Patents and the geographic localization of R&D spillovers in French manufacturing*

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Abstract

This paper adopts 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 the industry R&D one. At the regional level, university research therefore turns out to be the most crucial source of knowledge spillovers for the innovative activities of manufacturing firms.

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1. Introduction

The *geography of innovation* approach (Jaffe, 1986, 1989; Jaffe *et al.*, 1993; Krugman, 1991; Feldman, 1994; Henderson *et al.*, 1996, 1998) has pointed out the importance of the spatial dimension in analysis of the innovative process. In fact, innovation networks, 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 (1986), in the present paper we test for France the hypothesis that patent activity within each administrative region is related to the private corporate expenditures on R&D in that territory, as well as to the research expenditures undertaken in universities located in the same area. Section 2 presents the "geographical" approach to the knowledge production function, while section 3 contains description of the data set and the results from estimation of a modified version of Jaffe's spatial model. Finally, section 4 makes some concluding remarks.

2.The geographical approach to the knowledge production function

According to Griliches' (1979, 1984; cf. also Griliches and Mairesse, 1984; Adams and Jaffe, 1996) model of the knowledge production function, 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 approach yield contradictory results, and firms and industries not significantly involved in formal R&D activities have been shown to make a significant contribution to total innovative output (cf., 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 a unit of observation is considered which also comprises the spatial dimension of the system of innovation in which each firm and industry belongs.

The resulting geographical approach to the knowledge production function was originally developed by Jaffe (1986, 1989), who tested the hypothesis that not only is patent activity within a given portion of territory related to the private corporate expenditures on R&D in that territory, but it also depends on research expenditures undertaken by universities in the same area. 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 USA, the underlying hypothesis being that university research yields more spillovers in states in which both university research and industry labs are concentrated in metropolitan areas.

The resulting spatial model of the knowledge production function is

$$(1)\quad \ln PAT_{is} = \beta_1 \ln IR\&D_{is} + \beta_2 \ln UR\&D_{is} + \beta_3 \ln C_s + \beta_4 \ln POP_s + \varepsilon_{is}$$

where $\ln PAT_{is}$ is the natural logarithm of the number of patents granted to private manufacturing firms in the region; $\ln IR\&D_{is}$ stands for the natural logarithm of R&D expenditures by private manufacturing firms in each state; $\ln UR\&D_{is}$ represents the natural logarithm of R&D expenditures by universities in each state; $\ln C_s$ is the geographic coincidence index; $\ln POP_s$ is the natural logarithm of the total amount of resident population in each region, 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 geographic coincidence index is instead only marginally statistically significant.

3.A test of the knowledge production function approach for French regions

3.1. 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[1]. Inspection of Table 1 shows the clear predominance of industrial firms in terms of total R&D expenditures, whereas in two regions (Alsace and Languedoc- Roussillon) the number of research personnel in universities exceeds the number in the industry. In this respect, one should bear in mind a peculiarity of the national system of innovation in France, which is characterised by a contribution to total R&D activities by industrial firms far below the average of the most industrialised countries (cf. Hall and Mairesse, 1996).

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*		R&D personnel	
	Industry	University	Industry	University
Alsace	170	86	2134	2907
Aquitaine	548	43	5679	2610
Auvergne	245	11	3573	1025
Bourgogne	172	9	2477	742
Bretagne	252	25	2914	2088
Centre	339	24	4465	1217
Champagne – Ardenne	65	1	1028	628
Franche – Comte'	320	5	2905	707
Ile-de-France	7839	821	79446	24469
Languedoc – Roussillon	123	66	1712	2959
Limousin	35	1	610	486
Lorraine	164	45	2216	2184
Midi – Pyrenees	770	66	7101	3417
Nord-pas-de-Calais	202	20	2880	2319
Basse – Normandie	73	19	1143	836
Haute – Normandie	335	4	3780	759
Pays de la Loire	247	10	3432	1624
Pycardie	235	2	2937	613
Poitou – Charentes	94	14	1236	1032
Provence-Alpes-Cote d'Azur	854	126	8814	5075
Rhone - Alpes	1297	156	15818	7399
TOTAL	**14379**	**1554**	**156300**	**65096**

*= 000 ECUs in current prices
Source: EUROSTAT

As a consequence, private and state-owned firms are more specialised in the "D" portion of R&D, whereas public research centres and the universities preferably 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-

[1] 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

operation agreements involving Cnrs (Centre national de la recherche scientifique) and the universities, on the one hand, and industrial firms (in particular smaller ones) on the other[2].

More than 50 percent of total (industry + university) R&D expenditures are concentrated in the Ile-de-France region, which is however characterised by the lowest patenting intensity (number of patents per R&D employee) among French regions. This feature probably reflects the general tendency of larger firms and public institutions to locate the research facilities in which they undertake basic research in the surroundings of the largest metropolitan areas. Conversely, the highest patent intensity is found in the Limousin, Basse-Normandie, and Champagne-Ardenne regions, where research activities, due also to the structural features of local industries, are likely to be more "development" oriented.

Table 2
Patents granted to private and state-owned manufacturing firms and patent intensity by administrative region (1988-89)

Region	Patents	Patents/R&D personnel	Region	Patents	Patents/R&D personnel
Alsace	740	0.347	Lorraine	268	0.121
Aquitaine	473	0.083	Midi – Pyrenees	74	0.010
Auvergne	179	0.050	Nord-pas-de-Calais	451	0.157
Bourgogne	149	0.060	Basse – Normandie	535	0.468
Bretagne	404	0.139	Haute – Normandie	460	0.122
Centre	382	0.086	Pays de la Loire	328	0.096
Champagne – Ardenne	478	0.465	Pycardie	443	0.151
Franche – Comte'	5	0.002	Poitou – Charentes	178	0.144
Ile-de-France	329	0.004	Provence-Alpes-C. d'Azur	933	0.106
Languedoc – Roussillon	363	0.212	Rhone - Alpes	3107	0.196
Limousin	8522	13.97	**TOTAL**	**20700**	**0.132**

Source: INSEE, 1994

3.2. Empirical results

Due to the unavailability of patent figures broken down by industrial sector for the French regions, we followed Piergiovanni *et al.* (1997) in estimating a simplified version of Jaffe's model, the aim being to capture the impact of new knowledge generated through corporate and university research on the innovative output of manufacturing firms. The knowledge production function model for all sectors in manufacturing, incorporating R&D spillovers within regions, will thus be:

$$(2)\ \ln PAT_S = \beta_1 \ln IR\&D_S + \beta_2 \ln UR\&D_S + \beta_3 \ln C_S + \varepsilon$$

state-owned firms in France during the relevant period. Previous studies carried out for the U.S. have instead dealt only with private firms.

[2] And this in particular during the period considered for the empirical analysis carried in the present paper.

where $lnPAT_S$ 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[3]; $lnIR\&D_S$ 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; $lnUR\&D_S$ the natural logarithm of R&D expenditures by universities in each region divided by the total number of R&D (academic staff and researchers) personnel in the same universities; lnC_S the geographic coincidence index; and ε the stochastic error.

In this log-linear regression model the slope coefficients β_1, β_2, and β_3 measure the elasticity of P_s with respect to lnI_s, lnU_s, and $lnIGC_s$, 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, we used the Variance Inflation Factor (VIF) statistics to test for multicollinearity, and this 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 evades the multicollinearity problem and all variables have therefore been maintained in the estimate. An F statistics exceeding the critical value (14.153) at the 99 per cent significance level leads to rejection of the hypothesis that all the slope coefficients are zero. Accordingly, the high value of the coefficient of determination adjusted for the degrees of freedom (0.702) can be taken to be a reliable measure of the goodness of fit of the regression.

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

lnI_S	8.061*
	(2.588)
lnU_S	65.78*
	(2.552)
lnC_S	0.11
	(1.514)
Adj. R^2	0.702
F	14.153
N	21

All the coefficients have been multiplied by 100
t-statistics in brackets
* = significant at 99% level of confidence

The results of the estimate allow only partial extension of Jaffe's findings for the US to French regions. 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 geographic coincidence index

[3] The underlying hypothesis 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.

shows the expected sign but is not significant. French manufacturing firms are therefore shown to benefit significantly from knowledge produced within the geographical area 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: at the regional level, university research proves to be even more crucial than that carried out in corporate laboratories for the innovative output of both private and public manufacturing firms. This result is the reverse of that obtained by Jaffe and Henderson *et al.* (1996)[4], but it is consistent with those obtained by Acs *et al.* (1994) and Feldman (1994) for the US, and Piergiovanni *et al.* (1997) for Italy when dealing with the sources of spatial R&D spillovers in the case of small firms.

4. Concluding remarks

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

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[4] Who found that spillovers from university research (in the US) are less likely to be geographically localized than privately funded research.

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