DO NON-R&D INTENSIVE INDUSTRIES BENEFIT FROM PUBLIC RESEARCH SPILLOVERS? THE CASE OF THE AGRO-FOOD INDUSTRY*

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Abstract
The agro-food industry is a sector in which the percentage of firms which have done innovation in the past three years is high, whereas they have a low research capacity. According to an innovation survey (1986-90) in France, 70% of agro-food firms which responded in the Community Innovation Survey (CIS), reported innovations while less than 5% of them had internal research capacities. Our paper models estimates of determinants of innovation in the agro-food industry. Based on the comparison of several French databases (annual survey on firms, on innovation, on R&D in firms, on R&D in academic labs), it explores the determinants of innovation: sources of innovation (as defined in CIS), spillovers from public research and spillovers from other firms.
Since agro-food firms have a low absorptive capacity, we assume that the transfer of knowledge from public research or from large firms to agro-food firms is based on geographical proximity.
The paper presents three main results:
1. Intensity of innovation (defined as radical innovation versus incremental innovation) is linked with the presence of public research in life science in the same region.
2. Spillovers form academic laboratories do exist even if firms have no absorptive capacity.

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3. Density of the agro-food industry in a specific region has no influence on the propensity of firms in each group to innovate.

Introduction

The aim of this article is to enhance our knowledge of innovation mechanisms in sectors in which firms innovate without doing internal research. Greater insight into the motives behind innovation in sectors where R&D is weak, enables us to define appropriate tools for supporting innovation and to identify the most relevant levels of intervention (region, State, EU).

Agro-food has a few very large corporations (e.g. Nestlé and Danone), which co-exist with a large number of small businesses. Firms in the sector seldom participate in the major research programmes and hardly benefit from tax credits for research. Case studies (Mangematin, 1997) show that agro-food SMEs form local partnerships when they innovate. This observation raises two questions: first, can innovation policies suited to agro-food firms be defined? If so, what is the relevant level of intervention: region, country or European Union, and what are the relevant tools? Secondly, how can firms which do no perform formal internal research benefit from spillovers from research done elsewhere, when they have no research or absorptive capacities?

Based on a statistical analysis of the sources of innovation in agro-food firms, this article identifies innovation mechanisms in a sector in which R&D spending is low. By studying the link between public research in a region, the density of firms which do research in that region and the propensity of agro-food firms to innovate, we are able to grasp the relative importance of regional infrastructure in the innovation dynamics of non-R&D intensive firms.

The first section analyses the different ways of capturing spillovers, employed by those firms which do no perform internal research. The data and methods of analysis are presented in the second section which provides us with a typology of the intrinsic characteristics of innovative and non-innovative firms, in terms of the sources of innovation. The third section shows that not only large firms benefit from the externalities of public research on a regional basis, but also small firms without any internal research capacity. The fourth section considers the results obtained and their theoretical implications.

1. From support for R&D to innovation dynamics

Most of the models developed in the economics of technological change consider R&D as the main source of innovation (Cohen, 1995). However, the distribution of R&D expenditures is highly asymmetric. In the French innovation survey in 1993, almost 70% of agro-food firms (with more than twenty persons) claim to have produced at least one innovation while research expenditures account for less than 1.7% of value added.

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Innovation without internal research

Inter-sectoral comparisons show that large firms have a competitive advantage to innovate in specific sectors like instrumentation, the automotive industry and the aircraft industry, while SMEs have a higher rate of innovation in other sectors, especially low-tech sectors (agro-food, clothing industry, etc.) (Acs and Audretsch, 1988). According to the Frascati manual's definition, fewer than 3,000 firms perform R&D activities in France. These are mainly large or high-tech firms (computer, software, biotechnology, etc.). As established by Kleinknecht (1987), there is an obvious lack of formal R&D in SMEs, especially in low-tech sectors. Lhuillery and Templé (1995) emphasize the role of informal R&D in French SMEs, which causes us to wonder about alternative or complementary sources of innovation in these companies. In other words, the actual sources of innovation remain peculiarly mysterious if R&D expenditures are considered as the main input of innovation.

Based on multi-sector analysis of US data, Jaffe (1989) suggests that the weak linkages between innovation and R&D expenditures in SMEs are due to the collective nature of innovation. Small firms take more advantages from spillovers of R&D than large firms, whether research activities produced by public or private institutions. Link and Rees (1990) point out one interesting aspect regarding large and small firm research behaviors.

'Although large firms are more active in university-based research per se, small firms appear to be able to utilize their university based associations to leverage their internal R&D to a greater degree than large firms', (Link and Rees, 1990, p 30).

Acs *et al.* (1994) show that the propensity of small firms to innovate is positively correlated with research expenditures of neighboring universities. Interestingly, this correlation is weaker for large firms. Their propensity to innovate is correlated with private research centers' expenditures, wherever research centers are located. These empirical results are quite stimulating. They shed light on the complementarity between private and public R&D expenditures, on the one hand, and an SME's propensity to innovate, on the other. They may represent a first explanation of the distortion between R&D expenditures and the propensity to innovate in SMEs.

However, the way in which SMEs in the agro-food sector benefit from spillovers from public or private institutions remains uncertain. Are inside research capacities needed to be able to absorb research done outside the firm (Cohen and Levinthal, 1990)? Do low-tech firms require specific modes of collaboration to be able to absorb knowledge and technology from public or private institutions?

Cohen and Levinthal (1989) show that R&D investments « develop the firm's ability to identify, assimilate, and exploit knowledge from the environment (p.569) ». Examining what they call the absorptive capacity of the firm, they elucidate the two faces of R&D investments. On the one hand,

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firms invest in R&D to generate innovations. On the other, research activities contribute to the constitution and broadening of the firm's absorptive capacity. Defined as a set of knowledge and competencies, the firm's knowledge base remains a preliminary condition in the assimilation of spillovers from public research institutes and private R&D efforts. For Rosenberg (1990), fundamental research inside the firm has strong complementarities with external R&D from either the public or private sector. Both Cohen and Levinthal and Rosenberg insist on potential synergies between the firm's own knowledge base and external flows of scientific and technical knowledge. However, absorptive capacity is considered as a by-product of R&D investments (Cohen and Levinthal, 1990, p.129) which implies that it cannot be built for its own sake.

Other contributions have paid further attention to absorptive capacity. Arora and Gambardella (1994) distinguish between the scientific and the technological capabilities of a company. The former is required in the evaluation of relevant inter-organizational alliances. It is both a means of knowledge diversification and a phase of scientific specialization. The latter (*i.e.* technological capability) implements such knowledge leading to innovations. Convincingly, Arora and Gambardella identify the role of R&D in the building of a firm's ability to exploit external knowledge flows. Therefore, absorption mechanisms cannot be limited to passive attitudes but include active processes of assimilation as well. In a similar vein, Mangematin and Nesta (1999) show that a firm's absorptive capacity is linked to the characteristics of the assimilated (or absorbed) knowledge. They analyze the relationship between three basic, empirically defined concepts: the fundamental or applied nature of knowledge, the tacit or codified form of knowledge and the absorptive capacity of the firm. They show that a low absorptive capacity inhibits co-operation in R&D. This collaboration concerns mostly applied fields and needs informal interaction to support transfers (such as telephone calls, informal interviews and meetings). A high absorptive capacity extends the assimilation to all kinds of knowledge (applied, fundamental) through all types of channels (PhD students, scientific papers, technical devices). Altogether, absorptive mechanisms seem to diversify as the firm's absorptive capacity increases. They have also shown that channels of absorption in firms with research activities differ from those in firms without. This difference of channels of absorption of knowledge leads us to assume differences in organization. Mangematin and Nesta show that channels of knowledge transfer are more informal (personal contacts, unpublished written notes, instruments) in low-tech sectors than in high-tech sectors. Even if goals are similar in low-tech and high-tech sectors, the forms of knowledge produced are different: technical devices for low-tech; articles, patents and also technical devices and new materials for high-tech.

In short, innovation does exist without formal internal research activities. What we do not know is whether the propensity of firms to innovate is different in sectors in which R&D expenditures are high and in sectors in which they are low. It is generally assumed that the propensity to innovate is strongly correlated with the level of R&D expenditure.

Absorptive capacity and intensity of innovation

If one accepts that innovation is based on research (whether internal or contracted out), innovation in firms which do not realize internal R&D is based on spillovers from outside research. Economic theory remains unclear on the type of spillovers from which low-tech industries benefit. Empirical evidence shows a correlation between intensity of university research in a geographic area and propensity to innovate, irrespective of the economic sector. But research undertaken to evaluate the influence of local research infrastructure in innovation dynamics does not take into account problems encountered specifically in low-tech sectors. A number of conclusions can be drawn from research undertaken in this field:

- Innovation in a given region is closely related to public and private research spending in the region (Feldman, 1994).

- Innovation in a given region is related not only to public and private R&D spending, but also to all the region's technology transfer infrastructure (presence of technical centers, of a technology transfer organization, etc.) (Feldman, 1994; Llerena and Schaeffer, 1995). Thus, the presence of complementary activities generates greater spillovers and reduces the costs and risks related to firms' innovation.

- There are no eviction effects between public and private R&D spending; they are self-reinforcing and thus create areas of expertise (Jaffe, *et al.*, 1993).

- Only Audretsch and Stephan (1995) have focused their analysis exclusively on high-tech sectors. In sectors where innovation is based on science, geographic links disappear. These authors show that 70% of all relations between biotechnology firms and universities are not based on geographical proximity. Several explanations can be suggested. Ties based on geographical proximity are strong when businesses are created, since entrepreneurs maintain steady relations with their network of local contacts. Having a "star of science", like a Nobel prize-winner, for example, creates impulsion effects in the region since firms have less need to turn to the outside. By contrast, in other cases, ties based on geographical proximity are very quickly replaced.

If we combine the different elements, the following two assumptions can be made for low-tech sectors:

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H1: The greater the public research is in a specific area, the higher the intensity of innovation

H2: Only firms which have absorptive capacity can benefit from public research externalities

In low-tech industries the absorptive capacity is low and the channels of technology transfer between research organizations and agro-food firms are likely to be based on trading of tacit knowledge and know-how, rather than on trading of codified knowledge.

We intend to identify the impact of spillovers from public research and from R&D performing firms in the sector, on innovation in agro-food firms. This approach will enable us empirically to examine the notion of absorptive capacity, by linking it both to the intensity of firms' innovation (radical innovation, incremental innovation or no innovation) and to the characteristics of those firms which innovate (size, capacity to generate added value and to invest).

2. Methods and data

In other words, do innovative firms have intrinsic characteristics different from those which do not innovate?

2.1. Sources

The matching of three separate surveys *i.e.* (1) 1986-90 innovation survey, (2) the R&D survey by the research ministry, and (3) the annual survey of firms, enables us to characterize the type of enterprise, the sources of innovation, the propensity of firms to innovate, and the type of innovation performed by the firm. Although the concept of geographical proximity is more relevant in terms of the coherence of the local industrial district, we chose to base our assessment of geographical proximity on the firms' postal addresses since that was the only available information. Despite the limits of this approach, it enabled us to make comparisons with other empirical studies carried out in the United States, in particular (Jaffe, 1993; Audretsch and Stephan, 1995).

At the time of the study, only the 1990 CIS (innovation survey) was available for agro-food firms since the 1993 survey had excluded this category.

In 1990 the population of agro-food firms in France was 4,218 firms with over ten employees. 1,902 firms participated in the innovation survey and 1,320 claimed to be innovative. 80% of the firms had only one plant. We assumed that all plants belonged to the same region as the firms.

2.2. Innovation in the agro-food industry

The 1990 survey distinguishes five types of innovation: a) product innovation (with three sub-categories: (1) improvement of existing products; (2) products which are new for the firm but which already exist in the market; and (3) products which are new in the market); b) process innovation, which distinguishes (1) technological breakthroughs and (2) substantial improvements to an existing process; c) innovations in packaging; d) organizational innovation; and e) commercial innovation. In order to study the type of innovation in relation to the sources of innovation and the structures of research in the vicinity of the firm, we have grouped together innovations according to their degree of innovativeness:

.1. No innovation;

.2. Improvement of products or processes, including innovation in packaging *i.e.* incremental innovation;

.3. Achievement of technological breakthroughs (product or process) *i.e.* radical innovation;

Irrespective of the category, innovations are primarily market driven (58.6%). A minority is technology driven (39.5%). 43% of all firms claim to be innovative in general and 54% claim to be relatively more innovative than the average in their sector.

As shown in Table 1, the majority of innovations concerns improvements of products or processes.

Table 1: Type of innovation

	Number of firms that innovated
Incremental innovation	**53%**
Improvement of product	*69%*
Product new to the firm	*62%*
Process improvement	*63%*
Innovation in packaging	*52%*
Radical innovation	**40%**
Absolutely new product	*39%*
Absolutely new process	*21%*
Incremental and radical innovation	*7%*
Organizational innovation	**25%**
Commercial innovation	**21%**

Note : Innovations are primarily improvements to products or processes. They are rarely isolated. The same firm often improves a product and a process at the same time. Very few firms introduce only commercial or organizational innovations (8 out of 1,305 cases).

Firms rely essentially on the acquisition of capital goods (38%) to innovate. Next on the list are engineering studies (32%), then internal R&D (26%) and, finally, external R&D acquired from other organizations (18%) or from within the group (17%).

Judging from data on the sources of innovation, the number of citations of "internal R&D" as a source of innovation highlights the limits of statistical surveys. When two different sources are matched (those of the statistical service of the Ministry of Research and those of CIS survey), the number of firms which state use of internal R&D as a source of innovation and the number of firms

which claim to have internal R&D (Frascati definition) are different. In the research ministry's data base only 90 firms claim to do R&D, whereas 222 firms claim to have based their innovation on their own R&D. These two sources of information give a different picture of the same reality: the presence of internal R&D capacities.

2.3. Five clusters of firms

To understand innovation dynamics within firms, we characterized our sample in terms of the sources of innovation used by a firm when it wished to market new products or processes. Most of the variables are qualitative ones. Thus, we used a multiple correspondence analysis (Benzecri, 1973; Lebart, 1991) on the sources of innovation (internal R&D, R&D in the group, external R&D and engineering studies). It revealed three structuring dimensions: first, there is a contrast between firms which use engineering studies and those which do not; second, there is a contrast between firms which use R&D within the group, with those which do not; and, lastly, there is a contrast between those which do their own R&D with those which do not. We excluded from the analysis the innovative use of capital goods, new materials and patents since these dimensions are not significant.

In the multiple correspondence analysis, the different types of innovation were used as illustrative variables, which makes it possible to situate them on factorial axes structured by the implemented means of innovation. Thus, radical innovations seem related to internal R&D and engineering studies. Incremental innovations are equidistant from internal and external R&D, since innovations of this type tend to use these two types of resource. The firm creates new products in the context of research which mobilizes external R&D.

The multiple correspondence analysis was followed by a hierarchical classification (Celeux, 1989) of the means of innovation, which reveals five clusters of firms as described in Table 2 below.

Table 2: Five clusters of firms

Clusters	Number of firms	Sources of innovation	Nature of innovation	Characteristics of firms (Average)
1	706	No sources of innovation	No innovation	Number of employees : 66 Turnover : 104 MF Added Value on turnover : 0.20 Added value per employee : 263 KF
2	199	engineering studies No R&D	Product new to the firm Improvement of product Packaging innovation	Number of employees : 71 Turnover : 94 MF Added Value on turnover : 0.13 Added value per employee : 234 KF
3	237	Engineering studies Purchase of external R&D No internal or group R&D	Improvement of product Improvement of process Packaging innovation New product for the firm	Number of employees : 70 Turnover : 97 MF Added Value on turnover : 0.15 Added value per employee : 243 KF
4	349	Internal R&D No R&D from the group Engineering studies Purchase of external R&D	All kinds of innovation	Number of employees : 160 Turnover : 222 MF Added Value on turnover : 0.13 Added value per employee : 269 KF
5	381	All sources of innovation	All kinds of innovation	Number of employees : 298 Turnover : 478 MF Added Value on turnover : 0.12 Added value per employee : 343 KF

This table warrants some explanation.

Technical comments

1. We based the constitution of clusters solely on the sources of innovations (R&D and engineering studies).

2. The classification obtained was consolidated. This method enabled us to improve the first classification based on the factorial analysis of multiple components. After three iterations, inter-cluster inertia is stable (ratio of inter-cluster inertia on total inertia: 0.7300 before consolidation and 0.7344 after). From one iteration to the next, classes 2, 3 and 4 are very stable, and classes 1 and 5 are slightly distorted.

3. We then characterized the nature of the innovation in the 5 clusters and the firms in these clusters, by estimating the average value for 4 indicators:

- Number of employees: average number of employees in the firm

- Turnover: average turnover expressed in millions of francs

- Ratio of added value on turnover (AVTO): the AVTO ratio gives an indication of the firm's capacity to generate added value. It also constitutes an estimate of the degree of integration of the firm. The higher the ratio, the less the firm contracts out work.

- Value added per person: average VAPE expressed in kilo francs.

A Fisher test enables us to show that a substantial difference exists between the averages of each of the indicators, for each of the classes. The clusters obtained from R&D resources are different from the point of view of firms' structural variables.

Economic significance of clusters

1. Cluster 1 describes the firms which do not innovate and have no innovation resources. These firms are generally small in terms of both staff and turnover, are highly integrated, contract out very little and have an average of two factories.

2. Cluster 2 describes firms which, through engineering studies, achieve product improvement innovations. These firms are small (in terms of staff and turnover), do not make use of formal R&D, and base their innovations on engineering studies. They contract out work on a large scale and have a weak capacity to generate added value per franc of turnover or per employee.

3. Cluster 3 describes small firms which rely on engineering studies and on R&D bought from other organizations to improve products or processes and to create products that are new for the firm. These firms contract out work on a large scale.

4. Cluster 4 describes firms which have internal R&D capacities. They do not use R&D from within the group to innovate; they buy R&D from the outside and carry out their own engineering studies. These are firms which are substantially larger than those in the preceding clusters. They contract out on a large scale and are integrated to a very small degree, although they have a good capacity to generate added value per employee. They produce innovations of the first type: products or processes.

5. Firms in cluster 5 are larger than those in the other clusters and carry out all types of innovation. They are integrated to a very small degree and have a very high level of productivity.

2.4. Structure of public research in the life science sector

One of the characteristics of the environment of innovative firms is the presence of a public research organization in the vicinity. We therefore tried to estimate the weight of public research in each of the regions. No existing database combines the three key dimensions: scientific discipline, locality and resources.

The relative weight of public research in a region is a value which corresponds to a relative index. Indexes of presence of public research are calculated both for spending (spending by research organizations, colleges in the agricultural field, grants from the ministry) and for employees. The data used do not take into account the research expenditures of the regions.

The resources devoted by public research to scientific and technological production in the 4 fields studied (agriculture, sea, life sciences and environment) are spread in the following way:

Table 3: Relative weight of public research in each of the regions

Presence of public research	Weak	Average	Strong
Regions	Champagne, Franche Comté, Limousin, Picardie, Basse Normandie, Haute Normandie	Alsace, Bourgogne, Lorraine, Midi Pyrénées, Nord, Auvergne, Centre, Aquitaine	Rhône Alpes, Pays de Loire, Languedoc, Bretagne, Ile de France, PACA.

Public research is spread unequally across the territory in the four fields related to the agro-food sector (all four taken together). Thus, the regions have highly polarized research capacities. Links between the research capacities of the region and the innovative intensity of firms are not at all clear. An overall link appears to exist but the specialization of each region is not correlated with the intensity of firms' innovation.

2.5. Density of the industrial fabric in the agro-food industry and innovation

To explain regional differences in firms' propensity to innovate, it can be assumed that innovations appear in localized clusters. First a leading firm innovates and then others follow suit, especially if they are located close to the first one. We have chosen to describe the industrial district in the agro-food sector in relation to the size of firms: regions in which the density of large firms (>150 employees) is greater than 15% and regions in which the density is lower. We have chosen the threshold of 150 employees to distinguish large agro-food firms because 99% of all firms with over 150 employees innovate. The small firms (20-50 employees) account for 55% of the sample while medium size firms (50-150) account for 30% of the sample. Relatively large firms account for only 15% of the sample.

Table 4: Presence of comparatively large firms (>150 employees)

	Fewer than 15% of the firms with 150 employees	More than 15% of the firms with 150 employees
Region	Limousin, Franche Comté, Languedoc, Basse Normandie, Auvergne, Lorraine, Haute Normandie, Bourgogne, Picardie, PACA, Poitou, Centre, Champagne, Alsace	Midi-Pyrenees, Aquitaine, Rhône-Alpes, Pays de Loire, Nord, Bretagne, Ile de France

Table 4 reveals 2 groups of regions:

. Low density of large firms (LD)

. High density of large firms (HD)

Firms' propensity to innovate (by type of innovation) is related to their size. However, the industrial structure of the region, as described in these two classes, is not linked to their propensity to innovate.

The construction of the three databases gives an idea of the national innovation system in the agro-food industry. These three bases describe all the institutions (public and private) on which the

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innovation dynamics in the agro-food industry are based. They are used to measure the extent to which a regional or national system exists.
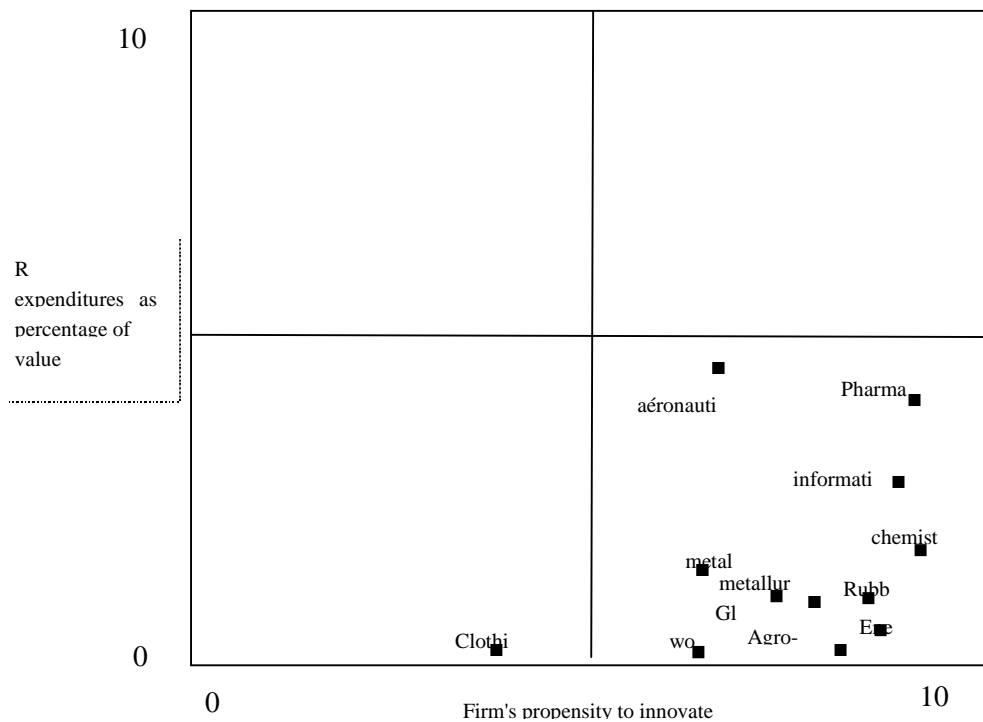
3. Results

3.1. Firms without any formal internal research capacity do not have a weaker propensity to innovate than others

The innovation survey in the agro-food sector, matched with other surveys (on firms, on research in firms, on public research), enables us to map the linkages between the propensity to innovate (all types of innovation versus no innovation) and R&D expenditures in the industrial sector. 70% of firms in the agro-food industry innovate although research spending is very low. The propensity of agro-food firms to innovate is similar to that of firms in high-tech sectors (information technology, electronics, etc.) where R&D spending is greater than 5% of the turnover.

On the one hand, Figure 1 exhibits no significant correlation between the propensity to innovate and the percentage of added value dedicated to R&D.

Figure 1: Propensity to innovate and R&D expenditures in some sectors in France

If one analyses the links between R&D and innovation at the sectoral level, no significant correlation appears. On the other hand, when one examines the relations between the intensity of

firms' innovation (radical, incremental or no innovation) and sources of innovation (defined according to the above clusters), the Chi square test shows that a link does exist. The more intense firms' R&D activity, the more they achieve technological breakthroughs. The example of the agro-

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food sector shows that firms without any formal internal research capacity do not have a weaker propensity to innovate than others do. By contrast, **the nature of their innovations depends on firms' research and absorptive capacities.**

3.2. Intensity of innovations, spillovers and characteristics of firms

Hypotheses H1 (the greater the amount of public research in a specific area, the higher the intensity of innovation) and H2 (only firms which have an absorptive capacity can benefit from public research externalities) can be tested simultaneously. There are two complementary analyses: first, the study of determinants of innovation intensity (radical innovation, incremental innovation and no innovation) and secondly, the analysis of the effects of geographical proximity with public research, or of large innovative firms, on the propensity to innovate. The typology of firms (section 2.3.) reveals the influence of intrinsic characteristics on the propensity to innovate.

The study of the influence of each of the variables which describe the characteristics of firms and the externalities of public research and of other firms in the sector, generates a better understanding of the relative role of factors influencing innovation in the agro-food industry. The method used to analyze the influence of various variables on the dependent variable is a multinomial logout model (Mattel, 1983).

The endogenous variable is the intensity of innovation (radical, incremental and no innovation). The models presented in Appendix 2 compare the marginal influence of exogenous variables on the intensity of innovation. The exogenous variables are grouped into two categories (individual characteristics of firms, and spillovers from public or private research).

Several models are estimated:

Model 1 : Prob(Inno=intensity of innov) = cste + αAVTO + βINVA + γNBE + ε

Model 2 : Prob(Inno= intensity of innov) = cste + αAVTO + βINVA + γNBE + δDENSITY + ε

Model 3 : Prob(Inno= intensity of innov) = cste + αAVTO + βINVA + γNBE + φPUBLIC R&D + ε

All the coefficients α, β, γ, δ, φ describe the marginal influence of a variable compared to the reference group "incremental innovation" of the endogenous variable.

AVTO is value added as a percentage of turnover;

INVA is investment as a percentage of value added;

NBE is the number of employees,

DENSITY describes the percentage of large firms in the region and

PUBLIC R&D the intensity of public research in the region.

- *Individual characteristics of firms*

Our estimates in Table 2 can be summarized as follows:

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1. Compared to firms which have a low AVTO (Added Value over Turnover ratio), firms which have a high ratio get a significantly higher marginal probability to realize radical innovation than to realize incremental innovation. Those which have a high AVTO (Added Value over Turnover) ratio have no significant difference of marginal probability to realize incremental innovation and to realize no innovation.

2. The higher the INVA ratio (Investment over value added), the higher the intensity of innovation is. Firms which have a high INVA ratio have significantly lower marginal probability to realize no innovation than to realize incremental innovation.

3. The higher the number of employees, the higher the intensity of innovation is. It appears to be an obvious relation between the size of the firm and the propensity to innovate. But, in that case, what is called "large firms" describes relatively small companies (over 50 employees). The intensity of innovation is higher (radical innovation) in firm with over 50 employees.

• *Spillovers from public or private research*

1. The proportion of large firms in a region has no relation to the intensity of innovation.

2. The degree of presence of public research in life science increases the probability of having some innovations. The intensity of innovation is not linked with the degree of presence of public research in life science in the geographic area. The presence of academic labs influences the marginal probability of firms to innovate but does not determine the intensity of innovation.

Empirical analysis in Table 5 confirms the relationship between the size of the firm and the intensity of its innovations (radical, incremental and no innovation). There are relations between the firm's propensity to invest (INVA) and its number of employees, on the one hand, and the intensity of innovation, on the other. For the firm's capacity to generate added value (AVTO), the logit model does not enable one to highlight a marginal difference between firms which produce incremental innovations and those which do not innovate. The intensity of innovation does not influence the capacity of the firm to generate added value.

3.3. *Sources of innovation, spillovers and characteristics of firms*

The typology designed in Section 2 is based on the sources of innovation used by firms. To what extent are the characteristics of firms and the spillovers they can benefit from linked to the sources of innovation ? Table 6 presented in Appendix 3 explains a firm's belonging to one of the following classes (1: No sources of innovation; 2: no R&D but engineering studies; 3: purchase of external R&D; 4: all sources except R&D in the group; 5: all sources of innovation). Does the propensity to invest influence membership of a class? Does the number of employees influence the class to which the firm belongs?

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• *Individual characteristics of firms*

The results obtained in Table 6 confirm the typology presented in Table 2 of Section 2.3.

1. As pointed out in Table 2, compared to firms which do not innovate, firms which do innovate do not have a greater capacity to generate added value per franc of turnover, except for class 2, which characterizes firms that produce incremental innovations without R&D.

2. Investments in tangible and intangible capital goods by firms which innovate are significantly greater than those of firms which do not innovate, except for firms in cluster 3 which produce incremental innovations by buying R&D from the outside.

3. The number of employees of firms which innovate is significantly greater than that of firms which do not innovate, for clusters 4 and 5, *i.e.* for firms which have in-house research capacities.

Confirmation has been found of the results obtained in the typology of firms, with significant differences of structure between firms, depending on the sources of innovation they mobilize.

• *Spillovers from public or private research*

1. By contrast, the presence in the region of a high density of large firms does not affect the overall innovation dynamics.

2. In general, the greater the presence of academic labs in a region, the higher the proportion of firms which have done some innovation. But the role of public research depends on the source that firms are using for innovation: The most significant effects are for type 2 firms (no R&D as a source of innovation and incremental innovations) and type 5 firms (all sources of innovation) when the presence of public research is strong, and only for type 2 firms when the presence is average. It seems that firms can benefit from public research of the same region even if the firm has no formal internal R&D but they realize mainly "small" innovations. The geographic proximity allows firms to benefit from the spillovers on an informal basis (advice, use of public research equipment, etc.).

4. Conclusions

The above sheds light on the specific dynamics of local spillovers of R&D and provides us with empirical material to define public policy to support innovation in low-tech. The propensity to innovate of firms in a particular a region is not linked with the density of large firms in the same geographic area. Spillovers from agro-food firms which have research capacity seem to be very low, and firms which have own R&D capacities are more likely to realize radical than incremental innovation.

The presence of academic labs in a geographic area influences the propensity of firms to innovate, but not the intensity of innovation. However, the presence of academic labs in a specific geographic area seems to stimulate mainly incremental innovation in firms. Academic labs seem to

play a role as a catalyst in innovation. They increase the linkages between actors potentially involved in agro-food innovation and allow small firms without any research capacities to innovate. But they provide no specific help to firms which want to realize radical innovation. Spillovers are more technical than scientific in that way. Expertise from public research and access to specific equipment as well as skilled human capital (public research and universities are closely linked) contribute to the production and diffusion of knowledge and know how. It increases the propensity to innovate of SMEs which do not have any internal research.

As public policy supports formal R&D rather than innovation, low-tech SMEs are excluded from public authorities support because they do not have any formal R&D structure. Our analysis shows that academic research plays a role for each cluster of agro-food firms. Such an observation questions the tools which can be used to stimulate innovation not based on internal research. To what extent do subsidies given to academics stimulate innovation? What is the relevant level of intervention by public authorities?

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Appendix 1 : Methodology to Estimate public expenditures by region in life sciences and agro-food sciences

The procedure used to estimate expenditures per region and per scientific fields is based on the matching of three databases:

- resources devoted to research (spending and staff) by research organizations and universities;

- distribution by socio-economic fields and by research organization and university;

- regional distribution of research organizations and universities.

The translation of a scientific discipline into a business sector is a hazardous exercise. We chose to adhere to two principles:

   - firms are capable of using knowledge, equipment and generic research equipment produced by public research in several sectors. In this way we are not, strictly speaking, limited to disciplines related to agriculture.

   - the breakdown into sectors of activity (NAF at INSEE) introduces a significant dead angle. It is not possible to distinguish between equipment manufacturers that are related to the agro-food industry and to what degree, and those that are not. The technology transfer by equipment manufacturers to the agro-food industry remains impossible to capture in firm-level statistics. It is also difficult to map the links between public research in the equipment and agro-food sectors.

The Ministry's databases reveal four fields related to the agro-food sector: agriculture, life sciences, sea and environment. Resources devoted to research are broken down in the following way in terms of region and in terms of fields:

1. Distribution of resources in terms of fields, institutes and scientific departments, for the institutes and scientific departments which state that one of the preceding fields is a primary objective.

2. Sum of spending per objective, per institute.

3. Location of firms, per region.

4. Breakdown of the resources devoted to research, per region and per objective.

5. Calculation of the relative weight of the region.

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Appendix 2 : Intensity of innovations, spillovers and characteristics of firms

The influence of variables is tested to explain the intensity of agro-food firms' innovation[1] (multinomial variable – radical, incremental, no innovation). The characteristics of the model are detailed in the following.

● The endogenous variable covers three categories: radical innovation, incremental innovation and no innovation. The models compare the marginal influence of exogenous variables on the intensity of innovation.

● The exogenous variables are grouped into three categories:

   ● Individual characteristics of firms

   - Ratio of Added Value/Turnover (AVTO) (strong, weak); the break is made at 0.2;

   - Ratio of Investment over value added (INVA) (strong, weak); the break is made at 0.2;

   - Number of employees (fewer than 49, more than 50) ;

In this model, we analyse the structural characteristics of firms rather than the source of innovation. Structural characteristics describe firms in the agro-food industry with no a priori relation to sources of innovation.

   ● Intensity of the presence of public research

   - Public research in the four fields (PUBLIC R&D), divided up into 3 classes: strong, average, weak);

   ● Density of large firms in the industrial district

   - Density of large firms in the region (DENSITY), divided up into 2 classes >15% of the total number of firms and <15%)

We tested several models. All coefficients are compared to the reference group 'incremental innovation'.

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[1] Since the explained variable is qualitative, it is necessary to transform explanatory variables into indicators. Unless otherwise stated, the principle applied is the following : When the variables divide the population into homogeneous groups for a given variable, we noted the values which allowed for this division. Thus, the AV/TO ratio was divided into two classes: strong/weak, with a break at 0.2 – a key value for the division of the populations into two classes.

Table 5: Analysis of the variables that influence the intensity of innovation by the multinomial logistic regression

		Intensity of Innovation	Model 1 Coefficient (St deviation)	Model 1 Probability	Model 2 Coefficient (St deviation)	Model 2 Probability	Model 3 Coefficient (St deviation)	Model 3 Probability
Intercept		Radical/ incremental	-0,200 (0.067)	0.003 (***)	-0.193 (0.067)	0.000 (***)	-0.200 (0.07)	0.006 (***)
		No innovation/ incremental	-0.357 (0.074)	0.000 (***)	-0.366 (0.074)	0.000 (***)	-0.283 (0.07)	0.002 (***)
AVTO	High	Radical/incremental	0.101 (0.06)	0.09 (**)	0.105 (0.062)	0.08 (**)	0.098 (0.062)	0.002 (***)
	High	No innovation/ incremental	-0.083 (0.06)	0.17	-0.088 (0.06)	0.151	-0.106 (0.06)	0.614
INVA	High	Radical / incremental	0.16 (0.06)	0.001 (***)	0.161 (0.06)	0.01 (**)	0.157 (0.06)	0.08 (**)
	High	No innovation /incremental	-0.131 (0.071)	0.06 (**)	-0.134 (0.07)	0.05 (**)	-0.141 (0.07)	0.04 (**)
Nb employee	High	Radical /incremental	0.243 (0.059)	0.000 (***)	0.247 (0.05)	0.000 (***)	0.242 (0.05)	0.000 (***)
	High	No innovation /incremental	-0.227 (0.059)	0.000 (***)	-0.228 (0.05)	0.001 (***)	-0.221 (0.05)	0.002 (***)
DENSITY	<15	Radical /incremental			0.0375 (0.05)	0.531		
	<15	No innovation /incremental			-0.0423 (0.058)	0.467		
PUBLIC R&D	High	Radical/incremental					0.035 (0.08)	0.669
	High	No innovation /incremental					-0.191 (0.08)	0.017 (***)
	Medium	Radical/incremental					-0.053 (0.086)	0.535
	Medium	No innovation /incremental					-0.166 (0.081)	0.043 (***)
Likelihood ratio			DF=8	0.346	DF=22	0.220	DF=36	0.184
Number of observations	1785							

*** Significance 1%, ** significance 5%, * significance 10%

How to read Table 5

1. The likelihood ratio gives the general quality of the model. Thus, Model 3 appears to have a better quality than the others.

2. To read each line, the significance has to be interpreted as follows: for example, in Model 1, variable AVTO. Compared to firms which have a low Added value on turnover ratio, firms which have a high ratio have a significantly higher marginal probability to realize radical innovation than to realize incremental innovation. Those which have a high AVTO ratio have no significant difference of marginal probability to realize incremental innovation and to realize no innovation.

Appendix 3 : Sources of innovation, spillovers and characteristics of firms

The endogenous variable is the firm's belonging to a class. Exogenous variables are the characteristics of the firm, the density of large firms in the industrial fabric and the degree of presence of public research. The data are interpreted as a marginal probability in relation to class 1 (no source of innovation). The endogenous variable are the same as in Table 5.

Table 6: analysis of the variables that influence the presence in a cluster by the multinomial logistic regression

			Model 1		Model 2		Model 3	
		Presence in cluster n°	Coefficient (St deviation)	Probability	Coefficient (St deviation)	Probability	Coefficient (St deviation)	Probability
Intercept		Cluster 2 /cluster 1	-1.22 (0.099)	0.00 (***)	-1.22 (0.10)	0.00 (***)	-1.39 (0.11)	0.00 (**)
		Cluster 3 /cluster 1	-1.12 (0.099)	0.00 (***)	-1.11 (0.09)	0.00 (***)	-1.21 (0.10)	0.00 (***)
		Cluster 4 /cluster 1	-0.63 (0.08)	0.00 (***)	-0.62 (0.08)	0.00 (***)	-0.68 (0.08)	0.00 (***)
		Cluster 5 /cluster 1	-0.60 0.08	0.00 (***)	-0.60 (0.08)	0.00 (***)	-0.68 (0.08)	0.00 (***)
AVTO	High	Cluster 2 /cluster 1	0.14 (0.08)	0.10 (*)	0.14 (0.08)	0.10 (*)	0.15 (0.08)	0.09 (**)
	High	Cluster 3 /cluster 1	0.04 (0.08)	0.61	0.04 (0.08)	0.61	0.04 (0.08)	0.57
	High	Cluster 4 /cluster 1	0.09 (0.07)	0.18	0.09 (0.07)	0.19	0.09 (0.07)	0.18
	High	Cluster 5 /cluster 1	-0.05 (0.07)	0.42	-0.05 (0.07)	0.42	-0.05 (0.07)	0.44
INVA	High	Cluster 2 /cluster 1	0.18 (0.09)	0.06 (**)	0.18 (0.09)	0.05 (**)	0.19 (0.09)	0.04 (***)
	High	Cluster 3 /cluster 1	-0.03 (0.09)	0.78	-0.02 (0.09)	0.78	-0.02 (0.09)	0.87
	High	Cluster 4 /cluster 1	0.24 (0.08)	0.02 (**)	0.24 (0.07)	0.00 (***)	0.25 (0.07)	0.00 (***)
	High	Cluster 5 /cluster 1	0.29 (0.08)	0.00 (***)	0.29 (0.07)	0.00 (***)	0.30 (0.08)	0.00 (***)
Nber employee	High	Cluster 2 /cluster 1	0.05 (0.08)	0.58	-0.60 (0.08)	0.00 (***)	0.04 (0.08)	0.61
	High	Cluster 3 /cluster 1	0.13 (0.08)	0.09 (**)	0.04 (0.08)	0.61	0.12 (0.08)	0.10 (*)
	High	Cluster 4 /cluster 1	0.34 (0.069)	0.000 (***)	0.13 (0.07)	0.08 (**)	0.34 (0.06)	0.00 (***)
	High	Cluster 5 /cluster 1	0.72 (0.07)	0.000 (***)	0.35 (0.06)	0.00 (***)	0.71 (0.07)	0.00 (***)
DENSITY	<15	Cluster 2 /cluster 1			-0.03 (0.08)	0.72		
	<15	Cluster 3 /cluster 1			0.03 (0.07)	0.61		
	<15	Cluster 4 /cluster 1			0.05 (0.06)	0.43		
	<15	Cluster 5 /cluster 1			-0.01 (0.07)	0.82		
PUBLIC R&D	High	Cluster 2 /cluster 1					0.38 (0.12)	0.00 (***)
	High	Cluster 3 /cluster 1					0.21 (0.11)	0.05 (**)
	High	Cluster 4 /cluster 1					0.18 (0.09)	0.09 (**)
	High	Cluster 5 /cluster 1					0.26 (0.09)	0.00 (***)
	Medium	Cluster 2 /cluster 1					0.24 (0.12)	0.05 (**)
	Medium	Cluster 3 /cluster 1					0.17 (0.11)	0.12
	Medium	Cluster 4 /cluster 1					0.06 (0.09)	0.48
	Medium	Cluster 5 /cluster 1					0.08 (0.10)	0.42
Likelihood ratio	DF = 8		DF=16	0.322	DF=44	0.222	DF=72	0.632
Number of observations	1785							

*** Significance 1%, ** significance 5%, * significance 10%