Prolific inventors and their mobility: scale, impact and significance. What the literature tells us and some hypotheses

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Abstract

In this paper we survey the literature dealing with the category of prolific inventor. We set out some elements regarding nature, scale, significance and impact of the mobility of this population of prolific inventors. In particular the paper suggests an analysis that measures the effects on mobility on individual inventive productivity and the value of invention. We call "prolificness" the capacity to accumulate knowledge and experience through mobility (that is to say through their capital of contacts and interactions).

The first goal of this paper is to survey the literature dealing with the category of prolific inventor. It is a piece of a larger research project that aims to assess the mobility of this population of prolific by measuring its effect on the individual inventive productivity and the value of invention (see footnote 1). As a consequence we survey the literature on inventor mobility[2] as well. In the last part we give some insight on what we call "The Economics of prolificness".

1. Literature Survey on prolific inventors

a. The precursors. In the literature there are three basic references. First the well-known seminal study of Lotka (1926). He observes that the number of highly productive scientists was a relatively small fraction of all scientists. Acknowledging that a population of highly prolific inventors does exist, he suggests a law for laying out their distribution. Secondly, the study from Levine (1986) analysing the statistical distribution of a bulk of patents from a sample of 7392 inventors who received 9 patents or more under the time period 1975-1984. He observes the frequency distribution of patent output per inventor revealing "an

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[2] Up to now, we still do not have studies on the professional mobility of prolific inventors.

approximately logarithmic decline". He performs a patent citations analysis on a random sample of 45 prolific inventors and finds that there is no statistically significant differences as far as the average citations across the range of inventor patent outputs. This is interpreted as follows: the value of patent (patent quality) does not decrease as the quantity of patent per inventor increases. This point is particularly important since it underlines that there is decreasing returns as far as the productivity of prolific inventors is concerned. Thirdly, the Narin and Breitzman (1995) seminal paper on "highly prolific inventors". They investigate 4 companies in the area of semiconductors and they perform an "inventor name unification" (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". This study constitutes really the first modern study on prolific inventors even if it is on a limited sample of inventors and patents [3].

b. The previous studies from the LEFI research team (University Lyon 2). Latham, Le Bas and Touach (2006) using date from USPTO have untaken to measure the scale and assess the scope of prolific inventors from four countries (France, Japan, Germany, U-K). They find (see table 1) that Japan and Germany are the two countries having the larger proportion of prolific inventors (more than 9 patents over the period of time 1975-1999). They show that one consequence of the persistent productivity of prolific inventor is that the proportion (in comparison of the total amount of patents) of patents including in a prolific inventor is very large, between 40 and 94 % along the different countries (see table 2) [4].

Table 1. Distribution of inventors according to the number of US patents by country, 1975-1999 (%)

Number of patents	France	Germany	UK	Japan	TOTAL
1	56,72	50,24	52,14	42,74	47,32
2-9	38,76	41,83	42,03	45,89	43,59
10-49	4,36	7,41	5,60	10,64	8,53
50 et plus	0,16	0,53	0,23	0,73	0,56
TOTAL	100,00	100,00	100,00	100,00	100,00

Source: Latham, Le Bas and Touach (2006)

Table 2. Patents including a prolific inventor by country, 1975-1999

[3] A note from the USPTO (1998) giving the name of prolific inventors receiving utility patents from 1988 to 1997. The Ernst et al. (2000) study show that very productive inventors are associated to valuable patents.

[4] Their results must be considered as temporary because the data set has been quickly built up. Very recently in the same vein Harhoff and Hoisl (2006) noted few inventors produce the lion's share of inventions within an R&D department.

	France	Germany	UK	Japan
Number of US patents including a prolific inventor	26.299	111.985	24.448	368.844
Proportion of US patents including a prolific inventor (%)	40.45	65.93	42.29	94.41

Source: Latham, Le Bas and Touach (2006)

Latham *et al*. (2006) use the same data base of patents granted by the US Patent Office to French, German and British inventors over the period from 1975 to 1999 and the NBER data base. Negative binomial multiple regression models support for the hypotheses that both prolific and foreign inventors tend to be parts of larger teams of inventors[5] and that both prolific and foreign inventors tend to produce inventions having more value (value being measured by citations).

c. The Trajtenberg inventors patent data set (Trajtenberg, 2004 et 2007). Trajtenberg has undertaken to build up a large data set on the inventors. Knowing that in patent document we can observe their name, first name and address, there are a lot of difficulties and traps. He suggests a two stages methodology for matching the names of inventor using the SOUNDEX coding. A first assessment from the NBER Patent Data File (1975-1999) allow him onto 2 million patents and 2 inventors per patent on average to find 4,298 912 records. After matching it with the Trajtenberg procedure we obtain 1,565 780 inventors. As a first comparison with there is 58% with just one patent, and 5% with 10 patents or more[6]. Of course the research implemented by Trajtenberg (2007) does not deal with the population of prolific inventors, but represents a very rich tool for measuring and mapping it.

2. Inventor mobility: scale, determinants, theoretical background

a. Scale. The data set worked out by Tratjenberg (2007) enables us to trace the mobility of inventors among other issues. First of all mobility of inventors across assignees: for the overall sample of US patent we find 216, 581 (33% of the overall population of inventor) as a number of inventors movers[7]. The number of mobile inventors across countries: 12 371 for

[5] Harhoff and Hoisl (2006) observe that the dynamics of R&D team is salient feature of invention process.
[6] This result is in accordance with those found by Latham, Le Bas and Touach (2006).
[7] But Tratjenberg acknowledges there is a need to consolidate assignee code.

one country move, at the other 1 only inventor moves through 6 countries. Kim et al. (2005) have conduct a study on US patents and inventors with the Tratjenberg' method onto two industries: pharmaceutical and semiconductor. They add dissertation abstract to inventor data for mapping and explaining the international knowledge flows. They find out an increase in the extent to which US innovators access researchers with foreign R&D experience.

The PATVAL survey gives the number of times the inventor changes employment after the one of the patent: one time 14, 22 %, two times 5,15 %, three times 1,53 %, more 0,78 %. It means roughly speaking 20% of employers on a time period of 10 years.

Of course the time periods differ across the studies but the main finding of that story is that employer mobility is, if not large, very significant[8].

b. Determinants

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 (sign of age = negative), 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[9]? 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.

The two authors Tratjenberg (2004) and Hoisl (2007) finally consider as a very significant finding that the inventor creating more value for invention are more mobile, but Hoisl (2007)

[8] Intra-firm mobility inside R&D network stays still important. According to Criscuolo (2005) short-term forms of mobility are less costly and effective inside MNC.

[9] Turner (2003) studying the mobility of researchers in Physic (CNRS) found an elasticity quality of publication/ mobility of researchers = 0,3 citation more with mobility. Here the causality runs from mobility to quality.

only tests the causality productivity of inventor → inventor mobility, and find that more productive inventors (prolific inventors?) are not more mobile[10].

c. Theoretical background

In the Economics of Knowledge, the state of the Art as far as mobility is concerned, is well encapsulated by Teece (1982: 45): "The transfer of key individuals may suffice when the knowledge to be transferred related to the particulars of a separable routines,…only a limited range of capabilities can be transferred … . More often than not, the transfer of productive expertise requires the transfer of organizational as well as individual knowledge". Inventor mobility is key mechanism to transfer tacit knowledge between firms and then a mean for technological diffusion (Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Stolpe, 2002) or personnel rotation as a mechanism of knowledge (Kane et al., 2005)[11]. Transferring A study from Song et al. (2003) on the patenting activities of engineers shows that mobility is a special type of learning at the firm level: learning-by-hiring. Through the hiring of inventors the firm can get access to the inventor *capital of contacts* (Breschi et Lissoni, 2003).

In the frame of the standard Microeconomics it is acknowledged that individual mobility is an important source of knowledge externalities (Moen, 2005), in other terms "Knowledge flows are localized to the extent labour mobility also is" (Breschi et Lissoni, 2003).

But there is another face to the coin: mobility is a part of human capital formation, through mobility individual increases his/her knowledge capital ("learning by moving"). This explains the importance of strategic mobility.

d. New context for inventor mobility: the frame of strategic mobility

High tech firms actively encourage defection among competitors' technological personnel (Kim et Marschke, 2004): "If you have trouble with the competition, simply raid its talent". This pushes the firms to patent in order to protect their Intellectual Property against leakage through inventor mobility. Gilson (1999) explain (partly of course) the greater success of Silicon Valley as compared to Route 128 by the fact that while California and Massachusetts respect the Trademark Act protecting the loss of trade secrets through mobility, Califormia prohibits (Massachusetts enforce) "post-employment restrictive covenants" (also known as "employee non-compete agreements", non-compete restricts a departing employee from accepting new employment with a competitor for a specified time and geographical jurisdiction, Fleming and Marx (2006). Fleming and Marx (2006) show that there is a greater

[10] For Hoisl (2007) a move increases productivity but an increase in productivity decreases the probability to observe a move.

[11] This matches the knowledge "reuse" (Langlois, 2001), a type of increasing economies of scale at the core of economic growth.

mobility within and toward US regions that do not enforce non-compete agreements (non-compete restrict a departing employee from accepting new employment with a competitor). In this context mobility is pulled by rival firms and is not totally governed by the inventor rational decision. There are some grounds for thinking that strategic mobility has increased in the recent period of time (at least in the USA).

3. The Economics of prolificness

One basic characteristic of prolific inventor is that individually he produces more patents (productivity) and patents having more value. By *prolificness* we denote the twin process of high inventor productivity and great value of inventions produced by these inventors. To put it simply there is a relationship between the quantity and the quality of invention[12]. There is an accumulation of knowledge and experience behind the accumulation of patents.

Our point of view is founded upon the empirical evidence from two basic studies. First the paper from Gambardella et al. (2005) using the PATVAL survey (7000 patents). They note the characteristics of the inventor, his past number of patents is the *more important* (we underline) determinant of the private value of invention (gathered through a survey) than the characteristics of organization in which he is employed[13]. Secondly the research from Latham et al. (2006) confirms this result. Using a data set of patents granted by the US Patent Office to French, German and British inventors over the period from 1975 to 1999 they estimating a relationship explaining the citations received by each patent. Prolific inventors tend to produce inventions having more economic value. We now need to explain why there such a relationship between quantity and quality[14]. Nevertheless some intriguing stylised facts emerge from other empirical studies. For instance Mariani et Romanelli (2006) find with a sample of 793 European inventors drawn from the so-called PATVAL survey that individual and organisational characteristics affect the level of single inventor productivity (*quantity* of patent) after controlling for countries and sectors[15]. By contrast these factors produce no direct effect on the value of patent measured by the number of forward citations (*quality* of patent). Only the scale of the research project has a small effect the value of patent on what Latham et al. (2006) point out as well.

We can hypothesize Prolific inventors are "technological goalkeepers" who mediate the flow of knowledge into the research organization (Allen, 1970)[16]. In a sense they act as "Knowledge integrators" (see Latham et al., 2006). This knowledge worker plays a prominent

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[12] By contrast Mariani (2005) has suggested the existence of a trade-off between patent quantity and patent quality at the inventor level.

[13] In other terms there is no choice between quantity and quality: quantity _ quality.

[14] Mariani and Romanelli (2007) claim the relationship between quantity and quality is not direct but indirect: when an inventor produces a lot of invention the probability a technological hit is increased.

[15] Age, academic degree and involvement in large research team.

[16] Levine (1985) adds they are recognized as sources of information, top performers, valuable to the organization in meeting its technical objectives.

role in the design, development and integration of pieces of knowledge within a department of research. In the invention team there are people with different technological and scientific specializations. Prolific inventor and his/her Engineering knowledge are basically important. He/she increases the rate at which individuals and organizations learn and consequently achieve sustainable competitive advantages. The prolific inventors are innovation "champions". Prolific inventors through their professional mobility might be viewed as "knowledge translators" or "knowledge broker"[17] between different firms, organizations and communities as well. They help to transfer some pieces of knowledge through the different communities they overlap at one or different points of time.

At this stage, it is relevant to put in relation prolific inventors and "stars scientists" model exemplified by Zucker and Darby (2002). A "stars scientist" is an individual with higher-quality intellectual capital (measured in terms of number of citations), a "prolific inventor" is an individual with high intellectual capital (measured in terms of number of patents with likely higher values) at the beginning of their career or through their industrial evolution. A "star scientists" makes major discoveries (Zucker and Darby, 1996, 2001). That should be confirmed/infirmed for prolific inventor. 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, 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 scientists are important in the process of technology transfer because of the value of their knowledge to the success of firms[18]. It is clear that Stars scientists and prolific inventors are two close categories of highly productive knowledge workers, the first in Science, the second in Technology. It may be some Stars scientists patent as well. As a result they could be prolific inventors too. The stars scientists are "entrepreneurial individuals". It may be prolific inventors are entrepreneurial university researcher (first defined by Etzkowit, 2003) Entrepreneurial researcher is an entrepreneur active towards technology transfer and partnership with industry. There are reasons to think that there are more numerous in the USA.

Conclusion: some temporary remarks.

a. From the literature a double relationship between prolificness and mobility must be considered:

[17] See Brown and Duguit (1999) who define these two terms.

[18] Zucker and Darby emphasize the importance of the tacit character of the new discoveries. Knowledge being embodied in individuals this implies "bench-level" collaboration which is measured by co-authoring.

1) The relationship prolificness → mobility. A correlation between value of patents and high rate of inventor mobility is envisaged by Almeida and Kogut (1999). They observe a high rate of inter-firm mobility of skilled engineers who hold major semiconductor patents. This evidence is in favor of the idea that prolific inventors are more mobile than the others. By contrast, Hoisl (2007) show that high productive German inventors are less inclined to move. This result is consistent with the Schankerman et al. (2006) findings when they note that inventors in software who are very productive, have a decreasing probability to move assignees as their career progress (conversely: less productive inventors have larger probability to move in later periods of their career).

2) The relationship between mobility → prolificness. Hoisl (2007) show multiple moves German inventors produced patents with more value (measured by the economic value gathered through a survey). By contrast, Schankerman et al. (2006) found that the variable "cumulative moves of inventors" has no effect on the patent value measured by forward citations. In fact the authors estimate two different equations for explaining the number of citations received (a proxy for patent quality). The first indicates on a robust effect of moves between assignees on patent citations**.** The second contains a new variable "mean citation for the prior patents of the inventor" that plays the role of individual inventor's fixed effects. On the one hand this variable has an important significant effect, on the other there is no longer impact of moves on patent citations after controlling for this individual effect[19]. Our opinion is that this variable gives at each period of time a measure of the inventor intellectual capital. For this reason we can suspect in fact a correlation between the variable moves and this variable since moves participate to the inventor intellectual capital formation.

In the relationship mobility/value of patent it may be there are Country effects since the institutions governing the worker mobility differ across countries. For instance Trajtenberg (2004) has shown the Japanese inventors are less mobile than the American one. This result is of course linked to the employment rules of the large industrial Japanese firms.

The work of Allison and Steward (1974) on productivity differences among scientists enable us to understand why the differences in inventor performance (in terms of invention) persist if not increase. In the world of Science because of feedbacks in terms of resources or recognition the highly productive scientists maintain or increase their productivity. In the world of research on Technology a not too different mechanism seems to work: a good

[19] Interestingly Schankerman et al. (2006) note mobility "breeds" mobility: (software) inventors who have already moved in the past are more inclined to move again.

inventor will receive more resources and as a consequence will be implicated in more projects. There is the possibility that he leaves an organization for being hire by another organization. A virtuous circle (a self-reinforcing process) is at work. In the very beginning of our empirical study we observed two kinds of prolific inventors: the fast prolific inventors and the persistent prolific inventors. The first kind of inventors patent a lot on a short time period, while with the second type an inventor becomes prolific after a longer time period (of learning?). It might be the threshold of 15 patents and industry characteristics play a role in this story.

b. From the different studies it seems that the importance of countries characteristics emerges and may be more important than the sector (or technology) differences for explaining the inventor mobility:

- For Japan the style of employment management in the large firms is characterized by the persistent presence of the workers within the same firm
- For Germany the existence of German employees'inventions act creates a singular situation
- For USA the surge of starts-ups and the very large transfer of individuals from University to industry could affect the relationship between mobility and inventive productivity. In this country some evidence shows that the share of prolific inventors of large firms fell from 72 % to 69 % and the one of small firms rose from 12 % to 16 % from the mid 90's and earlier in the next decade (CHI Research Inc., 2004). The same study points out 1) that small firms were particularly attractive destinations for "elite" inventors[20] working for public sector organizations and 2) that elite inventors tend to move into the same category of firms (large versus small).

One basic hypothesis of the research is that knowledge (labour) markets is more important than Knowledge (non-market) spillovers. In this context it seems important to measure the extent to which the prolificness and the mobility of prolific inventor could explain firm R&D performance[21].

[20] Elite inventors have at least 10 patents in the time period (1993-95 and 2000-02) and at least one paten in each period.

[21] Work soon undertaken by Redor (2004).

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