the empirical literature notions that are close to prolific inventor: the *great inventors* and the *key inventors*. They also deserve some attention. Kahn and Sokoloff (2004) studied *great inventors* active in the USA. They define them as important inventors recognised by the *Dictionary of American Biography during the 19th and 20th century*. A large proportion of them were large appliers of patents over their respective careers. Some are very prolific in the sense that is given to the word nowadays. The authors show that the first generation of these great inventors, which was born during the period 1739-1794, had a very modest educational background. Because these technologically creative people were lacking financial resources to exploit inventions directly, a large proportion of these people would earn a great part of their income from their inventions by selling them or licensing off their patent rights. More and more inventors became engineers of R&D laboratories. We can retain that prolific inventor as a figure of inventors is not specific to the modern period of time. Very early, at the outset of the 19th century, some inventors patented a lot their inventions in order to extract economic return[6]. The report by Jones (2005) deals also with *Great inventors*. In particular, it uses data on Nobel Prize winners and consistent inventors in some technological fields. Many empirical investigations usually undertaken within the fields of Psychology and Sociology support the idea that innovative activity is greater at younger ages. By contrast Jones (2005) shows that the great knowledge achievements of the 20th Century occurred at later ages. Noticed innovations are produced at an age that has increased by approximately 6 years over the 20th Century. Some papers (see for instance Marx et al., 2007) refer to *star inventors* for inventors who have highly cited patents matching innovations of larger technical and market value (Harhoff, Narin et al. 1999). Clearly this type of inventors looks like prolific inventors. The notion of *key inventor* is also used in recent studies. For instance Ernst (1999) has identified key inventors in German engineering firms as inventors who are characterised by high patenting activity as well as *high patent quality* rating. Pilkington A. et al., (2009) consider key inventors as highly productive inventors and also as widely cited ones (it means that their patents have more value). They should be the leaders in

5 Two further documents share the same objective. A note from the USPTO (1998) giving the name of prolific inventors receiving utility patents from 1988 to 1997, and the Ernst et al. (2000) study showing that very productive inventors are associated to valuable patents.

6 The close notion of stars scientists will also be addressed later.

any developing new fields[7].

At this stage, it is relevant to put in relation "stars inventors" and "stars scientists", the latter model being exemplified by Zucker and Darby (2002). A "stars scientist" is an individual who has higher-quality intellectual capital (measured in terms of number of citations). A "star scientists" makes major discoveries (Zucker and Darby, 1996, 2001). In the biotechnology sector "the labour of the most productive scientists is the main resource around which firms are built or transformed" (generalized to high-tech industries, see Zucker and Darby, 2006). The model of mobility of Stars scientists is from "Academe to Commerce". In others words, technology transfer from University to Industry is important. Stars scientis ts matter in the technology transfer process because of the value of their knowledge as regards the success of firms[8] Stars become more concentrated over time as they move disproportionately from areas with few peers in their discipline to many (Zucker and Darby, 2007). "Stars scientists" and "prolific inventors" are two close categories of highly productive knowledge workers, the first in Science, the second in Technology. There shall be stars scientists patent as well. As a result, they could be prolific inventors too[9] . We answer, in the same vein initiated by Narin and Breitzman (1995), the following question: what is the role of prolific inventors? Studies in R&D management and Organization Science enable us to gather some material (see in particular Geuna *et al.*, 2003). As prolific inventors act often as research group leaders, we can hypothesize that they are "technological goalkeepers" who mediate the flow of knowledge into the research organization (Allen, 1970)[10].In a way, they act as "Knowledge integrators" (see Gay et al., 2008). Prolific inventors, as knowledge workers, play a prominent role in the design, development and integration of pieces of knowledge within a department of research as there are people, in invention team, with different technological and scientific specializations. Prolific inventor and his/her Engineering knowledge are essential. He/she increases the rate at which individuals and organizations learn and consequently achieve sustainable competitive advantages. Prolific inventors are innovation "champions". Through their professional mobility they can be viewed as

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[7] Recently Paruchuri (2009) argues "central inventors" have an important position in intrafirm coinventing network.

[8] Zucker and Darby emphasize the importance of the tacit character of the new discoveries. Because knowledge is embodied in individuals, there is "bench-level" collaboration which is measured by co-authoring.

[9] Sometimes, stars scientists are considered as "entrepreneurial individuals". Prolific inventors can also be entrepreneurial university researchers (Etzkowit, 2003). An entrepreneurial researcher is an entrepreneur which is active towards technology transfer and partnership with industry.

[10] Levine (1985) adds that prolific inventors are recognized as sources of information, top performers valuable to the organization in meeting its technological objectives.

"knowledge translators" or "knowledge brokers" [11] in between firms, organizations and communities. They help transferring pieces of knowledge through the different communities they overlap at one or different points of time. Thus, knowledge stays a collective structure in particular within firms as emphasized by the evolutionary authors (see among others, Winter, 2005). However, knowledge is not equally distributed among the members of a community or a work group, it can be concentrated by some individual[12].

2. Description of the data source and building of the data set.

The patent data give a lot of information on the invention process. First and foremost, it gives inventors' names and addresses. Combined with information about application dates and patent technological classification, names and addresses enable for instance to follow the individual trajectories of each inventor, his/her core competence. For this reason, it is intensively used into academic work for analyzing invention process and inventors (among others: Kim et al., 2005; Trajtenberg, 2004 and 2006; Sing, 2004). These studies mostly have recourse to the US patent data. The main advantage of using the US patents data is the existence of the NBER[13] data base that provides a lot of information about the US patents and, in particular, information about backward and forward citations. The NBER Patent Data File does not give the information that we want on the productivity of inventors. We have to build up inventor productivity data set. We adopted a pragmatic approach. With the patent documents, we get the name of the inventor, their first name and address. Such information makes up the raw materials for matching the names and obtaining for the same inventors his/her patents granted at different time periods. It is important to note that US patent office does not deliver special information about the inventors as for instance a code[14]. That increases the complexity of our task. Trajtenberg was the first to our knowledge to build up a large data set on the inventors by doing an inventors' name unification (Tratjenberg, 2004 and 2006). He has extensively and cleverly outlined the difficulties ("the name games") and traps ("the John Smith problem") of such a task. He suggests a two stages methodology for matching the names of inventors using the SOUNDEX coding method. He starts

[11] See Brown and Duguit (1999) who define these two terms.
[12] We have shown that the two notions of collective knowledge and prolific individuals were not contradictory (Gay et al., 2008).
[13] See Hall et al. (2001).
[14] By contrast we have for each assignee a code which enables us to gather the different patents for the same assignee overtime.

with the NBER Patent Data File (1975-1999) which contains 4,298 912 records, 2 millions patents and 2 inventors per patent on average. After matching them with the SOUNDEX coding, Trajtenberg obtains 1,565 780 inventors. 58% with just one patent, and 5% with 10 patents or more. Trajtenberg (2006) research, of course, does not deal with the population of prolific inventors, but represents a very rich tool for measuring and mapping it. Matching the names is the basic task that Singh (2004) and Kim et al. (2006) have also carried out. The main aim of our research project is to build up a data set that gives information on the population of prolific inventors and that can be retrieved in the US patent documents. We start with the data given by the US Patent and Trademark Office (through a disk) for the period of time 1975-2002. For each patent granted, we get the following information concerning the inventors and their patents (knowing in general there are more than one inventor per patent): nationality (if the inventor has been once primary inventor), family name, first name, mid name (sometimes) or the first letter, date of patent application, date of issuing, inventor address, assignee name, assignee number (code), technological class. Clearly a data base of this sort is not immediately built for a research project on the inventors, the distribution of their patents over time, on some their characteristics (geographical location, name of employer). We have not used any algorithm in order to realize the matching excepted for the U-K[15]. We used for the inventors of the U-K the SOUNDEX coding method that is considered relevant for Anglo-Saxon names. For the others countries, our method combines manual actions and automatic procedures. Cleaning the data set is the first step. The original data set form, the USPTO, contains a lot of orthographic mistakes, corrupted characters, errors, and so on[16]. The second step is the matching properly speaking. We have carried out the following methodology in order to match two records of the same inventor. We have considered that two records indicate the same inventor when the family names and the first names are the same and when the middle-name, when it exists, is identical in both records. We apply the same rule only the first letter for the middle-name is reported. Up to this point, we have implemented the same methodological rules than Singh (2004). The difference appears now. When we have no information concerning the middle-name we first look at the address of the inventor and secondly the name of the assignee [17].Two records with the same family name and

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15 The use of algorithms tends to be generalised.

16 Some examples of errors and consequently because of manual cleaning are given in our paper Le Bas et al. (2007).

17 By contrast Sing (2004) look at the technological class of the patent. For Kim *et al.* (2005), if the name and the first-name are the same and one item among the address, the partners in the team of inventors revealed by the patent document, then there is a matching.

same first name (and no information for the mid-name) match the same inventor if the address is the same (or if the name of the assignee is the same). One difficulty exists concerning the inventor's nationality. The USPTO data base does not provide the nationality of each inventor. Nevertheless this Office gives to any patent the nationality of the first (or primary) inventor. Then indirectly we have information about the inventor's nationality only insofar as an inventor has been once primary inventor. We know for our study the nationality of any prolific inventor who has been noted as primary inventor at least once. We want to assess the twofold dimension of inventor mobility: the geographic mobility and the inter-firm (or inter-organization) mobility (of course for inventors who work for an organisation, no matter which type of organization: industrial firm, university; and so on). At the prolific inventor level, each type of mobility is measured by an amount of moves. Geographic mobility is well laid out through the inventor address code. Inter-firm (or inter-organization) mobility is more difficult to capture. The code (and the name) of the assignee provides us with a first idea, but it is not always relevant for assessing the moves. For instance, large industrial firms can possibly decide to modify the way they apply their patents by charging another subsidiary to do so. In this context the assignee name can change, but not the one of the firm that carries out the research in which the inventor is implicated. The case of a merger can also occur. In this situation, the name of the firm (assignee) may be different but it does not match an inter-firm mobility. Although the names (and the code) of the assignee has been modified, the researcher continues to work for the same organization: a change of assignee name does necessarily imply that there is an inventor's mobility. This type of *false mobility* could be captured with information on the evolution of mergers and the making of conglomerates[18]. Sometimes, information on inventor geographic location can confirm that there actually was an inter-firm move (and not a pure change of assignee name). This is what we did in order to take into account the pure inter-firm moves. Finally the quality of data on inter-firm mobility remains slightly more flimsy than the data on geographic mobility. All patents we mention here have been granted by the USPTO between 1975 and 2002, but the date of application may be anterior to 1975. A patent application done during this period but still not issued does not enter our data set.

[18] We have used data bases on mergers and acquisitions. For instance EDGAR (Electronic Data Gathering and Retrieval) data base of the US Securities and Exchange Commission, Amadeus from the Wharton University of Pennsylvania (since 1997), it gives information on the European countries for tracing mergers and acquisitions, Who owns whom Continental Europe (High Wycombe, England, 1998), Dun & Bradstreet data file.

3. Prolific inventors across countries: size of their group and some of their characteristics

This section basically deals with some comparison across countries. We build up two indexes of prolificness to improve our measuring of the size or the scale of the population of prolific inventors. Then we analyze some characteristics of their population.

a. Indexes of prolificness

Table 1 and 2 display information onto the raw material data as well as our data on prolific inventors across the five observed countries. As we have explained how we have build up the data set in the previous paragraph, we can now focus our analysis on the prolific inventors' population. We decided to retain the threshold of 15 patents granted in his/her country over the time period under observation (1975-2002). We have checked that there is no large gap between the number of inventors having 13 or 14 patents and the (prolific) inventors having 15 or 16 patents. In others words, if we had fixed the threshold at 13 or 14 patents, the number of prolific inventors would have been obviously more important, but this increase would not have been dramatic. The motives for choosing this threshold are the following. Trajtenberg (2004; 2006) in his report on inventors in the US patenting system notes that in the period 1975-1999 the average number of patents per inventor was 2.74 (all countries). Our period of observation is larger on the one hand, and patenting has strongly increased at the end of the period under consideration, on the other. Thus we can expect that the average number of patents per inventor is around 3. It seemed to us that a prolific inventor would be an individual having at least a productivity (in terms of patents) five times above the average, thus the choice of 15 patents[19]. Another option would have been to retain for instance the top 1% or top 5% patenting inventors. Tratjenberg (2004; 2006) observes that inventors present in 10 patents and more represent 5% of the inventors' population. We thus estimate that with our threshold of 15 patents we focus on the 3%

[19] Pilkington A. et al., (2009) define the key inventors "*as having a higher than twice the average productivity (number of patents granted) compared to others in the data set, whilst also having a citation ratio (number of citations per patent) of at least twice the average of their peers*".

top inventors (in the US patent system) and are thus in line with debates about top or star scientists[20].

Table 1. Building the data set: from records to prolific inventors patenting by country.

	GB	FR	USA	GER	JP
Number of records	**14412**	**157394**	**2756476**	**487451**	**1312025**
Number of inventors	**61730**	**66127**	**985652**	**139671**	**265708**
Total amount of patents : A	**76532**	**76919**	**1459911**	**221081**	**490143**
Total amount of prolific inventors: B	**813**	**1157**	**26279**	**5270**	**19418**
Total amount of prolific inventors patents: D	**15515**	**26631**	**492268**	**88467**	**326497**

Table 2. Prolific inventors patenting: index of prolificness and descriptive statistics by country.

	GB	FR	USA	GER	JP
Index of prolificness (1) total amount of prolific inventors / total amount of inventors: B' (%)	**1.32**	**1.75**	**2.66**	**3.77**	**7.31**
Index of prolificness (2) C=D/A (%)	**20.27**	**34.62**	**33.72**	**40.02**	**66.61**
Inventor average number of patents	**2.34**	**2.38**	**2.80**	**3.49**	**4.94**
Number of records relates to prolific inventor: E	**20025**	**30477**	**677372**	**158344**	**604751**

[20] At this stage a point deserves particular attention. Thanks to recent empirical studies on the motives to patent, the links between patent and invention have been extensively investigated. We know that firms patent more than one patent to protect one invention. The size of the group of patents protecting the same invention is on average five (Reitzig, 2004). Of course there are variations across technologies and industries. For instance according to Reitzig (2004) in Chemicals, the size of the group of patents is around 8, by contrast in manufacturing machinery, the group is inferior to 5. In fixing the threshold of 15 *patents* we knew that our prolific inventors do not patent 15 *inventions* for the least productive amongst them into the observed period. If we consider the average of 5 patents for an invention, our threshold means that the least productive inventors, among the retained ones, are associated to the production of 3 inventions (on average). As a consequence it would be more relevant to some extent to speak about "prolific patentors" than "prolific inventors". Nevertheless the evidence shows that development of strategic patenting is an important factor in increasing the size of the group of patents, and so, since the 80s. As a consequence the size of this group of patents does not stay constant over our period study.

Prolific inventor average number of patents F=E/B	**24.63**	**26.34**	**25.77**	**30.05**	**31.14**
Prolific inventor number of patents Standard deviation	**14.04**	**17.79**	**19.82**	**26.46**	**25.58**

The population of prolific inventors is obviously different across countries (B in Table 1). First it must the population in the USA be noticed, but the population of Japanese prolific inventors is really consistent. This last evidence is a real surprise. By taking into account the size of the country in terms of their technological activity through, for instance, the total amount of inventors, we have a better overview on the differences across countries. This is why we have calculated the index B' (total amount of prolific inventors/ total amount of inventors), which gives a more relevant picture of the place of prolific inventors across each country. B' is the first of ours prolificness indexes. The score for Japan is noteworthy. Japan is by far the first country:

7.3 % of Japanese inventors are prolific. In the process of making the data for Japan, we faced a lot of difficulties when realizing the "who is who" as some Japanese names and first names are very close and differ only from one vowel once we translated from Chinese to Latin letters. But we have no evidence proving that the method we used tend to concentrate different inventors onto the same name [21]. By contrast a lot of people (mainly academics) have reported that assignees are used to report systematically in the list of inventors of the patent document the name of the R-D project managers, if not the director of laboratory. Surprisingly we have not found a paper or a report that deals with this practice. Of course the reader must bear in mind that these conventions tend to pollute the data for Japan. The population of prolific inventors is relatively more important in Germany, as it is twice the size of French and British prolific inventor population[22]. Interestingly, Germany exceeds the USA on that index: the weight of prolific inventors is more important in Germany than in the USA. We need to bear in mind that for an American inventor, the US system of patents is his/her national system. As a consequence we can expect to find a greater proportion of economic agents willing to protect inventions that have less value. Such inventors are usually sporadic patentors and non prolific by nature (Latham

[21] See Sung (2008). Some minor bias in the building up of the data set cannot explain this surprising importance of Japan in terms of prolificness. The only explanation would be the existence of numerous homonyms in the patent data. Several Attorneys have reported this fact. For this reason we have analyse very carefully the patents data with Japanese inventors.

[22] For France the data are here slightly different from those set out by Le Bas et al. (2007).

and Le Bas, 2006). It explains why the total number of inventors is more important in the USA and tends to decrease the B' index (all things being equal). The second index of prolificness (index C in Table 2) is built with the amount of patents. This index calculates the ratio of patents that have at least one prolific inventor in the team of invention (as noted in the patent document) and the total amount of patents. This index of prolificness is more complex than the first index (B'). It depends on the proportion of prolific inventors in the population of inventors (B') but also on the ratio of productivity of the prolific inventors. The ranking of the countries is not modified. This ratio is considerable in the case of Japan[23]. Two patents over three have a prolific inventor in the team of invention. This feature is equally explained by the number of prolific inventors and by their high productivity.

Comparing the levels of our indexes of prolificness with two further national indexes of technological activity appears interesting: 1) The first indicator of technological activity is the percentage of the national R&D expenditures funded by enterprises (two years are here taken into account: 1992 and 2002). It measures the private industrial capacity to invest in R&D activity. Japan is by far the first country, followed by Germany and the USA (while this country is catching up its lag). France and the UK are lagging but with diverging trends (France catches up UK that falls behind)[24]. The country ranking for this index is close to the ranking that emerges with our indexes of prolificness. The cases of France and U-K are more complicated due to their diverging trends of evolution. But the two countries are lagging as far as the two measures are concerned. Thus the trends of prolificness across countries are in accordance with the country ranking of national level of R&D expenditures funded by firms. 2) The second indicator is the following ratio: triadic patents/private industrial R&D (here see Lelarge, 2007[25]). This ratio is a measure of the capacity to invent and to protect inventions by patenting. Germany and Japan are by far the first countries, followed by the U-K and France. The USA are behind. This evidence does not completely match the data we have in terms of prolificness indexes since the USA are an intermediary country between the leaders Germany-Japan and the lagging couple, which composed of the U-K and France. In fact, a bias might be in our data as we measure our

[23] For Korea the two measures give respectively: 5.6 % and 48.5 % (Sung, 2008).
[24] We give the data in % (drawn from OECD MSTI data base) for two years (1992 and 2002): Japan (71.1; 74.1), Germany (61.2; 65.5), USA (58.0; 65.2), France (46.6; 52.1), U-K (51.3; 43.5).
[25] The data come from OCDE, Compendium of Patent Statistics, 2006 (Patent and R & D Databases), septemb.2006.

prolificness index with the US patent, which is a national patent for the US inventors. By contrast, the USA have no advantage when we use triadic patents. The "artificial" advantage of the US (when we use US patenting) might explain a part of the gap between the two rankings as far as the place of the USA is concerned. With respect to the game between the U-K and France we must bear in mind that our indexes of prolificness are calculated for a long time period (more 25 years). Regarding the ratio triadic "patents/private industrial R&D" France was well ranked in 1991 before the UK, the reverse is true in 2003. As a consequence, we view the ratio "triadic patents/private industrial R&D", which is a measure of the capacity to invent and to protect inventions by patenting, as a good factor in correlation with (eventually explaining) the score of countries in terms of prolificness (but the causality may equally runs in the other sense). The two last lines of the table give useful information on the average number of patents for the prolific inventors and the standard deviation. The point which deserves particular attention is the following: the average productivity (in terms of patents) of German and Japanese prolific inventors is significantly higher. With respect to the three other countries, the average productivity is close. Standard deviations show that the dispersion is larger in Germany and in France, much narrowest for Great-Britain. The USA stands in an intermediary position.

b. Distribution of prolific inventors according to the technological fields, the type of organization (assignee), the year of their first patent, the duration of their activity and their mobility.

More information on some characteristics of the population of prolific inventors can be now set out. Table 3 gives the distribution of the population along the different technological fields. The USPTO data file provides us with information onto technological fields (« Cat » that is the more aggregated) or sub-technological fields (« Subcat ») in which a patent is granted (for more details on the classification used see appendix 1) Since a prolific inventor can apply a patent in several fields (sub-fields) many options were possible as far as the technological distribution of their patents is concerned. We have chosen here to present the distribution of their patents by fields (« Cat »), which means that we have breakdown the patents of our prolific inventors into the different fields. Another option would have been to consider the only dominant technological field of the prolific inventor. The chosen option gives an accurate figure of the weight of prolific inventors patenting by technological fields. We first observe that prolific inventors patenting is distributed unevenly by technological fields. Each country has its own model[26]. Some countries have an unbalanced distribution (for instance Germany where Chemicals is the dominant field) others much more balanced (for instance Japan). Moreover we observe a strong relationship between countries' technological specialization (more exactly the technological specialization of large firms) and the technological importance of prolific inventors (measured here by their patenting): Great-Britain and France with Chemicals and Drug technologies, the USA with Chemicals but also with the two blocks "Computers and communications" and "Electrical and Electronic", Germany with the overwhelming weight of Chemical and to a smaller extent "Mechanical Technologies". Surprisingly Japan has a more balanced profile. Its prolific inventors are less concentrated in one or two technological fields. Four large technologies have a score of around 20 %, including of course the cluster "Computers and communications" and "Electrical and Electronic" for which it overtakes the USA (in proportion).

In order to test the existence of relationship between country technological specialization and the presence of prolific inventors; we carry out the following analysis. We study the specialisation at the 37 sub technological fields. For each of them, we calculate the RTA (revealed technological advantages) index that is a common indicator for measuring technological specialization at the country level[27]. We also have for each of the 37 sub technological fields the number of prolific inventors (or a fraction of the total number of inventors at each country level). We have pooled the data. The OLS regression (as a first approximation) gives a high Rsquare of 47%. Interestingly when we add dummy variables for countries and technological fields we find that no dummy for countries are significant. As for dummy variables for technological fields we found that CAT 1 – Chemicals- is very significant.

[26] Our results confirm and extent the data evidenced by Patel and Pavitt (1995).

[27] See our paper by Le Bas and Sierra (2002).that addresses the empirical literature on RTA.

Table 3. Prolific inventor patenting by country and technological field.

	GB	FR	USA	GER	JP
Chemicals	**29.35**	**32.51**	**26.03**	**38.00**	**19.41**
Computers and Communications	**9.25**	**7.95**	**13.62**	**3.60**	**19.18**
Drugs and Medical	**24.94**	**19.63**	**13.48**	**10.65**	**4.72**
Electrical and Electronic	**11.76**	**12.01**	**18.13**	**11.71**	**22.90**
Mechanical	**14.45**	**16.09**	**14.66**	**22.56**	**23.63**
Others	**10.25**	**11.80**	**14.09**	**13.48**	**10.15**
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

The evidence raises the following question: in what sense do the relationships between country technological specialization and technological importance of prolific inventors (measured here by their relative number) work? It may be the relationships are running both ways. On the one hand because the more R&D investments are made in the fields in which a country is specialized, the more inventions there will be and consequently the more prolific inventors there will be (indirect effects). On the other hand, the strengths of each country are reflected through the presence of large nationally-based firms [28] which are able to maintain their specialization persistently in the context of competitive pressures if they hire the best technological knowledge workers available (prolific inventors) [29].

In any case this finding is very important. It proves there is a strong linkage between the nation leadership in technological fields (at the 37 subCAT level) and the (relative) presence of prolific inventors. At this stage of we gave very few information. Other estimates and more analysis are being undertaken.

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[28] See Patel and Pavitt (1995).
[29] It has recently been shown that key inventors are primarily located within a limited number of key firms having a real technological leadership Pilkington et al. (2009).

Table 4 provides information about the assignees. The main evidence is that a great majority of prolific inventors have industrial enterprises as assignees. As a consequence they are salaried researchers or engineers. Correlatively the number of *individual* prolific inventors is very low. Some further particular situations come into view. For instance the large opening of the British industry to US firms, by contrast the Japanese situation is characterised by quasi-closeness.

Table 4. Prolific inventor patenting by country and type of assignee

	GB	FR	USA	GER	JP
US Enterprise	24.09	6.31	87.78	5.37	0.87
Non-US Enterprise	70.66	86.28	1.43	89.25	97.23
Individual	0.05	0.41	0.64	0.98	0.28
Others	5.20	7.00	10.15	4.39	1.62
Total	10000	100.00	100.00	100.00	100.00

Table 5. Population of prolific inventors (%) by country and year of the first application.

	GB	FR	USA	GER	JP
Before 1975	32.72	32.50	26.34	34.23	21.92
1975-1979	22.02	24.11	21.18	25.43	25.64
1980-1984	15.62	18.15	15.86	14.99	20.88
1985-1989	16.24	14.00	16.53	13.30	20.72
1990-1994	9.72	8.82	14.81	8.88	9.33
1995-1999	3.69	2.42	5.13	3.17	1.50
After 1999	0.00	0.00	0.14	0.00	0.01
Total	100.00	100.00	100.00	100.00	100.00

Table 5 dedicated to the distribution of prolific inventors according to the date of their first patent application provides interesting insights. We can check some trends. For instance, we shall check, firstly, whether prolificness is a new (recent) phenomena or, on the contrary, goes back far in the past and secondly, whether the new "*surge* » in patenting (Kortum and Lerner, 1999) in the 90s that we find in all the technological fields and the development of strategic patenting and patent thicket (Shapiro, 2001; Reitzig, 2004) has had an effect on the emergence of a new wave of prolificness. Regarding the first trend we see that near 30% of our population of prolific inventor got their first patent at the outset of the period of time under observation. Of course it is possible that they were not among the most prolific ones. This trend is quasi-general. It means that prolificness is not a recent phenomenon[30]. With respect the second trend we observe for the USA that a high proportion of prolific inventors had their first patent after 1990. For this country 20 % of the population of prolific inventors is in this situation. It is correlated to (or confirm) the surge in patenting identified by Kortum and Lerner (1999). For the others countries this percentage is much smaller.

Table 6. Population of prolific inventors (in percentage) by country and activity duration

	GB	FR	USA	GER	JP
1 to 5 years	**5.29**	**4.15**	**7.00**	**4.46**	**2.36**
6 to 10 years	**16.85**	**18,67**	**19.39**	**15.54**	**13.30**
11 to 15 years	**24.35**	**22.73**	**21.45**	**20.65**	**24.01**
16 to 20 years	**22.51**	**25.06**	**20.33**	**22.87**	**23.19**
21to 25 years	**22.51**	**20.83**	**21.17**	**24.42**	**23.19**
26 to 30 years	**8.49**	**8.56**	**10.33**	**11.86**	**13.74**
31 to 35 years	**0,00**	**0,00**	**0.34**	**0.21**	**0.20**
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

[30] Confirming the seminal work by Narin and Breitzman (1995).

Table 6 lays out the activity *duration* of our prolific inventor (by contrast table 5 gave the year of *birth* of their activity[31]). The first observation is the duration of patenting activity is very different. Some inventors are active over 5 years, others over 35 years [32]. In general the distributions are uni-modal with an exception for the USA. Japanese inventors have shorter period of activity, German longer.

The mobility is analyzed in table 7 and 8. We have distinguished the national inter-firms mobility (or inter-organizations mobility) from the international one. We faced difficulties for counting inter-firms mobility. Some people in the R&D department of a large firm do very short moves (sometimes one move a month) towards another firm (the researcher is put at the disposal of), or in joint venture, a subsidiary abroad, and so on. During this short move the researcher generally participates to a different research program, achieves a discovery and patents it. Such moves enter our definition. An important point is that inventors learn through these very short moves and increase their capital of experience and their social network. We have adopted the following rule concerning individual prolific inventors: when they stay all their period of patenting individual inventor their professional mobility is obviously null. Nevertheless when they are hired by a firm and work for it we consider that there is as a move. We count two moves when they leave their main enterprise for a short stay and come back to this firm. We have equally taken into account the fact that sometimes their previous firm applies a patent (in which we find their name) lately 1 or 2 years after the inventor has left. When we observe a chronological sequence of patenting, we remark that there is a patent protecting on an invention made during the employment in the previous firm. It can allow us to think that the inventor has moved back to this firm (this point is emphasized by Hoisl, 2007)[33].

[31] Of course crossing the two would reveal interesting inventor profiles.

[32] The reader must be aware that the table 6 does not give any information on the number of patents related to the inventors.

[33] Hoisl (2007) noted that sometimes the inventor is the applicant of one of the patents and the applicants before and after this patent match completely the same firm. She considers that the inventor has not changed his/her employer. We have not used this convention systematically. We analysed case by case for considering if yes or no there was mobility. One important element was the period of time between the different patentings.

International mobility is defined here in a restricted meaning. It matches a move in the four others countries (we recall that the five countries under observation match 85% of the overall patenting). The latter is considered as having a greater impact, at least potentially on the value of patent (Trajtenberg, 2004).

Table7. Prolific inventor's mobility by country and number of moves between assignees

Moves	GB	FR	US	GR	JP
0	**17.59**	**19.79**	**23.35**	**26.02**	**29.95**
1	**11.69**	**7.17**	**11.55**	**9.73**	**7.34**
2	**12.92**	**12.96**	**11.90**	**12.94**	**7.17**
3	**10.46**	**8.99**	**8.73**	**7.63**	**5.20**
4	**8.86**	**8.99**	**7.39**	**7.29**	**4.82**
5	**8.86**	**7.09**	**6.05**	**5.45**	**4.07**
6	**6.27**	**5.88**	**5.11**	**5.12**	**4.12**
7	**4.67**	**4.67**	**4.34**	**3.87**	**3.70**
8	**3.20**	**5.62**	**3.81**	**3.04**	**3.46**
9	**3.81**	**4.06**	**3.23**	**2.96**	**3.05**
10	**3.08**	**2.68**	**2.67**	**2.60**	**2.2**
11-20	**7.63**	**10.29**	**9.49**	**10.28**	**15.62**
+20	**0.98**	**1.82**	**2.40**	**3.07**	**9.3**
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 8. Prolific inventor's mobility by country and number of international moves

Moves	GB	FR	US	GR	JP
0	**66.64**	**97.67**	**97.72**	**77.55**	**99.94**
1	**16.97**	**0.61**	**1.15**	**11.75**	**0.04**
2	**7.38**	**1.21**	**0.42**	**4.52**	**0.01**
3	**5.04**	**0.17**	**0.27**	**2.03**	**0.007**
4	**2.09**	**0.17**	**0.15**	**1.29**	**0.003**
5	**1.23**	**0.00**	**0.07**	**0.68**	**0.00**
6	**2.09**	**0.00**	**0.04**	**0.65**	**0.00**
7	**1.60**	**0.00**	**0.05**	**0.34**	**0.00**
8	**0.49**	**0.00**	**0.02**	**0.25**	**0.00**
9	**0.37**	**0.09**	**0.02**	**0.11**	**0.00**
10	**0.49**	**0.09**	**0.02**	**0.17**	**0.00**
11-20	**1.23**	**0.00**	**0.05**	**0.53**	**0.00**
+20	**0.37**	**0.00**	**0.02**	**0.13**	**0.00**
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

First and foremost we give evidence for national inter-firm mobility. We find out that around 20% of the prolific inventors do not move (a little less for Great-Britain), which is a significant proportion of the population. The proportion of the movers' population is 80.2% for France, 82.4% for G-B, 76.7% for the USA. The Japanese inventors do not really move in accordance with what we know on the system of employment in the Japanese large firm. Of course, all these insights picture very general trends. Our data appear rich enough for running finer studies at the Technologies level or for particular sub periods of time. Tratjenberg (2007) traced the mobility of inventors across assignees: for the overall sample of US patent he finds that only 33% of the overall inventors are movers (but his period of observation is shorter by 3 years than ours)[34]. It enables us to state that the prolific inventors move more than the overall population of inventors. On average the number of moves per inventor is for three countries (France, U-K, USA) comprise between 4.5 and 4.9 (the latter being for France). The distribution is skewed to the right with a long tail (but rather thin). Interestingly, the forms of the distributions of moves between assignees for GB, France and USA are very similar. A very tentative regression[35] with a negative binomial function (not reported here) has shown, with some control variables, that more productive inventors are more mobile (inter-firms mobility).

The international mobility is weak. An important proportion of our prolific inventors do not move at the international level. 97% are in this case in France and in the USA. The Japanese inventors are the champions of non-mobility. We do not find here (excepted for G-B) the relevance of inter-organizational boundaryless careers, which recent research on careers has discovered (see among others: Becker and Haunschild, 2003). By contrast the case of Great-Britain appears to be different since one inventor over three are mobile at the international level. With respect to this type of mobility, one remark: there is a weak correlation between the two types of mobility,

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[34] He noted that this number probably overstates moves due to a lack of consolidation of assignee code.

[35] Tratjenberg (2007) regresses (negative binomial function) the number of moves across assignees (per inventor). He adds variables as age (= 1999 – year of first patent, different from: patent duration = last year – first year). The moves of inventors are correlated with "younger" inventors, inventors having more patents in Drug and medicine, inventors having more partners (large R&D team?), inventors more technologically specialised (less technologically diversified), inventors having more important patents (more citations) but the reverse in Japan, inventors US (versus Japanese). One result deserves a greater attention: it seems that *more "valuable" inventors move more*. But what is the causality? Hoisl (2006) observe that mobile inventors are more than four times as productive (patent per inventor divided by the age of inventor in 2002 minus 25) as non-movers (survey of 3049 German inventors). The level of education has no influence and *an increase of productivity decreases the number of moves*. In the post-move period inventors produce more patentable innovation that are characterized by more value (survey of 3049 German inventors), but the gains of mobility dissipate over time (effect noted by Tratjenberg as well: a past move has lesser impact). The two authors Tratjenberg (2004) and Hoisl (2007) finally consider as a very significant finding that inventors creating invention that have more value are more mobile, but Hoisl (2007) only tests the causality productivity of inventor => inventor mobility, and find that more productive inventors (prolific inventors?) are not more mobile.

which is higher for Great-Britain[34].To conclude our study on inventor mobility, we would like to underline the fact that we are aware of the difficulties of correctly assessing it. For this reason our data on inventor mobility has to be used with caution: we have to look at our data as a very first attempt to measure the moves of inventors.

4. Distribution of prolific inventors according to their number of patents: Empirical model, estimates, and results

Our prolific inventors differ greatly as regards their productivity (their level of prolificness). For each country we have build the distribution of prolific inventors according to the number of patents (we give in figure 1 the distribution of French prolific inventor). The plotting indicates that the distribution appears similar enough across countries: it displays heterogeneity and skewness in accordance with previous works on this issue (included the seminal work by Lotka, 1926). It clearly shows that the distributions are right skewed with a *long tail*[36]. The main characteristic of "long-tailed" distributions is that a high-frequency or high-amplitude population is followed by a low-frequency or low-amplitude population which gradually "tails off" asymptotically. This type of distribution often follows a power law qualitatively quite different from the histogram of people's heights (more narrow and peaked, in fact "Gaussian").

[36] The *long tail* is the name for some statistical *highly right skewed* distributions.

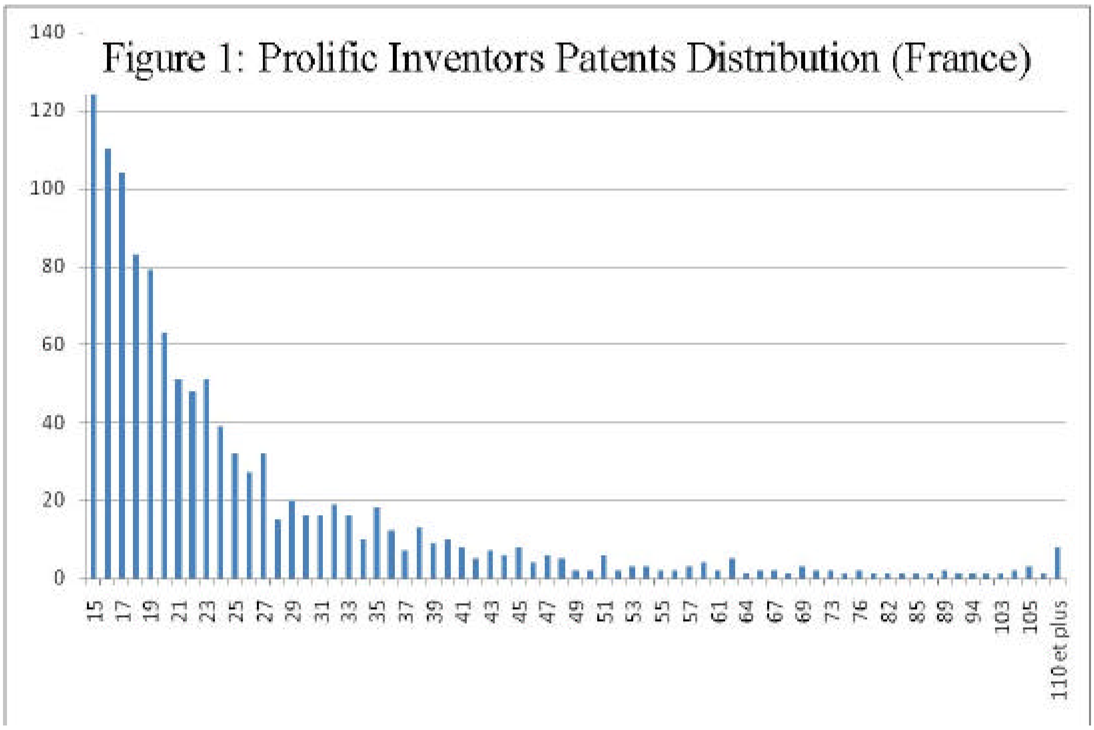

Figure 1: Prolific Inventors Patents Distribution (France)

Our main objective here is to explain the heterogeneity in terms of patents productivity: why a prolific inventor invents 15 patented inventions and others does 16, and so on. In the literature two sets of factors are usually put forward. The first concerns some inventors' characteristics: age, educational degree, talent, culture are among the most quoted (see for instance Gambardella et al., 2005). But the profile of the applicant organization in which they participate has also an impact. It seems that the size of the firms[37], the type of knowledge and motivations management affect individual and collective performance of the R&D department. Moreover it may be that the set of factors interact crucially: for instance the large corporations that have enough R&D budget can draw more talented people[38]. Unfortunately we have not enough information about the inventor's characteristics and we could not gather information onto the corporations that employ the inventors at a reasonable cost[39]. Nevertheless, our study allows us to test the existence of an impact of some factors on inventor productivity. For undertaking this very first assessment our base provides a set of relevant variables. The variable names and their accurate definition are

[37] For instance Knowledge workers are more productive in large firms (Kim et al., 2004). Hoisl (2007) confirms this trend for German inventors.
[38] The organization location may have also a role according to the localized knowledge spillovers thesis (Audretsh and Feldman, 1996).
[39] This task is in progress for a few countries.

presented in Table 9 (appendix 2 gives descriptive statistics as far as our main variables are concerned).

Table 9. Definition of variables

Variable description	Short name	Comment	Type
Number of patents granted by the inventor	NBPAT	Dependent variable	Quantitative
Assignee move	MOV_ASS	Inventor number of national moves between firms over the time period	Quantitative
International move	MOV_INTER	Inventor number of international moves over the time period	Quantitative
Technological variety	VARIETY	The number of different technological categories where the inventor has got patents granted (from the 6 principal categories quoted below).	Quantitative
Patent duration	PAT_DURATI ON	The number of years between the first and the last patent application. We use this variable as a proxy variable for the "inventive lifetime" of an inventor.	Quantitative
Temporal concentration	TIME_CON	maximun number of patents in one single year/total number of patents	Quantitative
Dominant technological category		Technological class in which prolific inventor patent more	Qualitative
Chemicals	CHEMICALS		(0-1)
Computers & Communications	COMPUTERS		(0-1)
Drugs & Medical	DRUGS		(0-1)
Electrical & Electronic	ELECTRIC		(0-1)
Mechanical	MECHANICAL		(0-1)
Other	OTHER		(0-1)
Dominant assignee type		The prolific inventor dominant type of assignee.	Qualitative
Unassigned	Assdom1		(0-1)
Assigned to a U.S. nongovernment organization	Assdom2	The patents assigned to a U.S. non-Federal Government	(0-1) (0-1)
Assigned to a non-U.S., nongovernment organization	Assdom3	agency do not appear in our dataset.	(0-1) (0-1)
Assigned to a non-U.S. individual	Assdom4		
Assigned to a non-U.S. government	Assdom5		
Assigned to a U.S. individual	Assdom6		
assigned to the U.S. (Federal) Government	Assdom7		
Year of the first patent application	FIRSTAPP(t)	Classes of period of 5 years	Qualitative (0-1)

We have two set of independent variables:

a. First of all the characteristics of the inventor profile. Enter this category the two types of mobility (national inter-firm and international), technological diversificatio n and time concentration. The two types of mobility have been pictured in the previous section. One of our basic hypotheses is that, by hiring a particular inventor, the firm gets access to a relevant stock of knowledge and to the networks of researchers through which the inventor has operated. The firm absorbs in fact a «social capital of contacts » (Breschi et Lissoni, 2003). The inventor mobility is a mean for "visiting" new "clubs" of inventors, to increase his own « network complexity », and to improve his intellectual capital, which strongly contributes to the firm innovative capacity. Our basic hypothesis is that there exists a positive relationship between the inventor mobility, his/her learning capacity, his/her performance in terms of patents. The variable "technological diversification" has been calculated for each prolific inventor with the number of different technological categories in which he invents (we use here the 6 principal technological categories). This proxy measures the inventor talent. The more the inventor is talented, the more he possesses the capacity to find new bits of knowledge in different technological areas. We expect their effects to be positive on inventor productivity.

b. Control variables are numerous. The patent duration is likely to be the most interesting one. It is crucial to control by the inventor patenting period of time i.e. the period of time in which the inventor is productive. It is obvious that the longer this period is, the higher will be the probability to invent and become a patentor. To put it simply two inventors who patent the same amount of patents but on different periods of time have not the same real productivity. Time concentration is a control variable as well. This variable controls for temporal effects. Hoisl (2007) point out that "this measure reveals whether an inventor kept on inventing constantly during his inventive life or whether he carried out his inventions within a short period of time". She finds a negative coefficient for this variable. The others control variables are binary variables for technological category[40], type of assignee[41], year of the first application[42].

[40]This variable enables us to control for the number of patents requested for protecting effectively the invention. This number differs greatly across technological fields (Reitzig, 2004).

[41] We can expect that an individual inventor is less productive than an inventor working in large firm for instance.

[42]This variable is different from patent duration (but might be correlated with it). Here it controls for the recent wave (upsurge) of patenting (the so-called pro-patent area).

The dependent variable is of course the productivity of each prolific inventor (their number of patents). Because the patents that the inventors have produced are « count » data, the estimation of both models required the use of an appropriate alternative to ordinary least squares. We have rejected the Poisson model for the number of patents that did not fit our data. The best alternative model for the data turned out to be the negative binomial model. Regressions were done for each country in order to emphasize the likely national specificities. We have excluded Japan because of the weak quality of the data covering the inventors, as explained previously. We used natural logs of all the non-dummy variables. The results were not nearly as good as those obtained with the strictly linear-in-the-variables models. The results shown in Table 10 are all from quasi-maximum likelihood estimation of the models. In general our results are in accordance with expectations. The impact of inter-assignee mobility is always positive and significant, confirming the work of Hoisl (2007) on Germany. Hoisl (2007) shows that mobile inventors are more productive than non-movers. Here we observe that the higher the number of moves the higher the inventor productivity (with control variables). We provide new insights on international mobility (not studied by Hoisl). With one exception (France) international mobility has a positive significant impact on inventor productivity. Of course here implicitly we assume that causality runs from mobility to productivity. Technological variety (a proxy for inventor competences) influences positively inventor productivity (with one exception: Germany). Patent duration may be the more important control variable is significantly positive for the four countries. The coefficient related to temporal concentration is negative. It is the sign expected. The inventors who concentrate their invention in a short time period are less productive. This result is in accordance with the Hoisl (2007) findings. Of course our model does not answer the question raised by Hoisl (2007) and Tratjenberg (2004 and 2007) which is: in what sense works the causality between mobility and productivity at the inventor level?[43] This study does not deal with the troncature problem. As the data set begins in 1975 it may be the case that patents of our prolific inventors are missing (or that some non prolific inventors are in fact prolific). The core of a future research agenda will be to envisage the endogenity and troncature issues.

[43] Interestingly we know from regressions ran with our data and not reported here that prolific inventor inter-firms mobility depends positively upon inventor productivity.

Table 10. Negative Binomial Regression Results for Number of patents (nbpat)

	GB		France		USA		Germany	
	Coef.	Std Err.	Coef.	Std Err.	Coef.	Std Err.	Coef.	Std Err.
mov_ass	.0139**	.0032	.0162**	.0022	.02195**	.0004	0.0162**	0.0011
mov_inter	.0226**	.0052	.0132	.0242	.0104**	.0034	0.0644**	0.0148
variety	.0434**	.0162	.0478**	.0122	.0114**	.0025	-0.0021	0.0070
pat_duration	.0041	.0033	.0164**	.0030	.0102**	.0006	0.0173**	0.0017
timeconc	-1.078**	.1821	-1.4286**	.1716	-.74630**	.0286	-1.6730**	0.0896
cat1	-.0254	.0555	.1154**	.0479	.1200**	.0093	0.1796**	0.0253
cat2	-.0334	.0672	.0505	.0629	.0441**	.0107	-0.0823	0.0527
cat3	.1687**	.0547	.2151**	.0487	.0556**	.0105	0.3251	0.0294
cat4	-.0443	.0621	-.0480	.0567	.0665**	.0099	-0.0303	0.0321
cat5	.0504	.0622	.04551	.0542	-.0205	.0105	-0.0144	0.0273
assdom1	-.0636	.2430	.1817	.1972	.0587*	.0244	-0.1565	0.1453
assdom2	-.0680	.2401	-.3606	.2081	.0383*	.0221	-0.1964	0.1421
assdom3	-.0882	.2399	.0686	.0544	-.0038	.0362	-0.2179	0.1366
assdom4	-.0742	.2663	-.0932	.0987	.2778	.3260	Included in Const.	
_cons	3.1573**	.2647	3.3223**	.1286	3.2555**	.0298	3.7200**	0.1489
	Number of obs = 813 Log likelihood = -2928.26 Pseudo R^2 = 0.0344		Number of obs = 1157 Log likelihood = -4282.38 Pseudo R^2=0.0492		Number of obs = 26279 Log likelihood = -100612.43 Pseudo R^2=0.0270		Number of obs = 5270 Log likelihood -=407234.68 Pseudo R^2= 0.032	

Dummy for time periods included for the 4 countries
The negative binomial dispersion parameter was estimated by maximum likelihood.
** significant at the 1% level, * significant at the 5 % level.

Conclusion

Previous studies on prolific (of key) inventors are focused on firms (four in one sector in the seminal work by Narin and Breitzman (1995)) or on industries (two in the recent paper by Pilkington et al. (2009)). We have adopted another perspective since we have carried out a comparison across countries. We use intensively US patent for five countries (among the more important in terms of scale of technological activities).

We sum up the main stylised facts that our study enables to produce:

1. The size of the relative population of prolific inventors (first index of prolificness) or the relative volume of their patents (second index of prolificness) differs across countries. The ranking is: Japan, Germany, USA, France, GB (USA et France permute with the second index).
2. The countries ranking that we found is coherent (correlated) with what we know about the main national technological indicators (R&D expenditures funded by enterprises or triadic patents/private industrial R&D).
3. We observed that prolific inventors patenting is distributed unevenly by technological fields. There is a strong relationship between countries' technological specialization and the importance of prolific inventors (measured by their patenting). We show there is a strong correlation between the Revealed Technological Advantages Index and the proportion of prolific inventor at technological class level (37 Subcat).
4. A great majority of prolific inventors have industrial enterprises as assignees. They are consequently salaried researchers or engineers. Correlatively the number of individual prolific inventors is very low. The differences across countries are significant.
5. Near 30% of our population of prolific inventor got their first patent at the outset of the period of time under observation (1975). In the USA a high proportion of prolific inventors (20%) have their first patent after 1990.
6. The variable patent duration differs greatly across inventors (and countries). Some inventors are active over 5 years, others over 35 years. Japanese inventors have shorter period of activity, German longer. This variable should be used for building a taxonomy of inventors: inventors who patent persistently becomes prolific overtime, others are prolific quickly (the study should control for interindustrial differences).
7. We give evidence for national inter-firm mobility: around 20% of the prolific inventors do not move. The international mobility is very weak.
8. Binomial regressions explaining the inventor productivity after controlling for patent duration and time concentration (among others factors) show that inter firm and international mobility and technological variety (at the inventor level) affects positively the inventor productivity. The overall results suggest that the same factors impact positively productivity with no difference across countries (with some exceptions).

Some remarks on implications for management. Prolific inventors make up very specific human resources that request particular management. First, in order to motivate these people, to prevent their move (or to refrain them from moving too quickly[44]) and to make them share their knowledge and know-how. Leonard and Swap (2005) set out some inputs for the management of "deep smarts", that is to say people who have a good of amount expertise in all the areas of the industrial life. It seems possible to spread their analysis to prolific inventors.

It seems to us that a point would deserve of course more analysis. As a research agenda we have to study the relation between the prolific inventor productivity and the quality of patents (citations) that is at the heart of prolificness, as we defined it.

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[44] As far as inventor mobility is concerned a new context is emerging with strategic mobility. High tech firms actively encourage defection among competitors' technological personnel (Kim et Marschke, 2004): See also Fleming and Marx (2006).

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Appendix 1. Technology category (USPTO).

Cat	SubCat	SubCatName	CatNameShort	CatNameLong
1	11	Agriculture,Food,Textiles	Chemical	Chemical
1	12	Coating	Chemical	Chemical
1	13	Gas	Chemical	Chemical
1	14	Organic Compounds	Chemical	Chemical
1	15	Resins	Chemical	Chemical
1	19	Miscellaneous-chemical	Chemical	Chemical
2	21	Communications	Cmp&Cmm	Computers & Communications
2	22	Computer Hardware & Software	Cmp&Cmm	Computers & Communications
2	23	Computer Peripherials	Cmp&Cmm	Computers & Communications
2	24	Information Storage	Cmp&Cmm	Computers & Communications
3	31	Drugs	Drgs&Med	Drugs & Medical
3	32	Surgery & Med Inst.	Drgs&Med	Drugs & Medical
3	33	Biotechnology	Drgs&Med	Drugs & Medical
3	39	Miscellaneous-Drgs&Med	Drgs&Med	Drugs & Medical
4	41	Electrical Devices	Elec	Electrical & Electronic
4	42	Electrical Lighting	Elec	Electrical & Electronic
4	43	Measuring & Testing	Elec	Electrical & Electronic
4	44	Nuclear & X-rays	Elec	Electrical & Electronic
4	45	Power Systems	Elec	Electrical & Electronic
4	46	Semiconductor Devices	Elec	Electrical & Electronic
4	49	Miscellaneous-Elec	Elec	Electrical & Electronic
5	51	Mat. Proc & Handling	Mech	Mechanical
5	52	Metal Working	Mech	Mechanical
5	53	Motors & Engines + Parts	Mech	Mechanical
5	54	Optics	Mech	Mechanical
5	55	Transportation	Mech	Mechanical
5	59	Miscellaneous-Mechanical	Mech	Mechanical
6	61	Agriculture,Husbandry,Food	Others	Others
6	62	Amusement Devices	Others	Others
6	63	Apparel & Textile	Others	Others
6	64	Earth Working & Wells	Others	Others
6	65	Furniture,House Fixtures	Others	Others
6	66	Heating	Others	Others
6	67	Pipes & Joints	Others	Others
6	68	Receptacles	Others	Others
6	69	Miscellaneous-Others	Others	Others

Appendix 2 Summary statistic

Variable	Mean	Std. dev.	Min	Max
NBPAT	24.630	14.058	14	163
MOV_ASS	4.433	4.661	0	41
MOV_INTER	1.057	2.644	0	37
VARIETY	2.418	0.991	1	6
PAT_DURATION	16.203	6.591	2	29
TIME_CON	0.239	0.102	0.07	0.78

Variable	Mean	Std. dev.	Min	Max
NBPAT	26.341	17.794	15	243
MOV_ASS	4.903	5.163	0	53
MOV_INTER	0.059	0.501	0	10
VARIETY	2.417	1.065	1	6
PAT_DURATION	16.260	6.515	2	29
TIME_CON	0.227	0.093	0.07	0.73

Variable	Mean	Std. dev.	Min	Max
NBPAT	27.024	19.827	15	731
MOV_ASS	4.745	6.257	0	115
MOV_INTER	0.062	0.735	0	58
VARIETY	2.779	1.254	1	6
PAT_DURATION	16.124	7.358	0	100
TIME_CON	0.237	0.110	0	0.94