

Patents and the Geographic Localization of R&D Spillovers in French Manufacturing

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PIERGIOVANNI R. and SANTARELLI E. (2001) Patents and the geographic localization of R&D spillovers in French manufacturing, *Reg. Studies* **35**, 697–702. This paper follows a ‘geography of innovation’ approach to test for France the hypothesis that patent activity within each administrative region is related to corporate expenditures on R&D in that territory, as well as research expenditures undertaken in universities located in the same area. It emerges that French manufacturing firms (both private and state-owned) benefit significantly from knowledge produced within the geographical area in which they are located, although the coefficient estimated for the university R&D variable is equally significant but higher than that for industry R&D. At the regional level, university research proves to be the most crucial external source of knowledge for the innovative activities of manufacturing firms.

Patents R&D spillovers French manufacturing Geography of innovation

PIERGIOVANNI R. et SANTARELLI E. (2001) Les brevets et la localisation géographique des retombées de la R et D pour l’industrie en France, *Reg. Studies* **35**, 697–702. Cet article cherche à employer la façon dite *la géographie de l’innovation* afin de mettre à l’épreuve pour la France l’hypothèse suivante: le nombre de brevets obtenus au sein de chaque circonscription d’action régionale est en corrélation étroite non seulement avec les dépenses de R et D des entreprises implantées dans cette zone, mais aussi avec les dépenses de recherche des universités situées dans la même zone. Il s’avère que les entreprises industrielles françaises (soit privées, soit publiques) profitent de façon non-négligeable des connaissances acquises à l’intérieur de la zone géographique où elles se situent, bien que le coefficient de la variable qui embrasse la R et D universitaire soit aussi important du point de vue statistique mais supérieur à celui qui se rapporte à la R et D industrielle. Sur le plan régional, la recherche universitaire s’avère la source des connaissances externes la plus importante pour ce qui est des activités innovatrices des entreprises industrielles.

Brevets Retombées de la R et D
Industrie française Géographie de l’innovation

PIERGIOVANNI R. und SANTARELLI E. (2001) Patente und lokal-geographisch bestimmtes überfließen von Forschung und Entwicklung in die herstellenden Industrien Frankreichs, *Reg. Studies* **35**, 697–702. Dieser Aufsatz benutzt einen ‘innovationsgeographischen’ Ansatz, um die Hypothese für Frankreich zu prüfen, daß in jeder Verwaltungsregion Patentanmeldungen sowohl mit Firmenaufwendungen für F & E in ihrem Gebiet zusammenhängen, als auch mit Mitteln für Forschung in Universitäten mit Standort in demselben Gebiet. Es erweist sich, daß französische (private wie in staatlichem Besitz befindliche) Herstellerfirmen beträchtlich von Kenntnissen profitieren, die in dem geographischen Gebiet ihres Standorts gewonnen werden, obwohl der für die Universitätsforschung und –Entwicklungsvariable geschätzte Ko-effizient zwar gleich bedeutend, jedoch höher als derjenige der von Firmen betriebenen Forschung und Entwicklung ist. Auf Regionalebene erweist Universitätsforschung sich als die bei weitem wichtigste externe Quelle von Kenntnissen für innovative Unternehmungen herstellender Firmen.

Patente Überfließen von Forschung und Entwicklung
Französische herstellende Industrie
Innovationsgeographie

INTRODUCTION

The *geography of innovation* approach (JAFÉ, 1989; KRUGMAN, 1991; JAFÉ *et al.*, 1993; FELDMAN, 1994, 1999; HENDERSON *et al.*, 1996, 1998; ANSELIN *et al.*, 2000) has pointed out the importance of the

spatial dimension in analysis of the innovative process. In fact, thick labour markets, an appropriate network of suppliers, externalities, contracting and subcontracting with other firms, reverse engineering, spillovers and knowledge originating from outside the industrial system are largely instrumental in determining the path

and intensity of innovation activities carried out by industrial firms within a given portion of territory. As far as the knowledge originating from outside the industrial system is concerned, it is to a large extent the result of R&D undertaken within universities. The channels through which the industrial system benefits from university R&D are mostly the hiring of graduate personnel and/or former researchers, co-operation agreements in R&D, conferences, participation in permanent education programmes, etc.

Following JAFFE, 1989, the present paper tests for France the hypothesis that patent activity within each administrative region is related to corporate expenditures on R&D in that territory, as well as research expenditures undertaken in universities located in the same area. The next section presents the 'geographical' approach to the knowledge production function, while the third section contains a description of the data set and the results from estimation of a modified version of Jaffe's spatial model. A final section makes some concluding remarks.

THE GEOGRAPHICAL APPROACH TO THE KNOWLEDGE PRODUCTION FUNCTION

According to GRILICHES's, 1979, 1984, model of the knowledge production function (see also GRILICHES and MAIRESSE, 1984; ADAMS and JAFFE, 1996), the crucial *innovative input* is new technological knowledge generated by R&D, and the relevant *innovative output* is technological knowledge resulting in patented innovations. From this input-output perspective, one would expect to observe a positive and significant relation between the stock of R&D and the number of patents for any unit of analysis, whether this is a firm, an industry or a given portion of territory. However, empirical tests of this knowledge production function approach yield contradictory results, and also firms and industries not significantly involved in formal R&D activities have been shown to make a significant contribution to total innovative output (see, for example, KLEINKNECHT, 1987; SANTARELLI and STERLACCHINI, 1990). Thus, the prediction that innovative activity favours those (either firms or industries) with direct access to knowledge producing inputs does not necessarily apply to all cases. In this connection, innovation studies benefit if they take consideration of a unit of observation which also comprises the spatial dimension of the system of innovation in which each firm and industry belongs. This implies integrating the knowledge production function approach with an 'externalities approach' (see ANTONELLI, 1994), within which the unit of analysis becomes broader than the individual firm, and which also comprises the overall innovation environment – or 'milieu innovateur', as defined by Philippe Aydalot¹ (see AYDALOT

and KEEBLE, 1988; GREFFE, 1999) – of which each firm is part.

The resulting geographical approach to knowledge production was originally developed by JAFFE, 1989, who tested the hypothesis that patent activity within a given portion of territory is related not only to the private corporate expenditures on R&D in that territory, but also to research expenditures undertaken by universities in the same area. In effect, since universities do not have a strong incentive to keep research secret, the new knowledge that they help to create is likely to affect the innovative activities carried out at the firm level. Thus, geographical proximity produces results of particular importance when the transport mechanism of these spillovers is either informal conversations between university researchers and firm insiders, or the hiring of university graduates, who embody the new knowledge generated via university research, by the firm. Jaffe also assumes that the proximity of universities to corporate R&D laboratories increases the potential for spillovers from the universities. In order to correctly identify this effect, JAFFE, 1989, constructs an 'index of geographic coincidence' of industry R&D and university research for each state of the US, the underlying hypothesis being that university research yields more spillovers in states in which both university research and industry laboratories are concentrated in metropolitan areas.

The resulting spatial model of the knowledge production function is:

$$\ln PAT_s = \beta_1 \ln IR \& D_s + \beta_2 \ln UR \& D_s + \beta_3 \ln C_s + POP_s + \varepsilon_s \quad (1)$$

where: $\ln PAT_s$ is the natural logarithm of the number of patents granted to private manufacturing firms in the state; $\ln IR \& D_s$ stands for the natural logarithm of R&D expenditures by private manufacturing firms in each state; $\ln UR \& D_s$ represents the natural logarithm of R&D expenditures by universities in each state; $\ln C_s$ is the geographical coincidence index;² POP_s is the total resident population in each state, and is inserted in the model to control for the different sizes of the various states; and ε is a stochastic error. Estimating the model for 29 US states over the period 1972–77 and for years 1979 and 1981, Jaffe shows that corporate patenting is significantly affected by spillovers from both private corporate expenditures on R&D and research expenditures by universities within the state, although the former (elasticity > 0.7) have a stronger impact than the latter (elasticity < 0.1). The geographical coincidence index is instead only marginally statistically significant.

A TEST OF THE KNOWLEDGE PRODUCTION FUNCTION APPROACH FOR FRENCH REGIONS

Description of the data

In order to focus directly on the spatial dimension of the

phenomenon, for 21 out of 22 French administrative regions (with the exception of Corsica) we used R&D expenditures undertaken by manufacturing firms (both private and state-owned) and universities, and the total number of domestic patents granted to both private and state-owned firms.³ R&D expenditures are measured in term of the salaries paid to full-time equivalent research employees (i.e. in proportion to the part of the working time which they spent on R&D activity) for both the universities and the firms.

The data are taken from EUROSTAT, 1994, which used various sources to collect regional R&D statistics allowing comparison of the intensity of R&D in the regions of the European Union, and from INSEE (National Statistical Office of France), 1994. In spite of careful refinement and reclassification by statistical offices and scholars of technology, these traditional indicators are unable to handle all the problems raised by the implicit contrast between technological complexity and the economic value of innovations (R&D measures) and by the distinction between *inventions* and *innovations* (patent-based indicators). However, as aptly shown by GRILICHES, 1990, a common finding in empirical studies is the existence of a strong relationship between patent numbers and R&D expenditures, at least in the cross-sectional dimension. Thus, in the absence of more detailed regional level data on the specific features of innovative activities carried out by French firms, R&D expenditures and the number of patents can be taken as reliable indicators of inventive input and output. Inspection of Table 1 shows a clear predominance of industrial firms over universities in terms of total R&D expenditures, although in two regions (Alsace and Languedoc-Roussillon) the number of research personnel in universities exceeded the number in industry. In this respect, one should bear in mind a peculiarity of the national system of innovation in France, which is characterized by a contribution to total R&D activities by industrial firms far below the average of the most industrialized countries (see HALL and MAIRESSE, 1996).

A recent paper by MULKAY *et al.*, 2000, points out that cash flow and profits do not exert any significant impact on R&D investments by French firms, which appear instead to be more sensitive to the possibility of exploiting technology transfer from the public sector (see SMITH, 1997). In the resulting innovation environment, private and state-owned firms are more specialized in the 'D' portion of R&D, whereas public research centres and the universities prefer to perform basic research aimed at developing new knowledge potentially exploitable in industrial activities. The purpose of permitting the widespread diffusion of the results of basic research within the industrial system is effectively served by bridging institutions like ANVAR (Agence National de Valorisation de la Recherche) and co-operation agreements involving CNRS (Centre National de la Recherche Scientifique)

Table 1. Total R&D expenditures and R&D personnel in manufacturing (private and state-owned firms) and universities by administrative region, 1991

Region	R&D expenditures ¹		R&D personnel ²	
	Industry	University	Industry	University
Alsace	170	86	2,134	2,907
Aquitaine	548	43	5,679	2,610
Auvergne	245	11	3,573	1,025
Bourgogne	172	9	2,477	742
Bretagne	252	25	2,914	2,088
Centre	339	24	4,465	1,217
Champagne-Ardenne	65	1	1,028	628
Franche-Comté	320	5	2,905	707
Ile-de-France	7,839	821	79,446	24,469
Languedoc-Roussillon	123	66	1,712	2,959
Limousin	35	1	610	486
Lorraine	164	45	2,216	2,184
Midi-Pyrénées	770	66	7,101	3,417
Nord-Pas-de-Calais	202	20	2,880	2,319
Basse-Normandie	73	19	1,143	836
Haute-Normandie	335	4	3,780	759
Pays de la Loire	247	10	3,432	1,624
Picardie	235	2	2,937	613
Poitou-Charentes	94	14	1,236	1,032
Provence-Alpes-Côte d'Azur	854	126	8,814	5,075
Rhône-Alpes	1,297	156	1,5818	7,399
Total	14,379	1,554	156,300	65,096

Notes: 1. ECU000s in current prices. R&D expenditures are defined in terms of the salaries paid to full-time equivalent research employees as defined in note 2 below.
2. All personnel figures are in full-time equivalent, i.e. in proportion to the part of the working time which is actually spent on R&D activity.

Source: EUROSTAT, 1994.

and the universities, on the one hand, and industrial firms (in particular smaller ones) on the other. A special function has traditionally also been played by public research laboratories, such as those of CEA (the French Atomic Energy Commission) and ONERA (Office National d'Etudes et de Recherches Aérospatiales), whose most important scientific mission is to provide French firms with a source of basic knowledge fully exploitable in the development of commercial innovations (SMITH, 1997). Moreover, in France there has traditionally been a strong presence of students and university teachers in public laboratories which gives rise to a cross-fertilization between the two institutions that ultimately benefits the firms which hire university graduates.

More than 50% of total (industry plus university) R&D expenditures are concentrated in the Ile-de-France region, which nevertheless accounts for about 25% of total economic activity and 20% of resident population in the country as a whole. This region, however, ranks only third in terms of patent intensity (number of patents per R&D employee) among French regions (see Table 2). The highest patent intensity is achieved by the Limousin and Languedoc-Roussillon

Table 2. Domestic patents granted to private and state-owned manufacturing firms and patent intensity (no. of patents/R&D personnel) by administrative region, 1991–92

Region	Patents	Patents/R&D personnel
Alsace	740	0.347
Aquitaine	473	0.083
Auvergne	179	0.050
Bourgogne	149	0.060
Bretagne	404	0.139
Centre	382	0.086
Champagne-Ardenne	478	0.465
Franche-Comté	5	0.002
Ile-de-France	8,522	1.087
Languedoc-Roussillon	329	2.675
Limousin	363	10.35
Lorraine	268	0.121
Midi-Pyrénées	74	0.010
Nord-Pas-de-Calais	451	0.157
Basse-Normandie	535	0.468
Haute-Normandie	460	0.122
Pays de la Loire	328	0.096
Picardie	443	0.151
Poitou-Charentes	178	0.144
Provence-Alpes-Côte d'Azur	933	0.106
Rhône-Alpes	3,107	0.196
Total	20,700	0.132

Source: Elaborations on INSEE, 1994, and EUROSTAT, 1994.

regions where, owing to the structural features of local industries, research activities are likely to be more 'development' oriented. However, these regions, and Limousin in particular, are of scant importance in terms of total R&D expenditures and personnel. Accordingly, they do not represent a threat to the overwhelming technological supremacy of the Ile-de-France region. From a general viewpoint, one should also bear in mind the propensity, common to all the Member States in the European Union (EU), towards a relatively higher intensity of R&D in the region containing the capital city. As pointed out in EUROSTAT, 1994, this propensity is due to the fact that, since a relatively high number of company headquarters are based in the capital city regions, official estimates sometimes wrongly attribute R&D executed in other regions to the head office. Of course, this implies that R&D data covering other regions are likely to be underestimated.

Empirical results

We followed PIERGIOVANNI *et al.*, 1997, in estimating a simplified version of Jaffe's model – using the patent figures from INSEE, 1994, and the R&D data from EUROSTAT, 1994, mentioned above – the aim being to capture the impact of new knowledge generated through corporate and university research on the inventive output (number of patents) of manufacturing firms. The knowledge production function model for

all sectors in manufacturing, incorporating R&D spillovers within regions, will thus be:

$$\ln PAT_s = \beta_1 \ln IR \& D_s + \beta_2 \ln UR \& D_s + \beta_3 \ln C_s + \varepsilon \quad (2)$$

where: $\ln PAT_s$ is the natural logarithm of the number of patents granted to manufacturing firms in the region divided by the total number of employees in the same firms;⁴ $\ln IR \& D_s$ is the natural logarithm of R&D expenditures by manufacturing firms in each region divided by the total number of R&D personnel in the same firms; $\ln UR \& D_s$ is the natural logarithm of R&D expenditures by universities in each region divided by the total number of R&D personnel (full-time equivalent academic staff and researchers) in the same universities; and $\ln C_s$ is a very rough version of the geographical coincidence index used by JAFFE, 1986, computed for each region s , and is constructed as:

$$C_s = \frac{\sum [UNIV \star TP]}{[\sum UNIV^2]^{1/2} \star [\sum TP^2]^{1/2}}$$

where: $UNIV$ denotes research expenditures undertaken within universities; and TP denotes research expenditures in the manufacturing sector. The underlying hypothesis is that an average French franc of university research will yield more spillovers in those regions in which industry research expenditures are relatively higher, than in those in which there are almost no corporate laboratories. This is consistent with the findings of COHEN and LEVINTHAL, 1989, who showed that the ability to pick-up spillovers in the environment is connected to the complementarity of a firm's R&D activity with research undertaken by universities located in the neighbourhood. In effect, information flows from universities to industrial firms are favoured by the existence of communication channels between, and the employment of a similar language by, university and industry insiders.

In this log-linear regression model the slope coefficients β_1 , β_2 , and β_3 measure the elasticity of PAT_s with respect to $IR \& D_s$, $UR \& D_s$ and C_s , that is the percentage change in the dependent variable for a given percentage change in the independent ones. Since the measured variables used in estimation of the model are interrelated, the Variance Inflation Factor (VIF) statistic is used to test for multicollinearity, in order to drop redundant variables. However, low values of the VIF statistics, respectively 1.762 for industrial R&D, 1.811 for university R&D and 1.283 for the geographic coincidence index, confirm that the model escapes the multicollinearity problem, and all variables have therefore been maintained in the estimate. An F statistic exceeding the critical value (14.153) at the 99% significance level leads to rejection of the hypothesis that all of the slope coefficients are zero. Accordingly, the high value of the coefficient of determination adjusted for the degrees of freedom (0.702) can be considered a

Table 3. Regression results from estimation of the knowledge production function model

$\text{Ln}IR\&D_s$	8.061*
	(2.588)
$\text{Ln}UR\&D_s$	65.78*
	(2.552)
$\text{Ln}C_s$	0.11
	(1.514)
Adj. R^2	0.702
F	14.153
N	21

Notes: All the coefficients have been multiplied by 100.

t-statistics in brackets.

* = significant at 99% level of confidence.

reliable measure of the goodness-of-fit of the regression. The results of the estimate (Table 3) allow Jaffe's findings for the US to be extended to the French regions only in part. As in Jaffe's results, the input-output link between R&D expenditures and the number of patents is statistically significant, whereas the coefficient of the modified version of the geographical coincidence index, C_s , has the expected sign but is not significant. French manufacturing firms are therefore shown to benefit significantly from knowledge produced within the geographical area (administrative region) in which they are located. However, the coefficient estimated for the university R&D variable is equally significant but higher than that for the industry R&D variable. The resulting higher elasticity of patenting to R&D performed by universities proves that, at the regional level, university research is even more crucial than that carried out in corporate laboratories for the inventive output of both private and state-owned manufacturing firms.

This result is consistent with those obtained for the US by AUDRETSCH and FELDMAN, 1996, and FELDMAN, 1994, and for Italy by PIERGIOVANNI *et al.*, 1997, in determining the sources of spatial R&D spillovers in the case of small firms. It contradicts the common prediction that innovative activities favour only those with access to knowledge-producing inputs (namely, direct R&D expenditures). The high elasticity of the inventive output (number of patents) of industrial firms to university research implies that firms invest in R&D to improve their absorptive capacity and to enhance their ability to assimilate and exploit externally developed technological knowledge. Thus, interaction between firms and the institutional milieu sets in motion an overall process of *interactive* learning in which innovation emerges as a result of the integration of pieces of information and knowledge that are owned by different partners (see MORGAN, 1997; ANTONELLI, 2000).

CONCLUDING REMARKS

The findings in this paper show that, in the case of French regions, spillovers from university research are,

relatively, a more important source of innovation in private and state-owned industrial firms than industrial research itself. This result is to some extent consequent upon the features of the national system of innovation in France. In effect, the familiarity of French firms (in particular smaller ones) with programmes aimed at disseminating new technological knowledge from universities and public research centres is likely to result in a more effective exploitation of university research as a primary source of innovative inputs. The provision of financial assistance to co-operative R&D projects involving industrial firms and universities within the same regions could be a further step forward in the attempt to develop an even more effective and efficient innovation environment, one in which technological knowledge becomes true collective knowledge.

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NOTES

1. The late Philippe Aydalot founded in France the Groupe de Recherche Européen sur les Milieux Innovateurs (GREMI) in the middle of the 1980s. In so doing, he initiated an ambitious research programme aimed at finding a new paradigm for regional development.
2. This index is computed for each state as:

$$C_s = \frac{\sum_{ic} [UNIV_{ic} \star TP_{ic}]}{[\sum_{ic} UNIV_{ic}^2]^{1/2} \star [\sum_{ic} TP_{ic}^2]^{1/2}}$$

where: $UNIV_{ic}$ denotes research expenditures undertaken within universities by industry i and metropolitan area c ; TP_{ic} is the number of researchers in the manufacturing sector by industry i and metropolitan area c .

3. As in the study carried out by PIERGIOVANNI *et al.*, 1997, for Italy, we decided to focus on the innovative input and the innovative output of both private and state-owned firms, due to the large share of economic activity accounted for by state-owned firms in France. Previous studies carried out for the US have instead dealt only with private firms.
4. The rationale for this assumption is that a new patent may result from either direct or indirect R&D, i.e. formal R&D or other activities (informal R&D, engineering, marketing, etc.) which are likely to result in new, patentable findings.

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