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Profile of public laboratories, industrial partnerships and organisation of R&D: the dynamics of industrial relationships in a large research organisation [1]

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Abstract

There is a paucity of papers dealing with the system characteristics of laboratories or, put in another way, the institutional character of research organisations. Neither R&D economics nor the sociology of science, as traditionally conceived, has made much headway in providing insight into sets of R&D laboratories and their evolution. Drawing upon an empirical study in the plant breeding and biochemical industry, this paper presents a typology of public research laboratories which is based on three dimensions: scientific production and visibility, type of funding (public or private) and homogeneity of research themes. Three types of public laboratory emerge: the first, called "research centres for the profession", is composed essentially of laboratories with close ties with small and medium firms (SMEs) and industry associations. The second, called "designers of generic tools and methods", is oriented towards basic research and themes of general interest to the industry as a whole. The third type, called "basic and specialised laboratories", strives to develop its scientific visibility. Contracts between this type of laboratory and industry are mainly bilateral and demonstrate the complementarity between public and private research.

Each type of laboratory develops specific types of relationship with private partners. The authors have identified three logics underlying these relationships: proximity, market and club. The main objective of contracts based on a proximity logic is to test a hypothesis, while the knowledge produced is mostly tacit and specific. By contrast, knowledge is entirely coded and specific in the market logic, where the aim of the contract is to implement expertise in order to relieve a scientific bottleneck. In a club logic, the aim of contracts is to produce a technical referent. In each kind of contract, the learning trajectories, modes of co-ordination, role of trust and degree to which contracts are complete or not, are different.

1. Introduction

Based on a detailed analysis of public research laboratories' relations with industry, this contribution challenges certain stereotypes on which the economics of technological change is founded. It also highlights the various learning trajectories of public laboratories.

Generally speaking, stereotypes are highly resistant, especially when they are part of a secular

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scientific tradition. This very broad assertion is particularly relevant to the economic analysis of research laboratories. Relying on Mertonian sociology, economists thought for a long time that research laboratories were governed by behavioural norms which were independent of economic rules. Scientific production was thereby excluded from the economic field.

The entry of science into the economic sphere was based on two broad distinctions: fundamental research versus applied research, and public research versus private research. The separation between applied and fundamental research has been challenged by the emergence of models emphasising the interaction between the different phases of scientific and technological production. The most well-known of these is unquestionably the "chain link model" proposed by Kline and Rosenberg (1986). The division between public and private research has, however, lasted longer. In 1959, R. Nelson indicated that the uncertain and largely unappropriable nature of fundamental research resulted in a lack of investment from the private sector, which had to be offset by the State (Nelson, 1959). The justification for public support is rooted in the intrinsic characteristics of the knowledge produced, situated outside the economic sphere. Very recently, M. Callon (1994) showed that public support for scientific production can be justified because it permits a necessary degree of variety and flexibility to be maintained, and not because science is a public good. By emphasising the historicity of trajectories, he shows that the State alone can invest enough to preserve the diversity which keeps the entire field of possibilities open.

The sociology of science places research laboratories at the centre of the study of science in the making. We define the research laboratory as an entity which has autonomy both in the definition of its research programmes and in the conduct of its research. A laboratory could be composed of one, two or three different teams (a team is a homogeneous entity specialised in one scientific theme). From a hierarchical point of view, both laboratories as a whole and researchers as individual persons are evaluated. In our sample, all research laboratories belong to INRA, the French National Institute for Agronomic Research – a public organisation. The study is based on the analysis of 20 laboratories in two research departments: genetics and plant breeding on the one hand, and glucide and protein technology on the other. Each laboratory has between ten and 40 staff members. As public laboratories, they receive annual subsidies which cover salaries, general infrastructure (office, secretary, etc.) and a part of the acquisition of research materials. Additional funding has to be found to be able to develop research programmes.

To understand the logic and effects of the relationship between public laboratories and industry, three modes of analysis are proposed:

- the use of bibliometric tools to assess the production of scientists in public research organisations;
- the use of financial data bases to analyse laboratories' funding;
- the use of interviews to assess laboratories' degree of autonomy in determining their research themes.

We compiled a data base of 182 contracts between public laboratories and industry. [2] By computing original data from this data base, we were able to understand the logic and effects of this kind of contract. [3]

The observation of public laboratories helps to explain how scientific themes are constructed from the accumulated expertise of researchers and from strategies for securing access to resources. In order to obtain the resources they lack, researchers have to ally themselves with the players who have such resources. These may be financial, of course, but may also include biological materials, technical devices, industrial credibility, academic recognition, human resources or simply justification for the social usefulness of their research. Researchers have thus grasped the opportunity offered by relations with industry to complete their public funding while participating in the economic competitiveness of firms. They try to adapt their scientific research themes in

[2] Here, industry is defined in a very broad sense: we have included all contracts between INRA and other organisations, whatever the status of the other organisation (public or private). Contracts between INRA and a private organisation can be subsidised by the EC, the government or the region.

[3] Although we interviewed 14 R&D managers in the industry, our sample remains limited to seed and plant breeding industry and research.

relation to the network and relationships in which they are involved. In most cases, there is a co-determination of scientific themes and networks of partnerships. Research themes are often shaped by the new outlooks that industrial relationships generate. We show how these different mechanisms impact on the strategies of public laboratories, in respect to their 'industrial relationship logics'. The choice and orientation of scientific themes are part of a long-term process. The laboratory seems to be a place in which a logic of scientific production and relations with the outside merge in the most harmonious way possible.

The information gathered on the strategies of public research laboratories, [4] enabled us to test the following two hypotheses:

H1: the field of scientific options is not independent of a laboratory's relations;

H2: a laboratory's independence vis-à-vis industry cannot be measured in terms of its financial independence, but rather in terms of its autonomy in its choice and definition of research themes.

Our empirical study provides new elements enabling us to identify relations between the different modes of co-operation and the choice of scientific themes. A laboratory's financing, its role in economic life, its relations with firms and the nature of its scientific production are all closely related. Hence, the management of modes of learning and appropriability depends on a laboratory's type of relations (bilateral or multilateral) and its 'industrial relationship logic'. [5]

In the first section we considered it necessary to place our empirical analysis in a more general theoretical context. When the traditional vision of the 'great divide' between open science and private science is taken as a reference, a study of public laboratories' industrial relationships is greatly reduced. By assuming that the logic behind the production of knowledge is different in both cases, [6] one prevents oneself from thinking in terms of the structuring effects of industrial relationships on the scientific activity of laboratories. The research laboratory is then not a relevant unit for analysis. By contrast, if the new concepts of innovation (produced by the sociology of science and the economics of technological change) are taken as a reference, the study of laboratories appears as a priority field for investigation.

In Section 3, we present the empirical data on which our analysis is based. The typology of research laboratories is coupled with a typology of industrial relationship logics.

We then show, in Section 4, how the different industrial relationship logics have unequal effects on the dynamics of learning and appropriation of each partner.

2. The inadequacy of economic literature

From a theoretical viewpoint, the challenging of linear innovation models leads to an analysis of the interactions between these places where scientific and technical knowledge is produced, on the one hand, and the players who use this knowledge as a lever in innovation strategies, on the other. Moreover, the sociology of science has changed profoundly since the end of the 1970s. In a clear break with Mertonian theories, it prompts the social sciences to analyse 'science in action'. [7] Considering that the nature of ideas, knowledge and scientific theories is not independent of the context in which these are produced, many authors focus their research programme essentially on the functioning of laboratories. There is, however, a striking contrast between the wealth of analyses and results produced by sociologists of science, and the absence of research laboratories in the economics of technological change.

The first objective of this section is to explain that discrepancy. In our view, it can be ascribed to the dual dichotomy (distinction between science and

[4] The distinction made here between public and private research is based solely on the institutional affiliation of the observed laboratories. In no way does this distinction indicate the nature of the knowledge produced.

[5] Translator's note: The authors use the term *logique relationnelle*.

[6] In the one case, priority and peer-recognition and, in the other, appropriability, secrecy and sanctioning by the market.

[7] Latour and Woolgar (1979) and Latour (1987).

technology on the one hand, and between public and private research, on the other) underlying entire sections of economic analysis (Section 2.1). Numerous analyses emphasising the role of learning and tacit knowledge in the innovation process show that this division is more the fruit of out-dated theoretical conceptions than of sound empirical observations (Section 2.2). Thus, despite the present deficiency of economic analyses, it is necessary to identify research directions for economists which draw upon the observations and results of the sociology of science but have their own methods and conceptual devices (Section 2.3).

2.1. A deep-rooted traditional concept – the distinction between public and private research

Concepts developed by both sociologists and economists until the mid-70s all neglected research laboratories. Indeed, Mertonian sociology, which dominated the discipline for a long time, was based on the following three precepts:

1. the functioning of the scientific community is founded on specific rules (e.g. peer recognition, priority rules in publications) which distinguish it clearly from economic activities;
2. nevertheless, an analysis of the functioning of this community may borrow the idea of competition from the economic model (e.g. being first is a precondition for success);
3. one of the means of gaining positions of strength and mobilising resources is *reputation*, acquired in the *community of specialists*.

Clearly, such an analytical framework excludes the laboratory as an object of analysis. The reference framework in which competition takes place is a broad research community; access to it depends merely on the community's rules, and not on local arrangements which can be observed on a laboratory level.

Economic analysis, on the other hand, when it examines research (a recent phenomenon!) is characterised by a dichotomy which Richard Nelson's seminal article (Nelson, 1959) summarises perfectly. In his economic analysis of basic research, Nelson identifies three essential properties: limited appropriability (due to the generality of the knowledge produced), uncertainty about results and very slow returns on investments. He therefore considers that fundamental research projects have intrinsic characteristics which in themselves discourage private investment. Since market forces are thus unable to attract sufficient funds, the State has to finance public research. In this analytical framework the economic problem is very simple: it amounts to defining the 'natural' border between fundamental and private research, and financing the former with public funds. This type of representation is all the more acceptable since, as Kenneth Arrow's illuminating article (Arrow, 1962) shows, research is then generally classed as the production of information. The only consideration is production costs, circulation and reproduction costs being treated as negligible. [8] For Arrow, the costs of using information (imitation) are therefore negligible. This representation has the significant advantage of concentrating on the position of the border rather than on its nature.

The two above-mentioned texts suffice to identify the following features of a deep-rooted conception of research in economic analysis:

- scientific production is outside the economic sphere;
- it is governed by rules and behavioural norms which are independent of the rules of the economic sphere.

Economists are therefore not obliged to take into account the players who produce scientific knowledge. All that counts is the distinction between fundamental and applied research (a distinction determined by intrinsic characteristics) and the financing of the former with public funds.

Although outdated, this type of representation remains present in recent literature. For example, even though they consider that the division in research is an institutional creation rather than an intrinsic feature of expertise, Dasgupta and David base their analytical model on the distinction between open science and private science. The two systems of research are each distinguished by a different logic of functioning (we recognise Merton's legacy, claimed explicitly by the authors). While the stock of knowledge is increased by means of the

[8] Hence, the three problems identified by Arrow to show market deficiencies: appropriability, indivisibility and uncertainty.

former, it is circulated and used by means of the latter. If the efficiency of the system as a whole is to be maintained, the distinction between the two spheres should also be maintained to a degree (Dasgupta and David, 1994). In their study of universities and industry in the United States, Rosenberg and Nelson reach similar conclusions. Despite an effective hybridisation of certain research, it is "necessary to respect the division of work between universities and industry" (Rosenberg and Nelson, 1994).

Similar considerations appear in the debate on research policy. For example, controversy surrounds the issues of science in the service of competitiveness and, more specifically, the control of academic research by industry in the biotechnology field (Kenney, 1986).

Our aim here is not, however, to take a standpoint with respect to general research policy arguments. Of more interest to us is the fact that traditional concepts seem to have made it possible to avoid examining laboratories as players in technological change.

2.2. *Research, tacit knowledge and learning – a fuzzy border between science and technology*

The large amount of empirical research undertaken since the 1960s progressively led to a revision of the conceptions discussed above. [9] Two principal conclusions are relevant to our study: (i) research does not produce information but knowledge, of which some is coded and other tacit; (ii) when knowledge is tacit, learning processes are localised and cumulative.

Mansfield's work on imitation shows, for example, that the costs involved are considerable; on average they account for 60% of all innovation costs. A general explanation for this observation is given by Cohen and Levinthal. The 'degree of spill-over', [10] they argue, depends on both the *nature of knowledge* and the *absorptive capacity* of firms (Cohen and Levinthal, 1990). All things being equal, the more knowledge is codified, the easier its absorption will be. Tacit knowledge is extremely localised and circulates very badly. Nevertheless, even in the case of coded knowledge, the user needs certain know-how and technical devices to benefit from the knowledge. [11] From this point of view, research activity has two complementary facets: it naturally contributes to the creation of information and knowledge, but it is also a learning process which helps to increase absorptive capacity. Not only are externalities not evenly distributed, they increase when the knowledge bases of firms are similar. [12] In such a context, external research cannot be substituted for internal research; the two are complementary. [13]

Rosenberg uses a very similar argument to explain why large firms, despite difficulties in protecting results, finance their own fundamental research (Rosenberg, 1990). To appropriate the results of academic research, even when it is coded, one has to 'know the code'. A firm's fundamental research makes it possible to translate the knowledge produced by academic research into terms that are usable in internal research. Its role is more to act as an interface, to enhance the absorptive capacity, than to produce original knowledge.

These works undermine the idea of science as a public good, still so present in the minds of numerous economists. Their conclusions hardly differ from those of the sociology of science, as Michel Callon so eloquently shows in a recent text (Callon, 1994).

Thus, not only is the border fuzzy, owing to the amount of hybridisation between fundamental and applied research, particularly in new technologies such as biotechnology, (cf. Joly and Ducos, 1993),

[9] Cf. the surveys by Dosi (1988).

[10] 'Degree of spill-over' can be expressed as the percentage of a firm's research which has a positive impact (for example in terms of cost reduction) on another firm. On these points see Joly (1992).

[11] Such an idea is incorporated in patent law which states that the obligation to provide an adequate description is appreciated by the man of the art. The case of biotechnologies, for example, generally concerns a team of doctors in molecular biology with all necessary instruments. The obligation to divulge knowledge is respected, but it is only accessible to entities with a very high absorptive capacity.

[12] On this point, see Jaffé's empirical work (Jaffe, 1986).

[13] Levin and Reiss (1986) reach the same conclusions by means of a different argument: when knowledge forms 'building blocks', external research creates technological opportunities which increase the marginal returns of internal research.

but the environment itself in which scientific and technological knowledge is produced and used is not uniform and amorphous. [14] It is structured by relations of proximity formed over time, the consequence of events and players' decisions. In this context laboratories are necessarily a focal object of research.

2.3. *The laboratory as an object of research*

The above conclusion comes as no surprise to sociologists of science who adopted the same position almost 20 years ago! It is, however, necessary to specify the main lines of research which show the validity of the approach from the viewpoint of economic analysis.

Knorr-Cetina accurately sums up the contributions of the sociology of science (Knorr-Cetina, 1982). In a clear break with Mertonian sociology, the analysis of 'science in action' challenges the idea of communities of specialists as a framework of reference for building up a reputation. If we consider that the production of scientific knowledge depends on the local organisational context, then the observation of laboratories helps to understand how scientific problematics are built from strategies for gaining access to resources. To account for this phenomenon, Knorr-Cetina introduces the notion of 'transepistemic arenas of research'. The selection of scientific research themes is not the doing of scientists alone. In their strategies for securing access to the resources they need, the latter are led to form partnerships and to 'translate' the needs of other players. Durable relationships permitting access to strategic resources therefore influence scientific work. In this context the traditional division between that which is scientific and that which is not, is irrelevant. Scientific production mobilises people, objects and ideas which belong to both worlds and frequently cross from one to the other. For this author the 'transepistemic arenas' are the relevant analytical levels of scientific production. (i) They embrace both the scientific and the non-scientific and (ii) from the study of laboratories one can locate them by identifying their relations with other entities, since they are organised according to players' strategies for obtaining resources.

These results and conceptual models have had a determining impact on the development of the sociology of science. They can similarly orientate the economic analysis of scientific production. Within this framework the approach which focuses on laboratories and their local networks must play a major role.

Very little empirical work has been devoted to the subject. Yet this constitutes a necessary step in testing the first hypotheses and constructing stylised facts.

Crow and Bozeman's article (Crow and Bozeman, 1987) proposes a break with traditional classification in which public laboratories undertook fundamental research and industrial laboratories applied research. Informed by a study of 32 laboratories, they show that the nature of research products (generic products with the characteristics of a public good or appropriable products intended for private use) depends more on the mode of financing research than on its institutional attachment. Some public laboratories function with private funds and therefore focus on research which is largely appropriable, while some private laboratories depend on public funds for their very survival.

The diversity of laboratories and the heterogeneity of their production appears as one of the main characteristics reflecting a highly contrasted image of scientific production. To account for this diversity, one of the most complete propositions is that of Callon et al. (1994). They propose describing research activity and results according to five main dimensions, which they call the compass card of research. To the production of certified knowledge (articles, books, theses, conferences) are added educational activities. Research also participates in a process of creation of economic value resulting in innovation, in activities of general interest whose finality is more diffuse, and in activities related to popularisation and expertise. Recognising the diversity of research activities and defining quantifiable indicators for measuring results are the first steps towards the identification of research laboratories as a constituted entity. The characterisation of their production is a necessary, although insufficient, condition for focusing analysis on research laboratories.

[14] J.L. Gaffard (1991) provided an interesting contribution in *L'évaluation de la Recherche et du Changement.*

Their diversity, to which the description indicators defined in Callon's work bear witness, does not seem to be a result of academic or industrial attachment alone. It can also be explained by means of other factors which need to be identified.

Relations between public and private research have been the subject of numerous papers. We look only at a limited number of works on the organisation of co-operation and the modalities of co-ordination. M. Cassier (1992) uses an extensive case study of contracts between the *Université de Technologie de Compiègne* and its industrial partners to explain the development of modes of co-ordinating university/industry research contracts. He notes the co-existence of two types of contractual research. One is based on a logic of diffusing the results accumulated by the laboratory, while the other consists of a dynamic process of joint creation, on more fundamental themes which are less directly applicable by the firm concerned. This duality in the type of research is also found in modes of organisation where commercial and non-commercial agreements complement one another. M. Cassier notes that only a part of university/industry research contracts corresponds to an R&D purchase on the market. Certain exchange amounts to a subsidy from the firm to the laboratory, with the firm expecting a right of access to the laboratory's network, rather than a specific service. Similarly, firms and public laboratories maintain numerous relations which are not based on commercial exchange but on the rules and norms of reciprocity. The research agreements studied by M. Cassier correspond to a model of 'unified technological research' [15] that allows for two types of output: one towards the academic world (e.g. articles, theses) and the other towards the industrial world (e.g. methods, patents). They clearly show that the only existing division is expressed in terms of results from unified technological research. Laboratories, whether in industry or in a university, participate in scientific and technological production in a relatively uniform fashion, notably in research procedures.

T. Gonard and T. Durand have investigated the conditions in which co-operation is effective (Gonard and Durand, 1992). Taking a case study of 32 industrial partnerships, they show that the effectiveness of co-operation increases when it involves ordinary innovations, as opposed to radical innovations. Similarly, the existence of a stable and clearly identified community of scientific or industrial players favours co-operation by reducing opportunistic behaviour.

These works provide useful indications to enhance the value of the laboratory as an object of analysis, yet their results are incomplete. In particular, they fail to deal with relations between the dynamics of the laboratory and the construction of networks, despite one of the main results of the sociology of science having been to highlight such relations. As a result of such deficiencies, our research is oriented towards three main goals:

1. the identification of relations between scientific strategies and types of insertion in networks;
2. the study of links between the modalities of relationships with outside partners (forms of co-ordination) and learning on a laboratory level;
3. the analysis of laboratories' development trajectories.

3. Laboratories at the core of networks

Our empirical study, [16] carried out in two departments of INRA, examined the strategies of 20 public research laboratories. This study enabled us to trace the different types of logic of the various laboratories that can influence the formalisation of relations between public and private research through contracts. Four complementary methods enabled us to classify laboratory types and put forward certain hypotheses on the evolution (dynamics) of industrial relationships. For the period 1988–1992, a bibliometric analysis of the publications of each laboratory gave an initial idea of the academic production of scientists per type of journal (basic research, strategic basic research, engineering and applied sciences). An

[15] The author speaks of "Recherche technologique unifiée".

[16] Estades et al. (1994).

analysis of the different types of funding and their evolution, in particular by separating automatically renewable grants and incentive grants, gave us insight into laboratories' strategies for obtaining resources, both from the organisations to which they belong and from firms. Interviews with the directors of the laboratories gave an idea of the strategies adopted vis-à-vis industries. A data base of 182 contracts between the laboratories of the national institute and the private firms concerned enabled us to identify the genesis of the industrial relationships (from the viewpoint of public research), the co-ordination modalities of co-operative research activities, and the nature of the exchange. We were thus able to appreciate the diversity of different types of industrial relationships. Finally, interviews on the determinants and modalities in the organisation of external R&D were held with 14 corporate managers.

3.1. Diversity and homogeneity of laboratories – trial of typology

After estimating the laboratory size and the proportion of researchers/engineers and technicians, we defined several indicators to evaluate the researchers' production. The number of publications per researcher per year, as well as the number of publications per year referenced in the Science Citation Index were calculated. The combination of these two criteria gave us an idea of the degree of academic recognition enjoyed by the laboratory's researchers. The type of journal in which these researchers published made it possible to specify whether they were visible in predominantly fundamental or applied research networks.

A laboratory's degree of financial dependence was estimated by means of the ratio of contract-generated revenue to State-supplied funds. Laboratories were considered as financially dependent if the major part of their revenue was contract-generated (salaries excluded). The degree of variability of contractual revenue from one year to the next was an indicator of the control that laboratories had over external resources. We are implicitly assuming here that the laboratories' objective was to have a steady source of income. The lower the variability, the greater their control over external financial resources would be.

The origin (public or private organisation) of the person who introduced the questions studied in the contracts was one of our main themes during interviews with the researchers working on the contracts. We wished to ascertain whether industrialists had a significant say in orienting research, or whether researchers tried to obtain funds for research projects of their own choosing. If we found that industrialists had proposed the research themes in the majority of a laboratory's contracts, and if the majority of that laboratory's publications were on applied research, we considered that the themes were oriented by industry. If, on the other hand, we found that the researchers proposed their own themes to the industrialists, and that their publications dealt with fundamental research, then we considered the logic of scientific production to be dominant. In cases where publications on basic research were combined with a strong presence of industrialists in the determination of research themes, we considered that the researchers were able to translate scientifically the predominantly technical demands of industry. Finally, where applied research was accompanied by little consideration for industrial demands, the themes were considered as variable.

The type of partnership was perceived according to a binary logic: contracts were either bilateral or multilateral. Indications on access to international networks were also noted, both on an academic level (amount of international co-operation on publications) and an industrial level (presence of foreign partners in the contracts).

Finally, the number of contracts receiving subsidies was calculated and the identity of the sponsors noted: EU, State, region, other.

The 20 laboratories studied were classified according to all these criteria. We tried to group together similar laboratories, without taking into account their affiliation with specific departments.

3.2. Compatibility between thematic independence and financial dependence

By following the conclusions reached by Crow and Bozeman (1987), we expected to see the emergence of modes of financing as a highly discrimina-

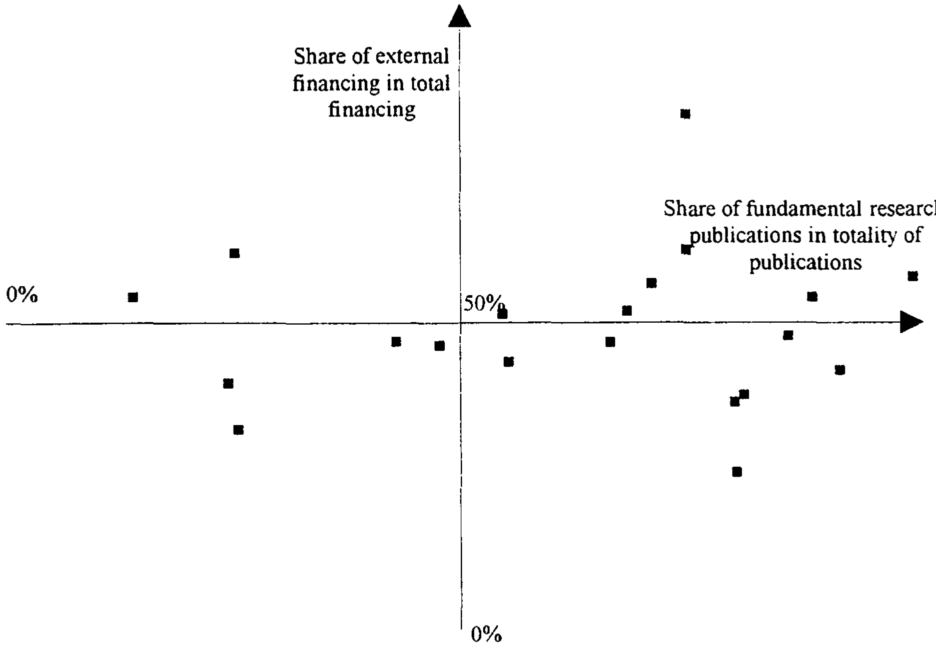

Fig. 1. Production of basic knowledge and private contracting are compatible. The borderline fixed at 50% corresponds in both cases to the means.

tory axis in the typology of laboratories. Yet, this variable was far less obvious than the thematic criterion.

Fig. 1 clearly shows that basic research is compatible with a strong tendency to enter into contracts with private industry. Amongst the 14 laboratories in our sample involved in the production of basic research, the rate of private funding (excluding salaries) was over 50% for seven laboratories. The dependence/independence axis was almost identical to that of the degree of assertion of research themes. This situation can easily be explained. A laboratory whose scientific approach is recognised by its peers, has more negotiating power than a laboratory with little peer recognition. Thus, a laboratory with a speciality that is well-known and recognised in the scientific world will benefit from its own dynamics. Partners [17] will turn to it for help in solving problems or formulating unanswered questions. Since the laboratory identifies firms which may need its specialised skills, and firms in turn identify the laboratory's skills, we can consider that the industrial relationship is based mainly on specialised exchange – even if the relationship is sometimes subject to fluctuations, possibly leading to financial dependence.

In contrast, if a laboratory's research themes are poorly displayed, appear vague or are effectively vague, it will receive diverse orders through a number of interpersonal and professional networks. In order to handle them the laboratory will have to mobilise resources, which will prevent it from focusing on a specific problem. Publications will appear dispersed, dealing with a variety of themes, and researchers will lack time to publish. Contracts will often be short, involving small amounts, and the researchers will have to make a huge effort to find, negotiate and realise them.

[17] Based on our interviews with R&D managers of firms, we make the implicit assumption that R&D managers are able to assess the academic position of a laboratory. That does not mean that all firms have scientometric specialists. But, owing to their participation in conferences, workshops and so on, and to their involvement in scientific networks, it is quite easy for a R&D manager to have precise information on the scientific credibility of a laboratory.

Dependence and independence are in fact the two extremes of a continuum based on the dynamic processes of self-reinforcement. Whether it is a product of the history of recruitment or of relations with industry, a speciality was at some stage adopted by the laboratory whose reputation relies on it. A number of researchers work on the theme and participate in numerous congresses, workshops, seminars and conferences. They build up relationships with potential partners (public or private) and develop contacts abroad. In short, they are present in the field and appear unavoidable. More often than not this presence is characterised by a fundamental profile in their publications, even if that element is not indispensable.

The second axis enabling us to define a typology of laboratories is the bilateral or multilateral nature of contracts. The type of partnership and contract affects exchange between the laboratory and its associate(s) as well as conditions of appropriation and exchange during the contract. Multilateral contracts involve one or several INRA laboratories, possibly a public partner (a sponsor), a technical centre and a group of firms specialised in the seed industry. Research deals with a specific, well-defined vegetal species. Exchange concerns knowledge, methods and vegetal material. The contracts are accompanied by financial transfers from the private to the public sector. In most cases they are backed by the State or regional authorities. The regime of appropriation may be considered as weak, [18] since a part of industry has access to the same expertise. In this context a firm's knowledge base plays an important role, since the capacity to absorb new knowledge depends on expertise accumulated earlier.

Bilateral contracts vary. They may involve the supply of specialised services, in which case relations with INRA are bi-unique since industries buy research which they cannot undertake internally. By contrast, INRA and its partners may conduct research together, each supplying its own specific expertise. This type of contract often results in a thesis in the form of a Cifre agreement [19] or co-financing. In each of these cases, the regime of appropriation is strong. Negotiations concerning industrial property rights are often lengthy, as are discussions about publishing conditions.

3.3. Typology of laboratories and dynamics

The typology of laboratories and that of industrial relationships are based on empirical data collected in a particular sector: the plant breeding and biochemical industry. They are clearly limited to this sector. However, the kind of dynamic and mechanism described has a larger degree of generality, even if additional data are needed to extend the degree of validity precisely. Data collected from interviews with researchers and laboratory directors, computation of scientometric and financial data, and exploitation of the contract survey formed the basis of our analysis and our typology.

The combination of these two axes brings to light four types of laboratory (shown in Table 1) which all have a relatively similar mode of operation.

The *first type*, (weak independence concerning choice of themes; multilateral contracts) called "*research centres for the profession*" [20] is composed essentially of laboratories with close ties with small and medium firms (SMEs) and industry associations. Researchers are alone or grouped into small teams to work on a particular species.

The *second type* (strong independence concerning choice of themes; contracts with institutions: foundations, public authorities, etc.) is represented in each department. Laboratories are oriented towards fundamental research and work on themes rather than on species. The declared objective is often to make fundamental research or generic tools available to SMEs and industry associations. We shall call these laboratories the "*designers of generic tools and methods*".

In the *third type* of laboratory, most of their contracts are bilateral and research is generally fun-

[18] According to the definition proposed by Teece (1986).

[19] Translator's note: A research agreement in terms of which a Ph.D. student is paid by a firm to work in co-operation with a university laboratory.

[20] Profession is defined as an informal body in which both public institutions and private enterprise are participating.

Table 1
Characteristics of different types of laboratory. Number of observations in parenthesis[a]

Variables	Research centres for the profession (4)	Designers of generic tools (9)	Basic and specialised labs (4)
Academic recognition and visibility (scientometric data base)	Weak, the main objective is to improve vegetal material and procedures	It is a highly visible objective. Recognition can be for both fundamental and applied research	It is the basis of this type of laboratory. Academic recognition is essentially for fundamental research
Financial dependence (financial data base)	Relatively insignificant	The laboratories are financially dependent but control external funds	Financial dependence
Critical resources (interviews with researchers)	Strong need for personnel for performing experiments	Strong need for qualified personnel (engineers)	Mostly Ph.D. students
Themes (interviews with researchers about the contracts they manage; contracts survey)	Multiple themes; general improvement of plants available to everybody is more important than the pursuit of a scientific logic	The scientific logic predominates but the laboratories remain attentive to the preoccupations of SMEs and industry associations	Retranslation of questions in scientific terms
Contracts (contracts survey)	Multilateral, accompanied by subsidies	Multilateral (in a leading position) and bilateral (easy access to subsidies)	Bilateral. Few subsidies
Foreign relations (contracts survey)	Relatively insignificant	Relatively insignificant	Insertion in international academic networks

[a]The sum is less than 20, since three laboratories fall into the fourth category called ''mutating laboratories''. These are laboratories in the process of changing.

damental. We call them "*basic and specialised laboratories*".[21]

Questions concerning industry seem to relate mainly to the *fourth type* of laboratory. Often newly created or undergoing profound change, these laboratories still have difficulty defining a structuring theme. We call this group "*mutating laboratories*".

Besides the above criteria, these different types of laboratory seem to be animated by different logics concerning their production and ways of obtaining value from that production. Hence, their ambitions, objectives and strategies differ.

3.3.1. Type 1: research centres for the profession

The main aim of research centres for the profession is to make available, to SMEs and industry associations as a whole, improved, high-yielding strains of plants which are resistant to disease and other types of stress. In certain cases INRA plays the leading role, notably when research concerns small species seldom worked on in private laboratories. In other cases INRA assists private breeders in improving plant strains. Its researchers are receptive to the industry's needs and determine their research themes accordingly. Work is carried out by small teams of highly specialised researchers who maintain a symbiotic relationship with SMEs and industry associations. A considerable amount of exchange does not have a contractual basis. This often concerns an exchange of vegetal material or 'little tips', or the lending of parcels of tests. The natural way to obtain value[22] from research is by cultivating an improved strain. Publications seem to be a secondary objective to these researchers who often 'love' the plants with which they work. Articles are usually on applied research and appear in technical journals.

These laboratories are dependent on professional associations research themes (even if INRA researchers participate to a large extent in their definition). Additional funding provided by contracts is not predominant in the budget (less than 50% of the total budget – excluding salaries), although is remains essential. The vast majority of contracts benefit from State, regional and, to a lesser extent, EU subsidies. Such funding corresponds perfectly with the logic of the researchers in these laboratories, who see research as a public good, rather than as something to be appropriated privately by industry or to be used for career advancement.

The progressive shift from species to themes is likely to lead certain laboratories to evolve towards Type 2.

3.3.2. Type 2: designers of generic tools and methods

Laboratories of this type are often large research centres uniting teams with different approaches. Their objectives are clearly academic. Whatever the nature of their revenue, they aim to be visible. In some laboratories that work on one or two research themes only, this aim has been achieved; in others not. Whilst the logic behind their work is scientific production, the researchers of these laboratories remain attentive to demand from the industrial sector. Such demand is retranslated into scientific terms. The researchers whom we met emphasised the necessity of working with partners to help them to specify their demands. They create value for their research in two ways: first, by making generic tools available to SMEs and industry associations and secondly, by providing for a wider diffusion of these tools through publishing.

3.3.3. Type 3: basic and specialised laboratories

The dozen or so researchers working in a laboratory of this type are divided into one or two teams, on the basis of well-defined themes which are clearly identifiable from the outside. The logic justifying their work is essentially academic; they carry out fundamental research for which they then create value through articles. Owing to the specific character of their work, industry solicits their research expertise in an attempt to solve specific, often long-term problems. The development of partnerships with

[21] Basic because this kind of laboratory produces mainly basic research and specialised because the nature of knowledge produced is highly specialised.

[22] We prefer using the term "obtaining value" rather than "valorisation" because the latter refers to monetary value only, while the former takes into account a wider range of possible valorisation (monetary but also scientific, for example). Moreover, the term "obtaining value" refers to a process in which researchers justify their own jobs by choosing the kind of value they produce (either directly related to technological innovation or more basic).

firms is not problem-free in terms of value creation, possibilities for publishing, and opportunistic behaviour on the part of the latter. Benefiting from these laboratories' central position in the academic world, industrialists have recognised their potential contribution. A laboratory's industrial partners are often large firms with huge potential for internal research. They expect to find in INRA specific skills which they then integrate into their research programmes. Yet, in certain cases the researchers who initiated these bilateral relations have been confronted with a logic that is not scientific and which has altered the efficiency of their research, e.g. interrupted financing, one-way exchange, a wait-and-see attitude on the part of the industrialists vis-à-vis the authorities, and so forth. The financial stability of these laboratories depends on external financing, and the preference for the short term expressed by industrialists, notably when signing contracts in which they have to participate financially (even if the research receives public funding) burdens certain scientifically important research programmes with debt. Some researchers have told us that they have the impression of '*losing their time negotiating with industrialists who skimp, with public money what's more*'. In this context the symbiotic quality of the relationship between the first type of laboratory (Type 1) and industry seems to wane. Researchers remain preoccupied with the creation of economic value for their results. Nevertheless, it seems that the respective roles of the industrialists and the INRA researchers are not completely stabilised.

3.3.4. Type 4: mutating laboratories

The legacy of the past and recent developments have led researchers to redefine their research themes, which have not yet reached maturity. The limited visibility of their research does not permit these laboratories to control relations with industry. Contracts are mostly bilateral. The laboratories encounter problems similar to those of 'basic and specialised' laboratories, but they lack the same scientific anteriority or a sufficient workforce in the field to negotiate on an equal basis with industry. Like the laboratories of Type 3, mutating laboratories are financially dependent on resources managed by industry. In this type of laboratory an industrial dynamic, compatible with the pursuit of a logic of scientific production chosen by the laboratories themselves, is still to be created. These laboratories are excluded from the rest of our analysis.

3.4. Industrial relationship logics

In analyses of research contracts, the respective role of informal relations, existing networks of personal relations, written contracts and trust is often somewhat vague. For the sake of clarity, we propose different logics of industrial relationships. The identification of these logics is the fruit of research carried out on 182 contracts between laboratories and industrial partners. The concept of 'relationship logics' comprises two complementary dimensions:

1. 'logics' can first be understood as a high level of coherence between the different variables characterising relationships (cf. Table 2); it is then a synchronic aspect of the analysis;
2. 'logics' can also refer to an evolution, relative notably to the learning processes involved in different types of relationship. This second dimension of the concept refers to the diachronic aspect of the analysis (see next section).

Thus, our analysis of research contracts brings to light very specific types of relationship, as much in the origin of the partnership as in the nature of objects exchanged and in the types of link between the players concerned. On the one hand, researchers often studied at the same type of institution, know one another well and trust one another. Private sector researchers turn to public sector researchers to test an hypothesis or an idea. The terms of reference are incomplete and the firm concerned participates in research work by lending equipment or parcels of tests. This exchange favours discussion and a transfer of knowledge. By contrast, a different situation exists when a firm contacts a researcher whose work, published in a journal or presented at a conference, it regards highly. Since the firm is relying on the researcher's reputation, the relationship is not necessarily based on trust. Together with the researcher it draws up the terms of reference, specifying a programme for experiments and the periodicity of meetings. These contracts between a firm and a public laboratory (both specialists in the same field) are aimed at resolving specific problems by developing new expertise. While in the first case a domestic

Table 2
Comparative table of industrial relationship logics

	Proximity	Club	Market
Number of contracts	63	106	52
Nature of the subject	Testing, realising an idea, a hypothesis	Producing a technical referent (genetic material, genetic maps)	Implementing expertise to relieve a bottleneck
Firm's choice of a partner	Expertise recognised by the partner, trust in a person	Recognition by SMEs and industry associations	Expertise recognised by the scientific community
Trust and reputation	Trust is built up during the contract	Little trust	Trust is not required; reputation is indispensable
Participation of several public laboratories	Probable	Highly probable	Highly unlikely
Nature of knowledge at stake	Tacit, specific	Coded, standardised	Coded, specific
Terms of reference	Incomplete	Incomplete	Complete
Participation of firm in the work	Unspecified secondary tasks to limit expenses, favours discussion and transfer	Standardised work to create a mass	Specific and complementary work
Role of the steering committee	Managing the progress of research	Creating a favourable climate for the adoption of the referent	Making sure that the terms of reference are adhered to
Nature of profit	Private	Social	Private
Benefits for the firm	Multiple (technological results and watch)	Multiple (technical and relational referent, technological watch)	Channelled
Follow-up to the contract (a priori)	Renewal of the contract if the original idea proves to be good	Exploitation of the technical referent	None
Other forms of relationship with the industrial sector	Training, services	Representation in national authorities (CTPS, AFNOR)	Publications, participation in conferences

logic prevails, in the second case it is more a market logic that governs the agreement. [23] Table 2 presents the three types of logic which we identified.

3.4.1. Logic of proximity

Initially the partnership has a 'local' base and develops from interpersonal relations which are more or less direct; e.g. the researchers have the same training, they meet in the professional association context, the firm already works with a similar team. At first the contract is defined fairly loosely, with the development of trust playing a key role in co-ordination. Co-ordination also relies on the importance of informal relations and frequent contact between partners, favoured by proximity (e.g. geographic proximity, frequentation of the same associations).

The researcher thus has some leeway in organising his/her work, but the objectives are strictly of an applied nature. In general, the relationship will be a lasting one. With time the researcher will become increasingly familiar with his/her partners' objectives and the efficiency of the technical system will improve.

In this context the firm manifests its needs with respect to expertise and access to a scientific network (scanning). The exchange of advice is thus of great importance. The laboratory tends to become the research centre of a firm or, more frequently, a group of firms. Within the framework of this type of relationship, the performance of academic research necessitates, on a laboratory level, an excellent ability to translate firms' technical needs into specific research programmes. In fact, the laboratory completes the firm.

The firm will either participate in the research by carrying out certain non-specialised work or will make a technician available to the laboratory. It can thereby limit costs or avoid possible rigidity, on the one hand, and involve the firm in the project by giving it technical tasks, on the other. The knowledge produced and/or exchanged is mostly tacit and specific. In many cases this knowledge would not have been produced outside the relationship since it is the context itself which gives rise to relevant questions.

The partners are generally small- and medium-sized firms which do not have the capacity to develop this type of device internally on a medium-term (5-year) basic research project. By means of this type of programme a small- or medium-sized firm can gain a lead over its competitors, enabling it either to develop an original product or to improve the efficiency of its research.

Outside the framework of contracts, the laboratory's researchers frequently move about in the firm, either acting as experts or simply gaining more insight into its requirements.

3.4.2. Market logic

In this case industrial firms look for the solution to a specific scientific problem and select the most competent laboratory, be it in France, Europe or the USA. But whereas they have this freedom of choice, they do not necessarily always have the initiative in the research project.

Mutual respect plays a significant role in this type of partnership. Trust, on the other hand, is less important. The firm identifies a laboratory by consulting data banks; its choice depends on the laboratory's 'visibility' – its scientific renown. This information is completed by questioning persons in the research network, so as to gauge the laboratory's reputation. It is thus in the laboratory's interests to undertake research on subjects with which it is thoroughly familiar and to provide services of a high quality if it is to maintain its reputation. After the firm has divulged the details of its project, the partners often sign an agreement of secrecy concerning the contents of their discussions. Finally, the terms of reference are defined in detail in the contract. The duration of the relationship varies between 2 to 4 years; its renewal is never a foregone conclusion.

The relationship between the laboratory and the firm is symmetric; their expertise is complementary.

[23] This distinction is similar to that of the different modes of co-ordination in Boltanski and Thevenot's analysis (Boltanski and Thévenot, 1991): a logic of proximity refers to domestic co-ordination, a market logic to market-co-ordination and a club logic to civic co-ordiantion. A market logic implies that there is little uncertainty on the nature of objects exchanged. In the sphere of scientific activity, it means that knowledge is generic and highly codified. A logic of proximity makes it possible to exchange tacit and specific knowledge. Note, however, that it is generally closer to the *product market* than is the market logic.

In some cases the expertise of both parties may be required for the realisation of the work. The knowledge produced and/or exchanged is coded but may be specific. It is possible that at the start of the contract it is not coded; in such cases a thesis is often written within the framework of the contract, in order to code the knowledge (the thesis may have to remain confidential).

In these partnerships the firm's absorptive capacities play a very important role. Firms are either high-tech SMEs, or large with active internal research.

Outside the framework of such contracts, contact between players at scientific conferences is a determining factor.

3.4.3. Club logic

The initiative in this type of contract generally comes from public research laboratories, government authorities or professional associations. According to the persons we interviewed, the contract is a response to a problem of general interest for SMEs and industry associations (which is why government gives subsidies). Its objective corresponds to a Colbertian conception of technological development (the State as a central player for the benefit of all). The aim is to produce a new common referent for SMEs and industry associations. This referent will generally be of a technical nature but the players will also discuss the consequences of this change of technical referent on INRA–private enterprise relationships. Clubs bring together all competing firms, or at least a large proportion of them. Consequently, the programmes are 'pre-competitive' since the firms involved do not wish to share strategic information in this context. The programmes are therefore defined and piloted by INRA researchers.

The contract defines only the main lines of this type of co-operation; co-ordination is generally handled by a steering committee. Decision making processes sometimes become fairly complex due to the plurality of the players. In the context of general interest research, decision making may lack efficiency, leading to the following paradoxical situation. The greater the general interest, the more complex the decision making processes and communication within the steering committee, and the more difficult the implementation of a club logic will be.

Depending on the situation, work will be centralised with a team or else carried out by all the players. Either way, the idea is always to create a critical mass with the aim of progressing one step further and continuing on the basis of a new technical or methodological referent. The objects exchanged (experimental protocol, knowledge) are codified because they have to be understood by all, but also because the referent is in effect a standard.

Forms of partnership are varied. Even if the fact that the entire SMEs and industry associations is involved [24] is an adequate condition, it is not an essential one (a bilateral contract with a technical centre could very well have a club logic). As in other relationships with a different logic, the choice of a type of partnership is based on criteria related to the efficiency of research (scientific expertise and competence, adequate funds). Moreover, since the objective is to produce a new referent, the (public and private) partners involved in the relationship may well be viewed as the first adopters of the referent. Consequently, in so far as the strength of the new referent will be a function of the strength of the first adopters, the choice of a partnership is also justified here in relation to the conditions in which the new referent is exploited.

The club logic is found in the participation of researchers as experts in voluntary standardisation committees, regulatory bodies, selection committees (CTPS [25]) or other official committees in which INRA participates in defining the rules of the game.

We have thus identified three main types of laboratory and three types of industrial relationship logic; the temptation is great to look for bijective relations between a type of laboratory and an industrial relationship logic. But such an approach, as satisfying as it may be on an intellectual level, clashes with the data. Laboratories are often composed of one or two research teams which have differing types of relationship with their environment. Industrial relationship logics therefore vary within the laboratories. It is, nevertheless, possible to draw up a conclusive table to account for the relations between types of

[24] We are then in the "maxi-club" population.

[25] Comité Technique Permanent de la Sélection.

Table 3
Synthesis of types of laboratory and industrial relationship logics

	Proximity logic	Club logic	Market logic
Research centres for the profession	Frequent	Frequent	Very rare
Designers of generic tools and methods	Rare	Frequent	Rare
Basic and specialised laboratories	Very rare	Rare	Very frequent

laboratory and industrial relationship logics (Table 3).

Research centres for the profession mostly develop industrial relationships based on a club logic or a logic of proximity. In this context contracts are often modular, with each laboratory undertaking a part of the research. The laboratories that design generic tools have access to all types of contract. In the clubs they have positions of leadership. Recently, the market logic has supplanted the proximity logic. A laboratory's presence in the clubs depends mainly on its specialisation in areas which it alone masters.

4. Which learning dynamics for which type of laboratory and with which industrial relationship logics?

The study of the dynamics of research laboratories' relations with industry is enhanced considerably by the combination of two typologies. On the one hand, the definition of scientific themes weighs heavily in an evaluation of the degree of research laboratories' dependence vis-à-vis their industrial partners. Certain laboratories are financially dependent yet maintain total control over their research themes. On the other hand, the often widespread idea that the intensification of relations with the private sector implies an orientation to more applied research proves to be largely unfounded. Several dynamics in industrial relationships co-exist. Co-operation between the private sector and public research laboratories exists in multiple forms expressed as much in the research object as in its organisation. Some work is undertaken jointly by both public and private organisations, with research laboratories sharing the work according to their expertise or their resources. Genetic or vegetal material may be exchanged during the research, with the results being the fruit of co-production. In other cases the public laboratory negotiates with its private partner a detailed schedule to which it has to adhere to provide the expected results at the end of the contract. The nature of objects exchanged, the organisation of research and the origin of contracts profoundly influence modes of scientific and technological co-ordination and production, and thereby modes of appropriation and learning.

In order to consider the dynamic interaction between industrial relationships and the scientific activities of laboratories, it is first necessary to specify the nature of the learning processes at work in each type of relationship logic. Only then can the role of networks (understood here as all industrial relationships) in laboratories' learning trajectories be explored.

4.1. Co-ordination and learning in industrial relationships

During our interviews with him, Mr. Biomol, director of research at INRA, spoke to us about his disappointment. Working on a subject of current scientific and commercial interest, he has published a great deal in international journals. His competence is widely recognised in the scientific community and large firms approach him to work together on certain highly specialised themes. He has thus been involved in several contracts with firms that have considerable potential for internal research. Contracts such as these are attractive and the researchers working on them, whether from the private or public sector, speak the same language and share the same scientific ambitions. Yet Mr. Biomol was intensely frustrated to find that the transfer of information took place in one direction only, from the public to the private sector. His involvement in what he thought was a joint research programme was in fact limited to the supply of information and expertise to a firm.

The latter retained the means for integrating and synthesising the different programmes undertaken in external co-operation. Mr. Biomol did not ascribe his frustration to the relationship as such, but to his position in the network which prevented him from learning anything (except the hard realities concerning modes of research co-ordination).

Mr. Biomol's story is enlightening. It shows that co-operative research is not synonymous with a process of combined learning. [26] Certain conditions are required to initiate a process of scientific and technical learning, notably in terms of the division of tasks and the co-ordination of work.

In fact, the contents of the learning process are very different in each type of relationship.

1. *In the logic of proximity, learning by relationships is very important.* Since the relationship is based on trust and the research object itself is defined fairly loosely, the partners willingly deal with strategic but peripheral issues. Personal contact favours the exchange of tacit knowledge. The evolution of relationships of proximity is subject to two contradictory tendencies:
   - 1.1. Learning by relationships which reduces 'transaction costs'. This is partly an outcome of the creation of a common language and the strengthening of trust which limit the risks of opportunistic behaviour. This first effect strengthens the value of the relationship. It is all the more important since the 'assets' underlying learning by relationships (trust, a common language) are lost when these relations are broken.
   - 1.2. The partners share the work according to their respective areas of expertise. After some time, intense complementarity in respect of these areas of expertise develops between them, which partly explains the longevity of the relationship. In this framework, the enhancement of the laboratory's expertise may be part of a deliberate strategy employed by its partner which provides it with access to staff and equipment. Despite the duration of the research, the objectives are very specific and have to produce tangible results in the short term; these are often defined by the partner. Given the tacit nature and the specificity of the knowledge produced, it is not easy to generalise research carried out in such a framework, or to publish it. The laboratory runs a considerable risk of finding itself 'trapped' in a relationship with a partner whose expertise profile resembles its own more and more and which tends, imperceptibly, to shift the co-operation towards the supply of services.
2. *In the market logic there is very little learning by relationships.* This surprising result is due to two characteristics of the market logic:
   - 2.1. The relationship generally makes it possible to co-ordinate complementary expertise without pooling it. This type of configuration is possible owing to the coded nature of the knowledge exchanged. Problems of interfacing and translation play a secondary role.
   - 2.2. The partners' profits are embodied in different outputs (publications, patents, genetic material etc.). This second characteristic explains a high level of strategic complementarity. Given these two characteristics, techniques as a mode of co-ordination replace trust. Learning by relationships is therefore weak. As a result, the advantages of co-operation grow weaker, along with the partner's interest in the laboratory's research themes. Relations are then highly mobile, which justifies the term 'market relations'.
3. *In a club logic, partners learn about the regulation of multilateral relationships.* In such cases, learning by relationships takes on specific forms:
   - 3.1. Given the multilateral nature of these relationships, trust plays a marginal role in co-ordination. On the other hand, the notion of a common interest is essential since it legitimises the functions of co-ordination and the status of the co-ordinator. Multilateral relationships depend on the setting up of specific rules which define the circulation of objects, the modalities of information exchange, and so forth. The establishment of rules corresponds to effective *collective learning*.

[26] Contrary to the implicit hypotheses in certain works which analyse co-operation as a learning process or as a race for learning (Hamel, 1991).

3.2. Despite the collective nature emphasised above, the contents of individual learning vary considerably according to the position of the various partners. The co-ordinator has a nodal position since all information passes via him/her, while the other actors occupy a more peripheral position in the system.

The evolution of these partnerships depends on the ability to redefine collective objectives in relation to the progress made in the research project. The maintenance of such an ability is not a foregone conclusion, particularly since it is subjected to the different partners' strategies. The current difficulties of maxi-clubs in the seed industry clearly illustrate the problem.

Over time these logics tend not to remain static:

1. One can easily conceive of a shift from a market logic to a logic of proximity. Such a move may, for example, take place when the industrial partner employs a Ph.D. student. It may also result from an opportunity to enter into informal relationships by means of research contracts. The latter may enable a firm to appreciate the qualities of the researcher, outside of the formal relationship, responsible for providing expertise or advice. If, for example, the researcher participates in the design of a new genetic engineering laboratory, the firm will pay for him/her to attend an international conference. This type of relationship is frequent with large firms.

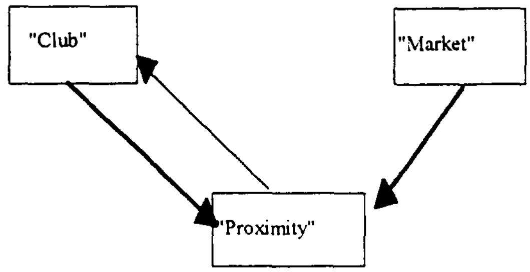

Fig. 2. From one relationship logic to another.

2. The shift from a club logic to a logic of proximity can also be envisaged, especially when the club relationship disintegrates.
3. By contrast, the shift from a logic of proximity to a market logic is by definition impossible. The shift from a logic of proximity to a club logic can be envisaged but it implies that the laboratory is of a certain size and highly visible in professional networks.

Other types of shift are highly improbable (Fig. 2).

4.2. Learning in networks

Laboratories can be considered as organisations which create scientific and technological expertise, knowledge and products. Scientific activities are, of course, singular; but owing to their production cycle, they are also subject to the question relevant to every

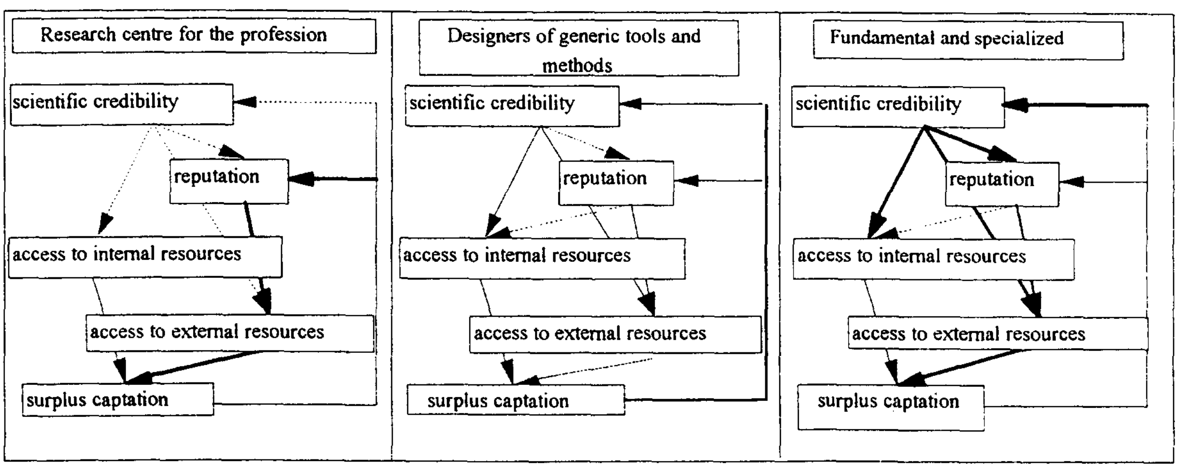

Fig. 3. Dynamics of resource acquisition of different kinds of laboratory.

other activity, i.e. how can the surplus produced during a cycle be maximised? how can the surplus appropriated by the laboratory be maximised?

One of the peculiarities of public research laboratories is that they benefit from two types of support (Fig. 3): (i) public, institutional support, which depends on the scientific credibility and reputation of the team (access to internal resources) and (ii) external support, negotiated with partners in exchange for the commitment of resources or results and which depends on credibility, reputation or trust (access to external resources).

One can well imagine a laboratory which is not adequately supported by its institution taking advantage of its external networks to gain access to the resources it needs. [27] If it does so in conditions in which its expertise is not (or badly) recognised, it could be led to 'sell off' its resources, for example, by pricing trial plots very moderately although this is not in its scientific interests. In extreme cases, the industrial relationship merely alleviates dysfunctions which are foreign to it. Conversely, it seems evident that a successful industrial relationship on a strategic subject would enable a laboratory to negotiate with its institute the granting of staff or important equipment.

In order to understand this central role played by industrial relationships in laboratories' strategies, we need to review the notions of scientific credibility and reputation.

Until now, we have neglected the study of the mechanisms by which reputation and credibility are built. The two are not, in fact, synonymous, although both notions can be considered as a capital which depends on past actions. Scientific credibility [28] depends on the scientific recognition enjoyed by a researcher or a laboratory. The number and visibility of a researcher's publications, titles, distinctions and even patents influence his/her scientific credibility. The concept of reputation goes beyond mere scientific visibility. A researcher's reputation will qualify his/her behaviour during contracts, his/her reliability, punctuality in delivering results, and respect for secrecy and deontology. Credibility and reputation are two similar mechanisms for qualifying partners in different networks. The notion of credibility belongs to the semantic field of academic research, while reputation refers to a more economic logic.

These two notions appear as important elements in the dynamics of laboratories. The following diagram gives an idea of the main channels for each type of laboratory (Fig. 3); for example, for research centres for the profession, reputation is the key variable for obtaining contracts from private partners. Since the evaluation of researchers and laboratories is based on academic criteria, and since these laboratories are not involved in academic production, it is difficult for them to negotiate internal resources. However, they are well known in the 'profession' for being competent and able to give comprehensible answers to questions. They therefore have good access to private funds, especially from small firms with a weak research base. Neither relationships nor learning are limited to the contractual framework. Researchers in the public sector are often called on for advice (expertise) on problems which researchers in the private sector have never encountered before. Conversely, researchers from the public sector can ask those in the private sector to 'give then a hand' in a particular experiment. Generally, researchers from research centres for the profession manipulate knowledge which is mostly tacit. They are therefore largely absent from initial training, but participate in the in-service training of professionals.

By contrast, basic and specialised laboratories rely on their scientific visibility to establish their reputation in the industrial world. This scientific credibility places them in a favourable position in negotiations on internal resources (premises, equipment, posts). Considering the scientific objects around which contracts are drawn up and the mode of organising co-operation, scientific and technical learning is often very limited. In these cases learning chiefly concerns the mode of managing relations and networks, even if researchers are sometimes a little helpless at the start. Researchers from the basic and specialised laboratories, who are highly specialised

[27] Which could explain, in certain cases, the practice of concealing contracts, e.g. 'slicing up' a large contract so that it resembles the provision of services, over which central control is not as strict.

[28] Note that the definitions of scientific credibility and those of reputation are respectively different to that of the B. Latour (Latour, 1987) and Merton one (Merton, 1973).

and strongly represented in academic circles, are rarely present in any branches of initial training. They favour more specific activities in their speciality. Given their scientific credibility, the research directors of these laboratories are often members of various scientific committees of public or private organisations (large firms have strong research potential). They may also be consulted sporadically on a specific point owing to their thorough knowledge of the field and of academic networks.

Finally, scientific credibility and reputation seem to be equally important for the laboratories which design generic tools. These laboratories comply with current scientific criteria in public research and correspond to the meaning INRA gives to the term applied research. Often in a position of leadership in the clubs, they provide SMEs and industry associations with the generic methods and tools it needs to develop knowledge and improve vegetal material and its use. While their scientific credibility depends on their visibility in the academic world, their reputation depends on the translation capacities they have developed to make their research available to SMEs and industry associations, thereby meeting the expectations that professionals have vis-à-vis an applied research institute. The researchers are often largely present in initial training (universities, agricultural colleges, etc.) where they control certain branches. Like their colleagues in basic and specialised laboratories, the research directors participate in numerous scientific committees of public bodies (CNRS, *Conseil National des Universités*, etc.) or of large firms specialised in the seed industry. Their participation in the initial training of engineers and their presence on scientific committees enables them to have a central position in the seed sector.

5. Conclusion

Although limited to the plant breeding sector and seed industry, this study of relations between public laboratories and industry sheds light upon the mechanisms through which a laboratory's relations influence its scientific choices. The laboratories which we have classified as 'research centres for the profession' maintain close ties with the seed sector. Their researchers' main objective is to make improved genetic material available to all potential users. They do not favour an academic mode of legitimisation [29] and they maintain relations based on proximity and a club logic with private researchers engaged in the same type of work. By contrast, academic recognition and visibility are primary objectives for researchers in 'basic and specialised laboratories'. Large chemical, pharmaceutical or seed firms rely on the scientific credibility of basic and specialised laboratories when entering into contractual relations with them. Contracts are often of limited duration and their object is clearly circumscribed. Finally, the laboratories which 'design generic tools and methods' have a focal position in SMEs and industry associations. Different types of firm contract with them, relying on both their scientific visibility and their ability to understand problems in the seed industry.

Thus, each type of laboratory has its own mode of legitimisation, type of scientific and technological production, preferred industrial relationship logic and favourite type of partner. Conditions of appropriation and learning differ according to the organisation of co-operation, the object handled (e.g. tacit knowledge, codified knowledge, vegetal material, technical object) and relations between the researchers and their environment. The visibility of its scientific themes is clearly an essential element in a public laboratory's independence. Types of scientific and technological production, networks in which laboratories are situated and the nature of relations are all closely linked.

The results of our research confirm the value of a study of research laboratories for understanding science in action. Although restricted to a particular industry, our analysis clearly shows that neither the institutional affiliation (contrary to the argument of Dasgupta and David, 1994) nor the mode of financing (contrary to the results obtained by Crow and Bozeman, 1987) enable us to determine the nature of knowledge produced. Contracts with a club logic illustrate the interactions between the different stages

[29] By "mode of legitimisation", we refer to the way by which researchers justify their work and the way of doing it. For example, they can emphasise their role in scientific discoveries or their participation in the national system of innovation.

of scientific and technological production. Public and industrial laboratories work together on both the design of generic tools and methods and the improvement of plant strains.

In spite of its exploratory nature, this empirical study illustrates the usefulness of qualifying relationships. In contrast with the proposal put forth by M. Callon (1992), it appears that knowing that a relationship exists between two players is not enough if we want to know the nature of the irreversibilities created. We show that it is necessary to identify relationships and their nature in order to follow the trajectories of research laboratories.

This study constitutes a first step in a much broader research project on the understanding of research laboratories' strategies. Further case studies would be required to extend our conclusions to other research organisations and sectors, while similar investigations of industrial laboratories would be needed to identify possible peculiarities.

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