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REGIONAL DISTRIBUTION, MOBILITY AND PRODUCTIVITY OF FRENCH PROLIFIC INVENTORS[1]

Abstract. In this paper we present empirical evidence about some geographical characteristics of French prolific inventors through an analysis of French patents deposits at the USPTO over a long time period (1975-2002). We found out that they are highly concentrated in the French space around three regional poles (Ile de France, Rhône-Alpes and PACA) and that inter-firms and geographic (regional) mobility is weak. Our estimates show that more mobile inventors (inter-firms) are more productive after controlling for effects of geomobility (with other control variables). By contrast, the more geomobile inventors are less productive after controlling for inter-firms' mobility effects. It means that the geographic dimension of mobility does not bring more effectiveness in the individual process of creativity. We must bear in mind there is a bias of simultaneity within the relationship productivity/mobility that is not dealt with here.

1. INTRODUCTION: BASIC ISSUES AND AIMS OF THE RESEARCH

The topic of inventor mobility has received a great attention in the recent literature dealing with the invention process and inventors behaviours. Mobility is a mean for transferring knowledge from firm to firm, region to region, place to place. As a consequence, mobility should have a positive impact on firms, regions, and nations' innovative performances. But mobility can be seen otherwise: it might increase inventor experience. As a consequence, it raises his/her knowledge base and matches a specific learning. To put it simply, inventor mobility is a mean for increasing inventor's performance (Hoisl, [2007]; Schankerman et *al.,* [2006]; Tratjenberg, [2004]). It is this last aspect that is at the core of this paper.

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The other hypotheses of research are the following: some individuals (researchers, scientists) and more generally highly productive inventors have an important role in the general process of knowledge accumulation, innovations and growth (at the firm or the region level). In fact, a set of converging empirical evidence show a crucial link between prolific inventor and innovative performance (broadly defined). For instance one characteristic of the inventor, *his own past number of patents,* is the main determinant of the private economic value of invention (Gambardella *et al.*, [2005]).

Prolific inventors tend to produce inventions receiving more value (Gay *et al*., [2008]). Firms having prolific inventors get a technological leadership (Pilkington *et al*., [2009]). At last a strong relationship exists between countries' technological specialization (measured by Revealed Technological Advantages Index) and the importance of prolific inventors (Le Bas *et al.,* [2010]).

The research is a part of a larger study that aims to map the geographical distribution (regional) of French prolific inventors, to scale their geographical mobility (between regions) - in short geomobility - and to explain its determinants, to test the hypothesis that the geomobility of prolific inventor has a positive impact on the inventor productivity and the value of inventions.

The paper is organised as follows: firstly we present our data set. Then the regional distribution of prolific inventors French and their geomobility will be delineated. Lastly the empirical relationship productivity/mobility will be studied.

2. DATA SET: US PATENTS FOR FRENCH PROLIFIC INVENTORS AND FIRST EMPIRICAL TRENDS

For the need of the study we use a data set built by a team from University of Lyon 2 (France) onto prolific inventors and their patents[2]. The raw materials were the patents applied in the US system of patenting over the period 1975-2002 for five countries among the most important in terms of technological activity (Le Bas et al., [2010]). We select here only the data related to French inventors.

As done in our previous study we take for threshold of "prolificness" 15 patents and more in the period under observation (1975-2002). 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

[2] The papers currently available giving the main findings are: Gay *et al*. [2008], Le Bas *et al*. [2010], Latham et al. [2010].

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 that a prolific inventor would be an individual having at least a level of productivity (in terms of patents) five times above the average, thus the choice of 15 patents[3]. We found that the French population of prolific inventors is 1157. It matches 1.75 % of the overall amount of French inventors but 34.62% of the overall amount of patents. The gap between the two numbers highlights perfectly what "prolificness" means. On average, the number of patents is 26.34 (versus only 2.38 for the overall population of inventors) with a standard deviation of 17.8.

With respect to inventor's mobility the data offers rich insights[4]. There are 21 French regions that become more and more important in terms of economic public policy. For this reason we wished to assess the weight of each region in terms of "prolificness".

Until today, there have been only few studies that dealt with the geographical location of highly productive inventors while with the development of Geography of innovation the location of inventors have taken more and more importance.

Thanks to the fact that patent documents give the personal address of inventors, we could build up a rich mapping of their location. As a consequence, we have data in order to follow the evolution of their location, that is to say their geographical mobility. Consequently, two types of mobility are taken into account in this paper, the professional or inter-firm mobility[5] and the regional mobility. As exemplified by table 1, the two types may interact.

Tab. 1. The interactions between different types of mobility

Geo Mob. / Inter Firm Mob.	Yes	No
Yes	Twofold Mobility	Mobility Inter-Firms Intra Regional
No	Mobility Interregional Intra Firm	No Mobility At All

Source : developed by authors.

[3] Pilkington A. et al., [2009] define the key inventors "*as having a higher than twice the average productivity (number of patents granted)...".*

[4] We give in Le Bas et al. [2010] the main assumptions and rules we use for scaling inventor mobility.

[5] The lecture we will look at the paper by Le Bas et al. [2010] for knowing how inter-firm mobility has been broken down.

3. THE REGIONAL DISTRIBUTION OF FRENCH PROLIFIC INVENTORS AND THEIR GEOMOBILITY

Table 2 gives the distribution of our French prolific inventors according to their regions. Due to the fact the inventors move from one region to another, we have adopted the following rule for building the distribution: the inventors are related to the region in which they have applied for their first patent and their last one. The two distributions are very close. The R^2 = 99 %, and the Herfindhal index equally calculated are nearly similar.

Tab. 2. The distribution of French prolific inventors by French regions

REGIONS	Distribution Frequency for the first patent application (%)	Distribution Frequency for the last patent application (%)
Alsace	2,2	2,6
Aquitaine	1,0	1,8
Auvergne	0,5	0,9
Basse Normandie	1,4	0,6
Bourgogne	1,4	1,0
Bretagne	1,1	0,9
Centre	2,8	2,2
Champagne	0,8	0,7
Franche	0,8	1,1
Haute Normandie	2,6	2,9
Ile de France	49,4	50,7
Languedoc	2,4	2,9
Limousin	0,3	0
Lorraine	1,0	0,8
Midi	2,0	1,6
Nord Pas de Calais	2,0	1,1
Pays de la Loire	0,9	0,9
Picardie	2,2	1,8
Poitou	0,3	0,3
PACA	4,4	5,4
Rhône-Alpes	19,0	18,8
Others cases (inventors living in foreign countries)	1,6	0,69
Herfindahl Index	2,871	3,002

Source : developed by authors.

Nevertheless the distribution is very uneven. The first places of the ranking are the following (we did the average for the two numbers available):

1) Paris region (Ile de France) concentrates 50 % of the French prolific inventors (versus 20 % in terms of overall population),
2) Region Rhône-Alpes 19 % (versus 10% % in terms of overall population),
3) PACA, far behind around 5 % (versus 8% % in terms of overall population).

Therefore we observe a strong concentration around Paris, larger than the concentration of the French population. This distribution is strongly correlated to the regional distribution of French inventions (R^2 de 99 %) and to the regional distribution of R-D expenditures (R^2 = 98.4 % for 1992 and 97.8 % for 2003. Moreover Herfindahl indexes show that the regional distribution of prolific inventors is more concentrated than the regional distribution of French inventions and the 2003 R-D expenditures.

We found that hyperprolific inventors (30 patents and more) are more concentrated, as far as geography is concerned, than prolific inventors (15 patents and more), in particular around Paris.

We give here the more important stylized facts[6]. Inter-firms mobility is weak: 20 % stay in the same firm over their entire career. The mean of prolific inventor's inter-firm mobility is equal to 0.15.

98 % French prolific inventors have no international mobility. With respect to that phenomenon the French situation is not significantly different from other countries (Germany, Japan, USA). In order to assess Geomobility we have calculated the inventor moves. The main statistical indicators of interregional mobility (international moves excluded) are Mean = 0.28, Standard deviation = 0.45. 73.04 % are non-mobile.

For the mobile inventors from the Rhône-Alpes region we map the sequence of their regional mobility. For 2 prolific inventors on 3 their first move goes towards Paris region (Ile de France). But for them their second mobility is a move back to Rhône-Alpes. Then the further moves (when they exist) have the same shape. These results enable us to note that the model of geomobility differs greatly from a "Tour de France", but takes the form of a sequence of moves outside Rhône-Alpes and moves back.

[6] We have dealt with inventor mobility related to other countries in another paper (see: Le Bas *et al*., [2010]).

4. THE RELATIONSHIP PRODUCTIVITY/MOBILITY: MODELS, VARIABLES AND ESTIMATIONS

We want to measure the effect of inventor mobility on their productivity and the value of their inventions. The variables and models that we have chosen are in line with our previous studies (Le Bas et al. [2010]; Latham et al., [2011]). We must first underline the limitations of our data.

For example, while we are well aware that there are both theories and empirical studies of productivity that highlight the roles of inventors' education and training, the capital available to them, the nature of the reward system and the role of institutional constraints such as retirement ages and the nature of the patent system, but we do not have such variables available in our data set. Similarly for both mobility and the value of patents, many other variables have been suggested in the theoretical framework and in other empirical studies. Consequently our work must be considered as a first attempt to propose an empirical frame for determinants of productivity, mobility or value. Instead ours is a partial approach. We examine the ways in which productivity; types of mobility and value influence each other.

Table 3 gives us the variables definition. The main dependent variables are inventor productivity and average value of their patent. This last has been calculated with the data from the NBER data set (Hall, Jaffe, Trajtenberg, [2001]). Two specifications are set out: Number of citations received for the overall amount of patents/total number of patent, and the Number of citations received for the overall amount of patents/patenting duration. The first takes into account the volume of the technological production of the inventor, the second records the patenting duration of each inventor.

We use some control variables found in the literature: the technological diversity (or technological diversification) of inventors that plays a certain role on the value of invention (TECH_HHI), the temporal (or time) concentration of patent for an individual inventor (CAREER_HHI), variable suggested first by Hoisl [2007].

The variable "technological diversification" has been calculated for each prolific inventor with the number of different technological categories (CATEGORY_i) in which he invents (we use here the 6 principal technological categories). This proxy can be considered as a measure of 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. 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. We control for the likely effects of technological fields in which the inventor carry out his/her activity. This variable encompasses two factors: the technological opportunities (that play a great role in the ease for producing new technological knowledge) and the different ways with which the patent system works (in some fields many patens are necessary for protecting effectively one single invention[7]).

The patent duration would be likely to be the most interesting control variable. 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 to 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. But by contrast with our previous papers we have decided to integrate patent duration in the construction of our dependent variable. Our variable for inventor productivity is defined as the "number of patents per year of activity" (or patent duration).

We integrate the duration of inventor activity as well in the second variable for value of invention. At last we put in each equation to be estimated as an explanatory variable the dependent variable of the other (the variable productivity in the value equation and conversely). In doing so, we hope to control the set of likely effects not taken into account by other explanatory variables.

The two basic independent variables are the infirm mobility and geomobility. 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. We expect that geomobility would have the same impact of the inventor personal capacity to invent and also should have a positive impact on inventive productivity and the value of inventions. All the variables are defined at the inventor level.

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

Tab. 3. Variables definitions

VARIABLE	DEFINITION
Inventor productivity	Number of patents per year = overall number of patent/patent duration
Value/patent	Number of citations received for the overall amount of patents/total number of patent
Value/year	Number of citations received for the overall amount of patents/patenting duration
INTER-FIRM MOBILITY	Number of times the inventor changed assignees in the sequence of his patentsing
TECH_HHI (technological diversity)	Herfindal-Hirschman Index (=sum of squared shares) for the six technical category dystribution
CAREER_HHI	Herfindal-Hirschman Index. Measure of the temporal concentration of the inventive activity into the inventive career
CATEGORY_1	Chemicals
CATEGORY_2	IC Technologies
CATEGORY_3	Pharmaceuticals
CATEGORY_4	Electrical and Electronic
CATEGORY_5	Mechanical
CATEGORY_6	Others
GEO MOBILITY : Move_Region	Number of moves between regions

Source: developed by authors.

We use a linear model and estimate the coefficient with ordinary least squares method. The results are shown in Table 4. The three estimations give heteroscedastic consistent results. The R^2 indicate that our variables explain a high part of the explanative variable variance. From this point of view the better estimation concerns the productivity equation.

With respect to productivity equation the impact of inter-firm mobility is positive and significant, confirming the work by Hoisl [2007] on Germany, 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). Technological variety (a proxy for inventor competences) influences positively inventor productivity.

The coefficient related to temporal concentration is positive. This result differs from the analysis by Hoisl [2007]. She chooses as an index for temporal concentration the ratio between the maximum of patents in one single year and the total numbers of patents of the same inventor. She pointed 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". It seems that there is here a mismatch due to the fact we have not the same indicator for measuring the inventor time concentration.

Tab. 4. Regression results for the productivity (value)/mobility equations

	PRODUCTIVITY		**VALUE/Patent**		**VALUE/year**	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
PRODUCTIVITY			-1.041	0	-0.342	0
VALUE/Patent	-0.115	0				
INTER-FIRM-MOBIL	0.819	0	-0.461	0.06	-0.475	0.16
TECH_HHI	0.472	0.01	-1.382	0.04	-1.763	0
CAREER_HHI	2.804	0	-2.495	0	-5.315	0
GEO. MOBILITY	-0.314	0	-0.334	0.11	-0.642	0.01
CONSTANT	1.137	0	8.071	0	9.301	0
R-SQUARED	0.281		0.220		0.137	

Source: developed by authors. Method of estimation: OLS, estimates with dummies for macro technological fields, number of observations: 1157.

Interestingly the equations concerning the value of patents do not give the same results. The impact of the two types of mobility is negative when it is statistically significant. It must be noted there are few studies that deal with the relations between the value of invention and inventor mobility. The study carried out on software inventors by Schankerman et *al.* [2006] remarks: "… *surprisinly, we did not find support in the data that mobility is a matching process between the inventor and his employer, and that the quality of the inventor's patents increases after a move*". In a sense our findings are in lines with their conclusion.

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? [8]. We ran only *descriptive regressions*. This study does not deal with the troncature problem as well. 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). As a consequence the core of a future research agenda will be to envisage the endogeneity and troncature issues.

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

5. CONCLUSION: MAIN EMPIRICAL FINDINGS AND RESEARCH AGENDA

In this paper we present empirical evidence that shows that French prolific inventors are highly concentrated in the French space around three regional poles (Ile de France, Rhône-Alpes and PACA). But inside this "club", Ile de France (Paris region) concentrates a lot of highly talented creative people. In general their inter-firm and geographic (regional) mobility is weak. We wanted to produce new pieces of knowledge on the complex relationship between inventor mobility and productivity (and invention value). In this paper we develop the lines that consider inventor mobility from at the inventor level of experience and competence.

We have hypothesized that mobility is a kind of learning increasing the inventor creativeness. The literature provides many evidence about inter-firm mobility, but only a few on geographical mobility.

Our study shows that more mobile inventors (inter-firms) are more productive after controlling the effects of geomobility (with others control variables). By contrast, more geomobile inventors are less productive after controlling the effects of inter-firms mobility. It means that the geographic dimension does not bring more effectiveness in the individual process of creativity. We must bear in mind there is a bias of simultaneity within the relationship productivity/mobility (as noted by many scholars) and likely a correlation between inter-firms mobility and geomobility. The latter statement defines new research directions in order to improve our understanding of the relationship productivity/mobility at the individual (inventor) level.

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