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Creation of Biotech SMEs in France

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ABSTRACT. The paper examines the determinants of the creation of high tech SMEs at a regional level. Relations between the scientific and technical profile of a region, the size of the local market for biotech products and services, and economic development are explored in the French biotech industry during the 1990's. Empirical analysis shows that a high level of scientific activity within a region is necessary to sustain a continuous flow of new business creation. The likelihood of firm creation depends on scientific and technological organizational factors like cooperation between academic and private organizations. Regional policies can have positive impact on firm creation, especially by promoting diversity and excellence in science. However, contrasting with the U.S. results, the size of the local market for biotech products and services matters in the industry development.

KEY WORDS: biotechnology, creation, knowledge spillovers, SMEs

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1. Introduction

In the United States, the biotechnology sector has developed around poles of scientific excellence (Zucker et al., 1996; Audretsch and Stephan, 1996; Zucker et al., 1998). Powell et al. (2002) underline that half of the U.S. biotech firms are located in four geographic clusters. The movement of researchers from academic laboratories towards the private sector has provided a vehicle for the diffusion of knowledge and has been a powerful force behind the creation of start-ups (Zucker et al., 1998; Almeida and Kogut, 1999; Zucker et al., 2002). In France, national and regional public policies are combined to stimulate the economic development of *high tech* sectors. National public policies support basic research in academia and commercialization of science through subsidies to university/industry research programmes and through the creation of science based start-ups (Reiss et al., 2003). The regional level shapes local interactions and designs infrastructures and organizational features like incubators, science parks, regional funding for technology transfer, etc. to promote local economic development through the emergence of new firms in high tech sectors like biotechnologies and information technologies. Within a given national system of innovation, the regions thus compete to attract start-ups, with a view to generating increasing returns to adoption in their territory (Edquist, 1997). Since the early 1990s the number of biotech SMEs has grown rapidly and firm location seems to depend on multiple factors: scientific excellence, regional specialization in scientific sub fields, regional industrial specialization and public incentives.

The paper examines the determinants of the creation of biotech start-ups in France during the last decade (1993–1999) to understand the role of local environment in the commercialization of scientific results. Its aim is not to assess different instruments of public intervention. Rather, it explores relations between the characteristics of the region in terms of research and development capabilities, industrial bases and local market size related to biotechnology. Regional profile covers scientific and technical characteristics (investment of R&D, specialization in biotech and degree of specialization in specific subfields in biotech), the intensity of competition in the local life science industry (number and characteristics of life sciences firms in the region) and the size and growth of the local market for biotech products and services. The paper estimates simultaneously the role of knowledge externalities and markets dynamics contrary to analyses which explore the determinants of firms location either on the role of the scientific environment (for example Zucker and Darby 2001) or on the demand side (Feldman and Ronzio, 2001).

In order to understand the determinants of the local dynamics of firm creation, Section 2 considers the main elements in the theoretical literature on which we base our analysis of geographic determinants in the creation of biotech SMEs. It concludes with a number of testable hypotheses. Section 3 presents the data and methods used in our econometric estimations. It also provides a statistical image of the scientific, technological and industrial profiles of French regions in life sciences. The results of estimations are interpreted in Section 4, and conclusions are presented in Section 5.

2. Determinants of the creation of biotech start-ups

In order to grasp the logics underlying spatial trends in this highly innovative science-based sector, three groups of studies can be mobilized. The first includes work on the "geography of innovation" which seeks to explain the concentration of innovative activities by measuring the spatial dimension of knowledge externalities. Here the focus is on the advantages of being located near sources of knowledge. The second group illuminates the role of local environment in firms' capacities to absorb knowledge. Studies in this group aim to identify local organizational profiles best suited to the creation of economic value from the externalities produced. The third group identifies broader determinants of location of industrial activities borrowed from economic geography: increasing returns, pecuniary externalities and market structures.

2.1. *Proximity to sources of knowledge*

Empirical analyses of the mechanisms of spatial concentration of innovative activities often proves to be difficult at an econometric level (Autant-Bernard and Massard, 1999), and inferring questions of localization from indicators such as patents, the number of innovations or even relations between geographic areas and R&D expenditures can be risky (Anselin et al., 1997).[1] We can nevertheless identify a number of conclusions of such research:

- Innovation in a given region is closely related to public- and private-sector research expenditure in that region (Feldman, 1994a), on this is also true for sectors that are not research-intensive (Mangematin and Mandran, 2001);
- Innovation in a given region is not only related to public and private R&D expenditure but also to the region's entire technology transfer infrastructure (presence of technological centres, of technology transfer agencies, etc.) (Feldman, 1994b). Thus, the presence of complementary activities generates more spillovers and reduces costs and risks related to firms' innovation;
- There are no eviction effects between public and private R&D expenditure. They enhance each other to create areas of expertise (Jaffe et al., 1993).

These initial conclusions emphasize the role of research infrastructure on the firm creation. The regional research infrastructure includes public sector research (universities) as well as private firm research labs.

H1: Biotech SMEs are set up in centres of excellence, near to public academic research.
H2: Biotech SMEs are set up in the regional neighbourhood of major firms with substantial research potential.

2.2. *Local environment and absorptive capacity*

Although the question of absorptive capacities (Cohen and Levinthal, 1990) defined at the level of a geographic zone is still seldom addressed in the literature, Autant-Bernard (2001) provides some bases on which to found hypotheses. She highlights three mechanisms that influence the impact of the local environment:

2.2.1. *Proximity and effective local collaborations*

Proximity to sources of knowledge is not a favourable factor as such; it has to be associated with the establishment of real links between the institutions through which the knowledge can flow. The results of Zucker et al. (1998) and of Cockburn and Henderson (1998) suggest that firms benefit from public research only if they collaborate with a university researcher. Theses collaborations may or not be enhanced by geographic proximity. Audretsch and Feldman (1996a, b) and Audretsch and Stephan (1996) showed that, in sectors where innovation is based on science, local links are weaker. 70% of formal relations between biotech firms and universities are not based on geographic proximity. Mangematin and Nesta (1999) showed that the lower the absorptive capacity, the more local the effective relations between academia and industry.

2.2.2. *The stage of the development of firms*

Studies of relations between existing firms and universities are not, however, transposable to choice of location when firms set up. In this phase, relations between start-ups and firms in their "natural" network are fundamental and location is often in the entrepreneur's "natural" environment (Liebeskind et al., 1996; Steier and Greenwood, 2000). On an infra-regional scale, Acs and Preston (1997) highlight the effects of local spillovers owing to the presence of a large university and reputable research departments.

2.2.3. *The impact of the degree of specialization*

To capture externalities from the university/industry formal and informal relationships, it is necessary to develop common languages and codes. The existence of a degree of specialization is thus a condition for the diffusion of knowledge. Yet, if use of a common internal language is all that is emphasized, the firm could fail to capture external knowledge because it is too specialized. We have here the well-known debate on the comparative advantages of diversity or specialization (Feldman and Audretsch, 1999). Specialization is necessary to master a set of common knowledge, and is particularly advantageous in the start-up phase. By contrast, diversity enables a firm to be more sensitive to a wider range of information. Based on a study of large pharmaceutical firms during the 90s, Arora and Gambardella (1994a) show that in the short term, specialized competencies are correlated with a better innovative performance in the firm, whereas in the medium term, diversified competencies predominate in firms with the best performance. Firms therefore try to set up in areas with varied competencies. Feldman and Audretsch (1999) confirm this point by showing how the presence of diverse but complementary knowledge is capable of creating economically beneficial local externalities.

To explore the effects of these four elements, the following hypotheses have been formulated:

H3: Local interactions stimulate firm creation within the area.
H4: Regional scientific specialization stimulates firm creation.

2.3. *Local industrial environment and agglomeration dynamics*

It is generally considered that biotech is an activity with a "high potential for concentration" (Steinle and Schiele, 2002). Yet, even if the link with basic research and the role of "star scientists" is unquestionable in the early development phases of biotech firms (especially in the U.S.), the characteristics of their development in France and, above all, the recent shift to a new phase of maturation, may modify this initial model. Gittelman and Kogut (2003) argues that the French institutional context is different from the American one because it does not support individual appropriation of knowledge (and of knowledge revenues). Thus, individual mobility is lower in France than in the U.S., and consequently has less effect on technology transfer. And the agglomeration forces based on temporary or permanent individual mobility may be weaker (Catherine et al., 2004).

Apart from the characteristics of national systems of innovation (Busenitz et al., 2000), the mechanisms of technology transfer may change as the industry matures. Cooke (2002) shows that the links with basic research and perhaps even with the research capacities of large groups are losing weight as relations with customers and with users become more important. As industry matures (Afuah and Utterback, 1997), the nature and channels for knowledge flows between trading partners can be expected to change over time. In particular, knowledge flows previously exploited in terms of externalities can be translated to well-functioning markets (Niosi and Banik, 2002). Certain factors explaining the location of industrial activities, inspired by economic geography, can prove decisive. Based on the existence of increasing returns, the size of the local market is a key element of attraction and of dynamic self-reinforcement. In the biotech business this market is measured not so much in terms of size of regional population as in terms of presence of user industries, since biotech firms are primarily suppliers of other organizations involved in R&D and other firms in the life sciences. The main markets for biotech are firms, hospital and university labs involved in life sciences, i.e. agriculture, agro food, pharmacy, medicine veterinary and biotechnology (human, vegetal and animal health and the production of research tools and devices). Feldman (2001) suggests that service companies in biotechnology set up close to major production centres rather than to universities.

In addition to the size of the market, economic geography models most often emphasize the role of diversity, whether it concerns consumer preferences (Krugman, 1991) or available intermediate goods (Krugman and Venables, 1995). The combination of economic geography and endogenous growth (Martin and Ottaviano, 1999) emphasizes the importance of a region's specialization in the production of technological goods (Massard and Riou, 2001). Spillovers from related industries increase region's attractiveness for firm creation. Contributions focused on biotechnologies highlight the advantages of specialization during the set-up phase of SMEs. It is based on the advantages of regional specialization in terms of available skilled manpower or outlets for specialized products/services.

Finally, the work of Krugman (1991) also highlights the dispersing effects of competition. The presence of too many firms in an area strengthens competitive pressure, both in the search for consumers and in the job market. This pressure is a dispersing force because it can discourage firms from setting up in the area.

Based on these theories concerning determinants of industrial agglomeration, the following hypotheses can be put forward:

H5: The larger the local market, the greater the number of start-ups.
H6: Specialization of a region in a sector related to the life sciences (biomedical, agro-food, etc.) stimulates the creation of biotech SMEs.
H7: The intensity of competition in related industries reduces the likelihood of firm creation.

To sum up, analyses on clusters underline the relative importance of the different effects (knowledge externalities, absorptive capacity, industry maturation, market competition and dynamics). However, only a few empirical works analyse the results of the different effects acting concurrently. The paper adds to the empirical analysis of such concurrent effects by measuring the relative importance of the scientific and technological framework as well as the impact of the local market dynamics.

3. Data and method

The empirical tests that we propose are based on a regional SME creation model. It explains a region's capacity to stimulate the creation of biotech SMEs in relation to four types of regional characteristic:

- Characteristics of public-sector research
- Characteristics of private-sector research which give an overall picture of research in biotech firms
- Characteristics of the market, describing the region's profile in related industries
- Organizational characteristics, in the scientific area as well as market area.

The creation model is as follows:

$$\mathrm{NBCREA}_{rt} = \alpha + \beta_1 \mathrm{RPUB}_{rt} + \beta_2 \mathrm{RPRIV}_{rt} + \beta_3 \mathrm{MARCH}_{rt} + \beta_4 \mathrm{ORG}_{rt} + \varepsilon_{rt}$$

With:

NBCREA_{rt} = the number of new SMEs set up in region r during year t,

RPUB_{rt} = the matrix of variables characterizing the public-sector research potential in region r in year t,

RPRIV_{rt} = the matrix of variables characterizing the private-sector research potential in region r in year t,

MARCH_{rt} = the matrix of variables characterizing the market in related industries in region r in year t

ORG_{rt} = the matrix of variables characterizing the organization of research (openness, collaboration, specialization, etc.) in region r in year t,

ε_{rt} = a random term.

Five data bases are mobilized for this study. Table I presents the different variables used as well as the main sources of data.

Data on SMEs were drawn from the database created by INRA/SERD[2] from the 1999 survey by the French research and technology ministry (http://biotech.education.fr). 250 independent SMEs created between 1960 and 2002 are recorded in the data base. We extracted from this base the number of start-ups created every year in each French region (except Corsica) between 1993 and 1999. NBCREA variable represents 147 observations corresponding to the number of regions where start-ups occurred during the period.[3] The variables characterizing firms are described in Table I.

Patent data were drawn from the OST/OEB data base of patents aggregated by geographic area. The inventor's address was used for location (PATENTREG variable).

Public research is evaluated in two ways, the first of which is inputs. The only available reliable variable broken down into both region and year is the number of biotech PhDs, provided by a survey by the research ministry. This variable gives a good approximation of existing research capacities (PhD variable). The second indication is output, estimated in terms of publications signed by authors belonging to institutions in the region (PUB variable). This measurement represents the role of public research in the production and diffusion of new knowledge. Publication data are drawn from the Science Citation Index (SCI) and the Biotech Citation Index (BCI) and are analyzed in terms of institutions' addresses, since the final figures relate to participation in articles by institutions located in a particular region.

Data drawn from the research ministry's annual survey are used to describe the regions' private-sector research potential (national expenditure on R&D and employee numbers). The selection of biotechnologies was based on the biotech code which appeared in the 1999 and 2000 surveys.

Finally, data concerning the customer industries of biotech firms, primarily in sectors related to the life sciences (human, animal and plant health, environment, agriculture and agro-food) that we term related industries (RI) are drawn from the SESSI[4] CDRom, "SESSI-region", on which data are regionalized on the basis of the EAE[5], the annual survey on enterprises.

Table I also presents a set of organization variables calculated for each domain: scientific (publications), technological (patents and private R&D expenditure) and industrial (employee numbers in related industries). Internal concentration within a region is measured in terms of Herfindhal indexes on the basis of distribution between departments and regions[6]. Sectoral specialization is measured by the classic "revealed technological advantage" (RTA) indicator (Frost, 2001; Nesta, 2001). If P_{ir} is the activity of region r in domain i, for a given year, the region's revealed technological advantage in relation to other regions in domain i is defined by:

$$RTA_{ir} = \frac{P_{ir} / \sum_i P_{ir}}{\sum_r P_{ir} / \sum_{ir} P_{ir}}$$

For domain i, if the proportion of the region's activity in this domain is superior (inferior) to that of all actors in biotechnology, the indicator is greater (less) than the unit. The variance of this indicator measured for each domain within a region gives an overall degree of specialization for the region[7].

TABLE I
List of variables used

Type	Name	Definition
Biotech SMEs	NBCREA	Annual number of SMEs created (1993–1999)
Public research in life sciences	PUB	Annual number of publications
	PhDs	Annual number of life science PhDs. Proxy of public research inputs in biotechnology per region.
	SPE_PUB	Index of specialization of publications (variance of the RTA – Revealed Technological Advantage, calculated on the basis of the different scientific disciplines).
Private-sector biotech research	RE_BIO	Number of researchers in firms doing biotechnology research.
	PART_DERD_BIO	Private R&D expenditure by firms doing biotech research, in relation to all R&D in the region
	CONCENT_BIO	Index of geographic concentration of R&D (Herfindhal index on departmental R&D expenditure).
	SPE_BIO	Index of sectoral specialization of R&D (RTA variance calculated on the basis of sectoral DERD).
	PATENT_BIO	Number of biotech patents of which at least one inventor lives in the region.
Biotech market: related industries	INV_RI	Investments of related industries.
	NB_ETS_RI	Number of firms in industries related to the biotech sector.
	CONCURR_RI	Average size of establishments in related industries.
	CONCENT_RI	Index of geographic concentration of the biotech market (Herfindhal index on employee numbers per department in related industries).
	SPE_RI	Specialization index of the biotech market (RTA variance calculated on the basis of employee numbers per sector in related industries).
	PART_EFF_RI	Share of employee numbers in related industries in total number of employees in industry.
Collaborations	TXCOPUB	Share of co-publications in the total number of life science publications.
	TXCOPEXT	Share of publications co-authored with researchers from outside the region in the total number of publications.
	TXCOPINT	Share of publications co-authored with foreign researchers in the total number of publications.
	COPUBPP	Number of publications co-authored by public- and private-sector researchers.
Overall regional characteristics	PUBTOT	Number of publications in all disciplines put together.
	DERDTOT	Domestic R&D expenditure in all sectors put together.
	INVTOT	Industrial investments in all sectors put together.
	PATENTREG	Patents filled by actors within the region

The level of competition in related industries is measured by the average size of firms present in the region. A large size thus represents a low level of competition.

Lastly, the degree of interactivity of regional institutions is measured in terms of the data on co-publications (COPUB).They reveal the existence of effective scientific collaborations (Autant-Bernard et al., 2002). Different variables have been defined to describe collaborations, i.e. public-sector or public/private-sector collaboration (COPUBPP), and whether they are purely internal to the region or involve institutions outside the region.

3.1. *Empirical results*

Table II presents the localization of biotech SMEs creation.

In France the biotech sector was still expanding fast in the late 90s. The number of institutions' participations in scientific publications in this domain rose by 64% from 1993 to 5879 in 1999. R&D expenditures by private-sector firms increased by 49.6% during the same period – a higher growth rate than that of all other sectors. Hence, the relative share of biotech R&D expenditures compared to all R&D expenditures rose

TABLE II
Regional distribution of SMEs creation

Regions	# of firm creation NBCREA93–99*
Ile de France	53
Champagne-Ardenne	1
Picardie	0
Haute-Normandie	2
Centre	1
Basse-Normandie	0
Bourgogne	2
Nord-Pas-de-Calais	3
Lorraine	4
Alsace	11
Franche-Comté	0
Pays de la Loire	10
Bretagne	6
Poitou-Charentes	0
Aquitaine	13
Midi-Pyrénées	15
Limousin	1
Rhône-Alpes	10
Auvergne	14
Languedoc-Roussillon	9
PACA	10
France	165

Source: INRA database.

by over 20%. Employee numbers in related industries also show the strong growth of these industries rising by nearly 3.5% between 1993 and 1999 and increasing their relative share in the total number of employees in industry. Despite these indicators of growth, the French biotech SMEs remain small and recently set-up.

Table III below provides a synthetic view of the regional distribution of biotech activities in France. Three facts emerge strongly.

– The strong concentration of activity in the Ile de France region, with the Rhône-Alpes region following far behind.
– Alongside these two large leading regions, another group of regions has a strong potential in biotech but with specific trajectories. This set of regions (Provence-Alpes-Côte d'Azur, Alsace and Languedoc-Roussillon) are well placed from the point of view of scientific potential but they lack buoyant markets for biotech since few related industries are established in the region. By contrast, Brittany, Nord-Pas de Calais and Pays de Loire have a high level of industrial activity in which biotechnology is used although their capacities for publication and research are more limited (even if these seem to have been growing rapidly since 1993).
– Finally, despite a few noteworthy developments, the relative positions of the regions appear to be relatively stable during the 1993–1999 period. This probably reveals the weight of structural determinants.

4. Results of econometric estimations

The data used for the dependent variable are count data. They are therefore positive integers with a large number of zero values. We therefore use a Poisson model which seems well adapted for business creation data at regional level. In addition, we perform negative binomial estimations, in order to allow for over dispersion.

The backward elimination method was used to select the variables.[8] The results are presented for the model which retains only significant variables (Table IV below). For information, the results of the global model are also provided in appendix (Table VI).

As we can see in Table IV, the "alpha" parameter estimated in the regression on the negative binomial model does not appear significant. Therefore, the Poisson model was preferred to the negative binomial model.

Relatively few variables significantly influence SME creation in each region. This is hardly surprising, given the strong correlations that generally link this type of variables. Thus, as regards the influence of global "weight" of the region, a single variable emerges significantly: the total amount of R&D expenditure in the region (all sectors taken into account). It appears that this variable alone reflects all the quantitative effects of agglomeration that prompt firms to set up more easily in areas that already have a strong scientific, technological and industrial potential. Yet the influence here seems much too weak to effectively validate this hypothesis.

Moreover, the absence of significance of potential variables measuring the relative weight of biotech capacities in the regions proves that even if the effect of overall size is relevant, relative specialization in the biotech sector has no particular attractive effect. Hypotheses H1 and

TABLE III
Regional distribution of biotech activities in France between 1993 and 1999

Region	Publications 1993 (%)	Publications 1999 (%)	Growth 93–99	R I Employment 1993 (%)	R I Employment 1999 (%)	Growth 93–99	Biotech R&D 1993 (%)	Biotech R&D 1999 (%)	Growth 93–99
Ile de France	47.9	42.08	44.41	13.1	13.47	6.43	58.55	58.63	49.80
Rhône–Alpes	8.07	10.34	110.82	10.19	10.29	4.55	13.85	15.68	69.36
Alsace	7.10	6.09	41.27	3.34	4.18	−0.36	2.8	3.03	61.95
Languedoc–Roussillon	6.1	6.17	66.80	2.01	1.92	−1.24	0.99	0.89	34.16
PACA	5.69	6.7	93.85	5.17	5.01	0.24	3.14	3.05	45.35
Midi–Pyrénées	5.15	5.00	59.70	3.17	3.08	0.53	5.51	5.33	44.75
Aquitaine	3.16	2.68	39.81	4.77	4.77	3.43	1.23	0.93	12.83
Lorraine	2.69	2.01	23.58	3.27	2.92	−7.49	0.08	0.19	238.41
Nord-Pas-de-Calais	2.41	3.42	133.50	7.12	6.91	0.42	1.67	0.99	−10.90
Pays de la Loire	1.94	2.36	100.48	6.4	7.53	21.67	1.48	1.07	8.16
Bretagne	1.94	3.55	162.24	8.77	10.12	19.46	0.86	1.2	108.58
Centre	1.46	1.78	101.67	4.74	4.62	0.89	3.18	2.89	36.21
Auvergne	1.4	1.79	110.58	2.12	2.22	8.37	0.78	0.93	78.13
Bourgogne	1.3	1.52	93.27	3.16	3.14	2.69	0.33	0.32	42.60
Picardie	0.76	0.77	66.14	5.55	5.05	−5.79	1.16	0.6	−22.43
Haute-Normandie	0.66	0.78	95.98	4.91	4.40	−7.22	2.55	1.95	14.75
Poitou–Charentes	0.63	0.77	103.64	2.73	2.53	−3.96	0.18	0.43	255.09
Franche–Comté	0.44	0.51	90.04	1.48	1.4	−1.54	0.41	0.7	153.24
Champagne–Ardenne	0.39	0.76	221.25	3.13	2.69	−11.27	0.46	0.51	66.44
Basse–Normandie	0.33	0.45	123.60	2.96	2.78	−3.07	0.66	0.41	−6.83
Limousin	0.12	0.38	411.34	0.81	0.86	9.81	0.01	0.16	1148.47
Total	100	100		100	100		100	100	

H2 therefore receive little confirmation in this study. This result points out the difference between the French and the American system of innovation concerning individual mobility from academia to industry. Embodied technology transfer is weaker in France than in the U.S. It may also result simply from the effects of the size. Considering the size of the French scientific clusters compare to the U.S. ones, one can hypothesise that most of the French clusters (except Paris) does not reach the critical size to generate self reinforcement.

TABLE IV
Results of estimations – Creation model

	Poisson regression	Neg. Binomial regression
Constant	2.98***(0.88)	2.98***(0.74)
SPEPUB	−0.38***(0.08)	−0.38***(0.08)
CONCENT_BIO	−1.55***(0.56)	−1.55***(0.55)
CONCENT_RI	1.54**(0.61)	1.54***(0.53)
TXCOPEXT	−3.81***(1.27)	−3.81***(1.10)
COPUBPP	0.23E-01***(0.69E-02)	0.23E-01***(0.83E-02)
DERDTOT	0.37E-07**(0.18E-07)	0.37E-07*(0.21E-07)
Log-likelihood	−160.97	−161.10
χ^2	220.76***	0.26 ns
Pseudo-R^2	0.63	
α		0.02 ns

Dependent variable: NBCREA
Number of observations: 147
The figures between brackets are standard deviations. The significance thresholds are indicated by *, ** and *** which signify 10, 5 and 1%, respectively.

TABLE V
Regional characteristics of biotechnology, 1993-1999

Regions	Characteristics of public research			Characteristics of private research			Regional characteristics of markets				Organization of research		
	PUB*	SPEPUB	PhD (mean per year)	CH BIO	SPE BIO	CONCENT BIO	EFF IR	SPE IR	CONCURR IR	CONCENT IR	TXCO PUB	TXCO PEXT	COPUB PP
Ile de France	15,343	0.11	734.0	2 710	27.6	0.25	77 625	1.17	81.7	0.23	58.2	54.1	134.5
Champagne-Ardenne	205	4.03	3.3	40	10.9	0.97	16 527	0.31	75.7	0.82	58.3	73.2	3.3
Picardie	256	4.98	36.7	49	2.2	0.35	30 200	0.03	127.0	0.63	53.3	66.7	2.9
Haute-Normandie	246	6.82	19.9	85	0.2	0.71	26 125	0.57	107.3	0.52	61.3	66.3	2.9
Centre	611	2.56	32.1	117	2.8	0.45	27 407	1.36	93.9	0.35	57.7	73.2	4.5
Basse-Normandie	167	7.69	11.1	30	4.4	0.78	16 167	0.38	92.9	0.42	49.6	61.5	2.3
Bourgogne	493	3.67	34.6	30	1.3	0.77	18 368	0.24	88.4	0.53	42.6	68.6	5.6
Nord-Pas-de-Calais	1007	1.56	67.7	60	8.1	0.81	39 983	0.14	98.9	0.52	63.5	59.6	9.3
Lorraine	678	8.08	85.6	10	2.6	0.66	17 611	0.30	89.5	0.56	46.4	63.8	9.2
Alsace	2156	0.59	90.6	167	25.5	0.57	24 453	0.09	100.9	0.57	47.8	76.1	18.1
Franche-Comté	186	4.97	15.0	32	0.5	0.54	8 417	0.40	68.1	0.41	60.2	57.5	3.9
Pays de la Loire	677	2.15	35.1	86	5.6	0.36	39 712	0.49	88.8	0.27	60.4	64.5	11.3
Bretagne	1010	2.13	67.4	97	9.1	0.44	54 020	0.57	101.2	0.30	57.7	62.3	11.5
Poitou-Charentes	234	5.23	20.0	9	24.1	0.60	14 982	0.30	72.8	0.37	52.2	71.1	3.6
Aquitaine	1032	1.12	80.9	67	18.1	0.36	26 620	0.04	71.1	0.39	52.8	58.2	9.7
Midi-Pyrénées	1764	1.86	77.3	347	24.4	0.41	17 348	0.03	59.7	0.55	47.8	63.8	22.2
Limousin	109	8.48	2.1	25	0.1	0.83	4 785	0.38	62.2	0.64	69.3	69.7	0.9
Rhône-Alpes	3047	0.43	199.4	756	14.7	0.65	58 433	0.29	85.4	0.66	55.8	68.5	37.9
Auvergne	544	3.00	37.1	50	13.7	0.60	12 158	0.11	63.4	0.82	51.1	60.5	5.9
Languedoc-Roussillon	2171	1.21	133.4	79	11.0	0.92	19 978	0.10	60.9	0.61	54.3	67.1	27.1
PACA	2240	0.45	131.4	240	3.5	0.49	28 519	0.67	71.6	0.31	58.3	66.2	21.6
France	34,178	3.39	1 914.7	5 089	10.0	0.60	570 441	0.38	83.9	0.50	55.2	65.4	348.3

TABLE VI
Creation model, results of estimation

		Poisson regression	Neg. Binomial regression
Constant		2.64 (1.68)	2.65 (1.71)
Public research	PUB	0.69^{E-02} (0.52^{E-02})	0.69^{E-02} (0.72^{E-02})
	PhDs	-0.40^{E-02} (0.50^{E-02})	-0.40^{E-02} (0.61^{E-02})
	SPE_PUB	−0.34*** (0.11)	−0.34*** (0.13)
Private research	RE_BIO	-0.13^{E-04} (0.17^{E-02})	-0.13^{E-04} (0.29^{E-02})
	PART_DIRD_BIO	−6.49 (5.20)	−6.49 (6.10)
	CONCENT_BIO	−0.85 (0.71)	−0.85 (0.74)
	SPE_BIO	-0.33^{E-03} (0.40^{E-02})	-0.33^{E-03} (0.51^{E-02})
	PATENT_BIO	0.14^{E-01} (0.19^{E-01})	0.14^{E-01} (0.26^{E-01})
Market for biotech i.e. interrelated industry	INV_IR	0.27^{E-06} (0.38^{E-06})	0.27^{E-06} (0.40^{E-06})
	NB_ETS_IR	0.46^{E-02}** (0.21^{E-02})	0.46^{E-02}* (0.26^{E-02})
	CONCUR_IR	-0.37^{E-02} (0.10^{E-01})	-0.37^{E-02} (0.10^{E-01})
	CONCENT_IR	1.73** (0.85)	1.73* (1.02)
	SPE_IR	−0.22 (0.57)	−0.22 (0.66)
	PART_EFF_IR	-0.47^{E-01} (0.33^{E-01})	-0.47^{E-01} (0.42^{E-01})
Collaborations	TXCOPUB	0.11 (1.53)	0.11 (1.90)
	TXCOPEXT	−3.44* (1.92)	−3.44* (2.04)
	TXCOPINT	1.90 (2.40)	1.90 (2.53)
	COPUBPP	0.27^{E-01} (0.20^{E-01})	0.27^{E-01} (0.28^{E-01})
Regional characteristics	PUBTOT	-0.27^{E-02} (0.23^{E-02})	-0.27^{E-02} (0.36^{E-02})
	DERDTOT	-1.08^{E-06} (0.82^{E-07})	-1.08^{E-06} (0.12^{E-06})
	INVTOT	-0.21^{E-06}* (0.12^{E-07})	-0.21^{E-06} (0.14^{E-07})
	Log−likelihood	−161.10	−160.97
	$\chi 2$	220.76***	0.26 ns
	Pseudo-R^2	0.65	
	α		0.02 ns

Dependent variable: NBCREA
Number of observations: 147
The figures between brackets are standard deviations. The significance thresholds are indicated by *, ** and *** which signify 10, 5 and 1%, respectively.

All the other significant variables are, in our terms, organizational variables. Both the industrial organization and the organization of research within a specific area influence firm creation. The linkages between public sector research and industry increase the regional likelihood to attract firms. The intensity of competition within the biotech sector decreases the attractiveness of the region, while the geographic concentration of user industries increases it. In this respect our results strengthen the validity of various theories which show that apart from effects of "automatic" self-reinforcement which give a systematic advantage to large size, the organizational capacities of the regions are essential. The creation of new biotech firms therefore seems to be a particularly relevant field for illuminating this type of regional determinant.

4.1. *The positive effect of capacities for private/public-sector local interaction*

Co-publication data measures the impact of the level of scientific interactions characterizing the region. The significant positive effect of the public–private co-publications variable (COPUBPP) validates our hypothesis H3. We show here that the presence of public research is not in itself beneficial. Using co-publications, McKelvey et al. (2002) show the importance of geographic proximity in public/private scientific collaborations in biotech. However, collaborations amongst organizations do not depend on geographic proximity. The value of the existence of real, identifiable collaboration between local public- and private-sector institutions is highlighted primarily when the creation of SMEs is being promoted. On the other hand, collaboration between local actors with institutions outside the region (TXCOPEXT) has a very strong negative effect on the likelihood to collaborate. This difference of results can be explained by the particular characteristics of processes of new business creation which prefer attraction effects in a region that immediately offers much potential for local public/private–sector interaction, whereas the effects of openness onto the outside immediately seem far more beneficial for public–sector research itself than for firms. It can also be explained by the size of the scientific base within the region. The weaker the scientific base, the higher the co-publication rate with partners outside the regions. Indeed, scientists in regions with a low scientific base *have* to work with leading partners elsewhere. On the contrary, scientists or firms in leading clusters do not need to find outside competencies and resources to develop leading-edge science and innovation (Owen-Smith et al., 2002) on the American case; (Largeron and Massard, 2001) on the French case). The lack of internal competencies and scientific resources (within a region) increases the level of extra-regional collaborations (TXCOPEXT) and simultaneously explains the negative effect on creation.

4.2. *The positive effects of the diversity of scientific competencies*

A particularly robust result of our regressions highlights the negative role of regions' scientific specialization. The beneficial effects expected from specialization, especially to facilitate exchanges of knowledge in the emergent phases of activities (H4), are not confirmed. In fact, this specialization acts negatively, thus accrediting the opposite hypothesis with a favourable effect on diversity in firms' start-up phase. Measured in terms of publications, specialization of public research describes the more or less limited scope of scientific fields of competence available in a region. The analysis of the role of scientific knowledge in the technological development of biotech can help us to interpret this result. First, the technological maturation of a sector transforms the modalities of related scientific research. The production of new knowledge involves more and more recombination of existing modules and less and less highly specialized original research (Arora and Gambardella, 1994a; Arora and Gambardella, 1994b). Secondly, and more specifically, the biotech sector has the characteristic of providing generic tools to a wide range of related industries. Generic orientation, linked to scientific and technical trends towards oneness of the living world, is leading scientific research away from specialising in this domain. A diversified regional research framework would therefore increase start-ups' opportunities for finding the varied scientific competencies they need.

This interpretation in terms of diversity is particularly appropriate here since our measurement of specialization concerns basic scientific competencies. Its negative effect therefore reflects no competitive effect. In many studies on the role of local sectoral structures in the development of innovative agglomerations, measurement of diversity concerns the characteristics of local employment or of private–sector research. The negative effects in this case cannot lead us directly to conclude that diversity is an advantage, without directly measuring the impact of diversity. Even if a specialized local structure logically allows many beneficial interactions between firms in the same sector, it is not for all that free of all forms of competitive behaviour, especially in the appropriation of knowledge. This argument is developed by Feldman and Audretsch (1999) who also observe that specialization is a relatively strong curb on innovation in local areas in the U.S. By contrast, in our results the variables directly intended to measure the impact of the degree of specialization in related industries and/or of the degree of competition (hypothesis H6 and H7) reveal no significant effects.

4.3. *Influence of intra-regional spatial structuring of activities*

The variables of spatial structuring within regions have a strong albeit contrasting influence. The degree of intra-regional spatial concentration of biotech research expenditure (CONCENT_BIO) proves to have a negative influence on business creation, whereas the spatial concentration of demand (CONCENT_RI) has a positive impact. The former point can be interpreted in two ways. First, this variable may reflect a competition effect not revealed elsewhere. However, observation of the data suggests another interpretation. It is often the very "small" regions (in terms of research potential) that provide the strongest concentration indicators. Hence, when this potential is very weak (in terms of research institution, for example), dispersion is impossible. It is therefore essentially an effect of size that we have here, due to the reduced attractiveness of areas with very little biotech research potential.

By contrast, intra-regional spatial concentration of related industries has a strong beneficial effect on the creation of new firms. Interest in a proximity effect therefore seems to concern above all a link to the market, to demand. Thus, rather than the size of the market itself (hypothesis H5), it is the ability to benefit from agglomerations of customer industries that is sought. The advantages of proximity, highlighted in studies in the geography of innovation as explaining the attraction of clusters of basic public research and centres of scientific excellence seem, in the context described here, rather to concern relations between start-ups and their potential customers. This confirms our hypothesis on a clearer orientation of SMEs towards the market, marking a new phase in the maturity of the biotech sector in the 1990s (Mangematin et al., 2003).

The main conclusions of this estimation of a regionalized model of SME creation attest to the complexity of the processes at play. The expected attraction effect of public-sector research has not been confirmed. (Note, however, that this absence of effect may result from the type of data used to characterize public research). Publication data describe a local productive capacity but one whose use is not limited in space, unlike the number of researchers which reflects not only the level of available resources in public research but also a capacity for local diffusion. Future research will have to confirm this hypothesis.

The importance of organizational variables is the other obvious result of these estimations. It is clear that apart from the resources mobilized locally, the organizational capacities likely to help local firms to take full advantage of those resources are decisive. Results clearly emphasize the role that local public authorities can play to encourage firm location, using economic tools like science parks, incubators and so on.

5. Conclusion

The simultaneous estimation of knowledge externalities and market dynamics highlights two main results :

(1) A large and diversified scientific and technological base within a region is necessary for the establishment of a continuous flow of firm creation. In specialised region, firm creation is not regular because scientific and technological discoveries concern only specific sub-fields. The dynamism of this positive trajectory nevertheless seems to depend strongly on organizational factors. Rather than the quantitative potential of public- and private-sector research in the region, it is the diversity of available scientific competencies and the capacity to develop public/private interactions that favour the establishment of biotech start-ups in the region.

(2) Local markets matter. Local clusters not only generate knowledge externalities, they also create a market for local SMEs which develop products and services for academic and industrial actors in life sciences. The impact of "research markets" (academia, R&D department) on the creation of start-ups is stronger during the emerging phase of the industry, when research activities prevail. It is weaker when the industry matures and become more consumer – and market – oriented. However, the set of data about the French situation in biotechnology during the last decade does not allow us to test this point.

(3) The expected attraction effect of excellence in the public-sector research observed in the U.S. situation has not been confirmed from the French data. Rather than the quantitative potential of public- and private-sector research in the region, it is the diversity of available scientific competencies and the capacity to develop public/private interactions that favour the establishment of biotech start-ups in the region. It is not so

much the size of the regional market itself that is important, but rather its ability to develop and sustain diversity in the scientific production. Different reasons may explain this distinction: (1) the national system of innovation are not similar especially concerning individual mobility at different stages of the career (weak mobility for senior scientists in France). (2) The sector is more mature in the U.S. than in France. The difference may reflect the evolution which takes place as the industry matures and it may also reveal the dissimilarity between a leading country and a peripheral country in the biotech research and the biotech industry.

Finally, this analysis suffers from several limitations which have to be solved in future research: (1) Methodological improvements are now envisaged (finding better proxies for public-sector research, using the panel method). However, first results obtained are fairly robust. (2) Empirical data covers the regional framework of research, technology, industry and market. It does not integrate public policy measures developed at the regional level mainly because data is not available. It also requires a hypothesis about the fit between the regional framework and public measures. Hence, in the biotechnology domain, regional policies cannot only count on the accumulation of regional resources. It is not simply the fact of belonging to the same region that facilitates transfers and stimulates phenomena of externalities. In this sense regional technology policy should be far more than support for R&D expenditures or for the direct production of artefacts. Its role is also to set up and support the variety of mechanisms that allow firms to capture and absorb external knowledge. In biotechnologies, diffusion of technological knowledge is complex, hence, the need for a varied institutional infrastructure. Promoting diversity, facilitating the establishment of relations and cooperation between actors with varied competencies, belonging to networks or institutional systems all marked by their own culture, using the agglomeration to encourage producer-user relations: all these are examples of the "organizational capacities" that can distinguish regions.

The definition of public policies (national or regional ones) to support technology transfer and firm creation cannot be only based on the analysis of the U.S. situation because different mechanisms seem at stake in France. Empirical analysis based on different set of data is needed to design policy measures adapted to the situation.

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Notes

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[1] Anselin et al. (1997) nevertheless show the relevance of econometric studies that use data on numbers of innovations and patents at detailed levels of location.

[2] www.grenoble.inra.fr, available on request.

[3] This is different from the total number of creations observed as you can find it in Table II

[4] SESSI: *Service d'Etudes des Stratégies et des Statistiques Industrielles*

[5] EAE : *Enquête Annuelle d'Entreprise.*

[6] In France, departments are administrative units within regions.

[7] In specialization is calculated on the basis of a nomenclature of publications in terms of theme, R&D expenditure in sectors of research, patents in technological domains, and employee numbers in related industries in main sectors of users.

[8] Step-by-step introduction yields similar results.

References

Acs, Z. and L. Preston, 1997, 'Small and Medium-Sized Enterprises, Technology, and Globalization: Introduction to a Special Issue on Small and Medium-Sized Enterprises in the Global Economy', *Small Business Economics* **9**, 1–6.

Afuah, A. and J. M. Utterback, 1997, 'Responding to Structural Industry Changes: A Technological Evolution Perspective', *Industrial and Corporate Change* **6**(1), 183–202.

Almeida, P. and B. Kogut, 1999, 'Localization of Knowledge and the Mobility of Engineers in Regional Networks', *Management Science* **45**(7), 905–918.

Anselin, L., A. Varga, and Z. Acs, 1997, 'Local Geographic Spillovers between University Research and

High Technology Innovations', *Journal of Urban Economics* **42**, 422–448.

Arora, A. and A. Gambardella, 1994a, 'Evaluating Technological Information and Utilizing It: Scientific Knowledge, Technological Capability, and External Linkages in Biotechnology', *Journal of Economic Behavior and Organization* **24**(1), 91–114.

Arora, A. and A. Gambardella, 1994b, 'The Changing Technology of Technological Change: General and Abstract Knowledge and the Division of Innovative Labour', *Research Policy* **23**, 523–532.

Audretsch, D. and M. Feldman, 1996a, 'Knowledge Spillovers and the Geography of Innovation and Production', *American Economic Review* **86**(3), 630–640.

Audretsch, D. and M. Feldman, 1996b, 'R&D Spillovers and the Geography of Innovation and Production', *American Economic Review* **86**(3), 630–640.

Audretsch, D. and P. Stephan, 1996, 'Company Scientist Locational Links: The Case of Biotechnology', *American Economic Review* **86**(3), 641–652.

Autant-Bernard, C., 2001, 'Science and Knowledge Flows: Evidence from the French Case', *Research Policy* **20**, 1069–1078.

Autant-Bernard, C., V. Mangematin and N. Massard, 2002, 'Biotech Maturing Sector, Specialization of Regions and Development of Biotech Smes,' in M. McKelvey (ed.), *The Economics and Business of Bio-Sciences & Bio-Technologies: What can be Learnt from the Nordic Countries and the UK?* Gothenburg, Sweden.

Autant-Bernard, C. and N. Massard, 1999, 'Econométrie Des Externalités Technologiques Et Géographie De L'innovation: Une Analyse Critique', *Economie Appliquée* **4**.

Busenitz, L., C. Gomez, and J. W. Spencer, 2000, 'Country Institutional Profiles: Unlocking Entrepreneurial Phenomenon', *Academy of Management Journal* **43**(5), 994–1003.

Catherine, D., C. Corolleur, M. Carrere, and V. Mangematin, 2004, 'Turning Scientific and Technological Human Capital into Economic Capital: The Experience of Biotech Start-Ups in France', *Research Policy* **33**(4), 631–642.

Cockburn, I. M. and R. M. Henderson, 1998, 'Absorptive Capacity, Coauthoring Behavior, and the Organisation of Research in Drug Discovery', *The Journal of Industrial Economics* **XLVI**(2), 157–182.

Cohen, W. M. and D. A. Levinthal, 1990, 'Absorptive Capacity, a New Perspective of Learning and Innovation', *Administrative Science Quarterly* **35**, 128–152.

Cooke, P., 2002, 'Rational Drug Design, the Knowledge Value Chain and Bioscience Megacentres', in J. Niosi (ed.), *Clusters in High-Technology*. Montreal: UQAM.

Edquist, C., 1997, (ed.) *Systems of Innovation*. London: Pinter Publishers.

Feldman, M. 1994a, *The Geography of Innovation*. Boston: Kluwer Academic Publishers.

Feldman, M. 1994b, 'Regional Innovative Capacity,' *The Geography of Innovation*. Boston: Kluwer Academic Publishers. 77–91.

Feldman, M. and C. Ronzio, 2001, 'Closing the Innovative Loop: Moving from the Laboratory to the Shop Floor in Biotechnology Manufacturing', *Entrepreneurship and Regional Development* **13**, 1–16.

Feldman, M. P. and D. Audretsch, 1999, 'Innovation in Cities: Science-Based Diversity, Specialization and Localized Competition', *European Economic Review* **43**, 409–429.

Frost, T. S., 2001, 'The Geographic Sources of Foriegn Subsidiaries' Innovations', *Strategic Management Journal* **22**(2), 101–123.

Gittelman, M. and B. Kogut, 2003, 'Does Good Science Lead to Valuable Knowledge? Biotechnology Firms and the Evolutionary Logic of Citation Patterns', *Management Science* **49**(4), 366–382.

Jaffe, Adam B., M. Trajtenberg, and R. Henderson, 1993, 'Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations', *Quarterly Journal of Economics* **108**(3), 57–598.

Krugman, P., 1991, 'Increasing Returns and Economic Geography', *Journal of Political Economy* **99**(3).

Krugman, P. and A. J. Venables, 1995, 'Globalization and the Inequality of Nations', *Quaterly Journal of Economics*, **110**.

Largeon, C. and N. Massard, 2001, 'La Géographie Des Collaborations Scientifiques En France: Une Étude De La Structure Des Co-Publications Entre Départements Français', *Revue d'Economie Regionale et Urbaine* (1), 39–52.

Liebeskind, J. P., A. L., Oliver, L. Zucker, and M. Brewer, 1996, 'Social Networks, Learning, and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms', *Organization Science* **7**(4), 428–442.

Mangematin, V. and N. Mandran, 2001, 'Innovation without Internal Research: Spillovers from Public Research or from Other Firms? The Case of the Agro-Food Industry,' in A. Kleinecht and P. Mohnen (eds.), *Innovation and Firm Performance. Econometric Explorations of Survey Data*. London and Basingstoke: Palgrave.

Mangematin, V., S., Lemarie, J. P., Boissin, D., Catherine, F., Corolleur, R. Coronini, and M. Trommetter, 2003, 'Sectoral System of Innovation, Smes Development and Heterogeneity of Trajectories', *Research Policy* **32**(4), 621–638.

Mangematin, V. and L. Nesta, 1999, 'What Kind of Knowledge Can a Firm Absorb?' *International Journal of Technology Management* **37**(3–4), 149–172.

Martin, P. and G. I. P. Ottaviano, 1999, 'Growing Locations: Industry Location in a Model of Endogenous Growth', *European Economic Review*, **43**, 281–302.

Massard, N. and S. Riou, 2001, 'Specialization and Diversity: The Debate on the Nature of Innovative Agglomerations', *Third Congress on Proximity, New Growth and Territories*. Paris.

Nesta, L. 2001, 'Cohérence Des Bases De Connaissances Et Changement Technique: Une Analyse Des Firmes

De Biotechnologie De 1981 À 1997', *Department of Economics*. Grenoble: Université Pierre Mendes France.

Niosi, J. and M. Banik, 2002, 'The Evolution and Performance of Biotechnology Regional System of Innovation', in J. Niosi (ed.), *Workshop Clusters in High Techlogy Aerospace, Biotechnology and Software*. Montréal: Cirst-UQAM.

Owen-Smith, J., M., Riccaboni, F. Pammolli, and W. W. Powell, 2002, 'A Comparison of Us and European University-Industry Relations in the Life Sciences', *Management Science* **48**(1), 24–43.

Powell, W. W., K. W., Koput, J. I. Bowie, and L. Smith-Doerr, 2002, 'A Spatial Clustering of Science and Capital: Accounting for Biotech Firm-Venture Capital Relationships', *Regional Studies* **36**(3), 291–305.

Reiss, Th., C., Enzing, V., Mangematin, J., Senker, J., Calvert, I., Dominguez Lacasa, S., Kern, P., Nesta, P. Patel, and A. van der Giessen, 2003, 'Efficiency of Innovation Policies in High Technology Sectors in Europe–Epohite', Brussels: EC.

Steier, L. and R. Greenwood, 2000, 'Entrepreneuship and the Evolution of Angel Financial Networks', *Organization Studies* **21**(1), 163–192.

Steinle, C. and H. Schiele, 2002, 'When Do Industries Cluster? A Proposal of How to Assess an Industry's Propensity to Concentrate at a Single Region or Nation', *Research Policy* **31**(6), 849–858.

Zucker, L., M. Darby, and B. Brewer, 1998, 'Intellectual Human Capital and the Birth of the US Biotechnology Enterprise', *American Economic Review* **88**(1), 290–306.

Zucker, L., M. Darby, M. Brewer, and Y. Peng, 1996, 'Collaboration Structure and Information Dilemmas in Biotechnology: Organisational Boundaries as Trust Production', In RaT Kramer, T. (ed.), *Trust in Organizations*: 90–113. Sage: Thousand Oaks, CA.

Zucker, L. G., M. R. Darby, and J. Armstrong, 2002, 'Commercializing Knowledge: University Science, Knowledge Capture, and Firm Performance in Biotechnology', *Management Science* **48**(1), 138–153.

Zucker, L. G., M. R. Darby, and J. Armstrong, 1998, 'Geographically Localized Knowledge: Spillovers or Markets?', *Economic Inquiry* **36**(1), 65–86.

Zucker, L. G., M. R. Darby, and M. Torero, 1997, 'Labor Mobility from Academe to Commerce', *NBER Working paper*. n° 6050.

Zucker, L. G. and M. R. Darby, 2001, 'Capturing Technological Opportunity Via Japan's Star Scientists: Evidence from Japanese Firm's Biotech Patent's and Products', *The journal of Technology transfer* **26**(1/2), 37–58.