Technological platforms in the life sciences

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Public policies, organizations and performance

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The collective management of technological platforms is one of the key-issue of life sciences policy in France. Technological platforms have been given two missions by public policies: contributing to knowledge production and realize technological transfer to the industry. The historical and empirical analysis of six different platforms reveals heterogeneous operations and performances, including a rapid obsolescence of equipments for some of them. How to explain this empirical heterogeneity? Why performances and operations are far behind initial expectations? To answer these questions, we have assumed that research and innovation dynamics are due, not so much to the economic properties of research, to the goods exchanged on platforms or to public incentives, rather than to largely unknown organizational and governance mechanisms. Based on the characterization of three models of organization and governance of platforms, we stress two key factors for success: the development of engineering capabilities within platforms enabling to absorb rapidly changing technologies; the building of new multi-level governance rules to address the co-evolution of platform activities and research programs.

This article has been originally published as : Franck Aggeri, Pascal Le Masson, Anne Branciard, Catherine Paradeise , Ashveen Peerbaye, 2007, Les plates-formes technologiques dans les sciences de la vie, Revue d'économie industrielle, n°120, 4e trimestre 2007 p. 21-40

Introduction

Scientific research needs economic and public policy-making to identify those incentives and organizational mechanisms, in scientific institutions, which favour the production and diffusion of knowledge. The question of what these mechanisms are has given rise to numerous theoretical proposals and recommendations aimed at increasing the social and private outputs of research. The most well known is that of Dasgupta and David (1994), who analytically distinguish two types of research institution –open science and proprietary science– that function very differently: peer evaluation for open science and market evaluation for private science. Their efficiency is based on different incentive systems (in the former, the "rule of priority" organized within the peer community and, in the latter, the guarantee of intellectual property).

The case of biotechnologies and life sciences enables us to qualify the interpretive relevance of this analytical framework. Instead of two distinct, co-existing research worlds, several authors have found the creation of clustered networks consisting of public laboratories and private firms sharing equipment and competencies (Zucker *et al.*, 1998; Mc Kelvey, 1996). The development of spin-offs from basic research and vice-versa, along with researchers' large-scale use of technologies and services produced by firms to build scientific knowledge, attest to an evolution towards forms of close collaboration between science and innovation.

The analysis of these alliances and of the formation of such networks in the United States shows that they have benefited from, and been stimulated by, specific public interventions in the field of intellectual property rights (*Bayh-Dole Act*), along with measures to support innovation and investment. Scientific instrumentation is a fine example, which various authors agree has been a key factor explaining the success of development in the biotechnology sector and of research in the life sciences in the US (see Arora & Gambardella, 1994).

The French government, wanting to take advantage of the lessons learnt from the US and to remedy France's backwardness as regards its scientific instrumentation, identified three areas of intervention as the basis for the collective management of such equipment. This so-called "platform policy" consisted in: (i) pooling investments to meet increasingly high purchase and maintenance costs; (ii) concentrating them in centres of excellence in order to stimulate dynamics of innovation and cooperation between scientific teams from different disciplines, as well as proximity synergies; (iii) and, finally, recruiting qualified staff to operate high-tech equipment.

Whereas the government was hoping for a concentration of research around these platforms, and a standardization of their functioning under the effect of this national policy, empirical studies of six platforms[1], [2], [3] have revealed a variety of modes of functioning and performance. Not only do the platforms studied have differing rules and forms of organization, they also have contrasting results. Most are characterized by rapid obsolescence and under-utilization of equipment, and only some are able to maintain a research dynamic around rapidly evolving technologies.

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[1] Following Keating and Cambrosio (2003), we define the concept of a platform as a specific configuration of instruments, individuals and programmes. Based on an historical analysis of platforms in the biomedical field, these authors found that platforms which generated routines, entities, actors and knowledge had gradually been integrated into an expanding set of biological strategies.

[2] The results presented in this article are drawn from research funded by the Ministry of Research in 2005-2006 and published in the report *"Les plates-formes technologiques dans les sciences du vivant: quels effets sur les pratiques de recherche et les formes de couplage science-innovation?"*, to which four teams contributed: F. Aggeri and P. Le Masson (CGS, Ecole des Mines de Paris), A. Peerbaye and C. Paradeise (Université Paris-Est, LATTS), A. Branciard, C. Lanciano-Morandat and H. Nohara (LEST, Aix-en-Provence), C. Genet (Grenoble Management School) and V. Mangematin (GAEL, INRA/UPMF).

[3] These six case studies were selected for the diversity of their fields of activity (transcriptomics, structural genomics, dynamic imagery, etc.), the types of commercial activity concerned (production of standardized versus customized services, no design versus co-design, with users, of new niche services), and their modes of governance (public versus private, autonomy versus affiliation with one or more research institution(s), degree of formalization of rules of governance). Three private platforms were studied: one had developed an offer of standardized mass services for research (Eurogentec), another was specialized in the production of customized services (Ipsogen), and the third was oriented towards the co-design of niche services (RoBioMol). Three public platforms were studied: one multi-site and multi-institution, centred on the production of standardized services (the transcritomics Marseille-Nice-Génopole platform), the second was owned by the CEA and oriented towards the production of customized services (the transcriptomics platform of the functional genomics service of the CEA), and the third was a group of platforms covering various ranges of activities at the Pasteur Institute.

How can this empirical heterogeneity be explained? Why have the functioning and performance of these platforms turned out to be so different from the objectives set for them by the government?

To answer these questions we posit that the dynamics of research and innovation can only partially be attributed to the economic properties of research or of the goods traded in the framework of the platforms, and to the incentives produced by public policy-makers. To a large extent they can also be imputed to organizational mechanisms and local governance, both of which are largely unfamiliar to or poorly understood by national policy-makers. The consequences of public policies can therefore be assessed only by taking into account the forms of organization in which they are embedded. We base this hypothesis on the following three sets of theoretical propositions from the history of science (Shinn, 2005), evolutionary economics (Bonaccorsi, 2002) and management of innovation (Aggeri & Hatchuel, 2004; Mustar & Laredo, 2002):

1. Contemporary scientific innovation is based on the growing intensity of the alliance between research and scientific instrumentation. The ability of research policy to facilitate this alliance is therefore critical for scientific and economic dynamics[4];

2. A discipline can be characterized at a particular time by the scientific production regime to which it belongs, identified by *a coherent set of properties of the research process*[5]. Various regimes co-exist at the same time. The field of application of an area of research can change the regime over time. This is the case of biology over the past 20 years.

3. The relevant organizational ecology for an effective alliance between research and instrumentation varies with the scientific production regime[6]. Thus, public policies promote changes of regime by making new institutional and organizational forms available.

The first part of this article presents the history of the institutional construction of technological platforms in the life sciences in France, in response to the transformation of their knowledge production regime. It then highlights their empirical heterogeneity from the

[4] Terry Shinn emphasizes the fact that instrumentation builds up a *lingua franca* (metrology, concepts, standards, images, etc.) which allows for cross-fertilization with research when its cross-cutting nature respects the division of work between technologists and scientists. It is this intermittent and selective circularity (boundary crossing – reverse boundary crossing) that induces scientific dynamics and innovative capacities, and that public policies should aim to promote.

[5] Andrea Bonaccorsi identifies the diversity of research regimes and their endogenous dynamics by combining three variables characteristic of the production of the various scientific sectors: growth rate, degree of diversity, and level of complementarity. The growth rate can be blocked or unblocked suddenly (e.g. by solving a problem that created a bottleneck, by a technology that makes it possible to observe or develop large-scale data processing, by the intensification of research in response to needs in other sectors, etc.). Development can be convergent or divergent. Convergence can stem from the unification of theoretical frameworks, the formulation of technological standards, or the comparative costs of convergent versus divergent strategies. Divergence can stem from the discovery of the same entity allowing for the exploration of a diversity of phenomena, or from competition between diverse representation strategies embedded in instruments, etc. Complementarity identifies the minimum resources necessary for the realization of a given research project (in scientific and technical staff, specialized knowledge, equipment, and in devices for coordination in time and space).

[6] Aggeri and Hatchuel start with the identification of socio-economic orders, which they define as spaces of collective action, historically constructed through a series of public and private interventions at different levels. This action articulates market mechanisms, organizational forms and public and private actors, contingently to the activities, actors and territories engaged, in order to identify the concrete links between institutional models, regimes of cooperation, and production and innovation. The following question then arises: if certain organizational forms are better suited to certain regimes of cooperation and innovation, how can changes be made to modes of governance which historically have favoured the organizational models peculiar to one of these regimes, e.g. in France the physics of large scientific facilities, in particular. Mustar and Laredo explore this question with regard to national research and innovation policies. In this article we examine this question by way of an approach articulating three levels of analysis: micro (cooperation between laboratories and platforms around research facilities), meso (the policies of research institutions and private firms as regards platforms) and macro (national policy on scientific instrumentation).

point of view of both their rules and their functioning. The second part characterizes their models of organization and governance, and examines the conditions under which a real organizational reflexivity can be instituted. This enables us to point out the key role of two factors: engineering capacities which, within the platforms, make it possible to absorb and take advantage of rapid technological developments; and the existence of multi-level rules of governance that allow for an evolution of the perimeter and activity of platforms with the programming of research. We show that the absence of any of these mechanisms impedes the management of the co-evolution between the instrumentation and research, leading to the obsolescence of the equipment and the closing down of the platforms.

1. The institutional construction of technological platforms in the life sciences

A –The constitutions of platforms as the subject of public policy

In France it was traditionally through the TGE[7], the "very large facilities" category that the financing, construction and organization of large scientific research instrumentation was conceptualized, from the 1960s (Laredo and Mustar, 2002). At the end of the 1990s things changed when policies pertaining to the financing and administration of life science research facilities were made within a new institutional framework. As the instrumentation of genomics did not match traditional conceptions inherited from physical science, it was unsuited to the categories historically applied to all large scientific facilities. Genomics did not require unique, large-scale facilities, built on strategically chosen sites, but rather networks of smaller instruments spread across the country (with concentration effects around certain poles of specialization). Their costs were moreover incomparable to those of particle accelerators or synchrotrons (Mangematin & Peerbaye, 2004).

One of the main outputs of the Genome programme, the creation of a national genopole network (NGN)[8] in February 1999, substantially changed a context characterized until then by the dispersion and compartmentalization of resources. Most of the instrumentation in biological research laboratories was historically acquired around equipment and competencies specifically developed within universities, university hospitals, and laboratories affiliated with public life science research institutions (CNRS, INSERM, INRA, CEA), in order to further internal research programmes[9]. But to remain internationally competitive over time, scientific laboratories had to have access to equipment and competencies whose costs far exceeded what most of them were able to afford individually.

The creation of the NGN aimed to promote entities throughout the country at regional level, grouping together on the same site public research laboratories, biotechnology firms and top-level educational institutions in the field of genomics and related sciences. The aim was to endow the academic community with high-performance research tools, in order to facilitate the rapid diffusion of technological progress, promote biological approaches on a large scale, and thus enhance the capacities to produce new knowledge. The second aim was to contribute to reducing the gap between research results and their transformation into innovative products or services. Embedding the local interactions of scientific and industrial communities in a national context was thus intended to improve the quality of French genomic research, and stimulate the performance of biotechnological activities measured in terms of jobs and firms created.

[7] *"Très Grands Equipements" (TGE*

[8] *"Réseau National de Génopoles" (RNG)*

[9] National laboratories such as the Genoscope and the Centre National de Génotypage, created in 1997 in Evry, are exceptions. See: Branciard, 2001; Peerbaye, 2004.

Initially, this politico-scientific process of "genopolization" accelerated putting on the agenda the question of instrumentation as a means to orientate research, at operational level, towards national priorities, in the framework of complementary research programmes around five key themes[10]. The state's financing of genopoles over three years (1999-2002), via the National Science Fund, was limited to the creation of "technological platforms". The mode of constitution and renewal of laboratory equipment was altered with the introduction of new conditions for pooling and grouping together funded instruments within approved genopoles, as well as the opening of these facilities to multiple users. State approval of genopoles, which had the twofold mission of scientific excellence and innovation, was thus a mechanism of selection in the access to indispensable complementary resources and indirect public incentives for coordination between academic and industrial actors (Branciard, 2005; Peerbaye, 2005).

The heterogeneity and complexity of local arrangements rapidly became an obstacle to the Ministry of Research's wish for programming and evaluation of genomic research. In this context, technology platforms afforded public research organizations, until then hardly present in the creation of genopoles, an opportunity to regain some control. In order to increase the visibility of existing resources and practices, the departments devoted to the life sciences at the CNRS, INSERM, INRA and the CEA decided in 2001 to come together in a coordination entity called the RIO (*Réunion Inter-Organismes*). Its first initiative was to conduct a census of French public research platforms in six areas of life science, from the point of view of their instrumentation[11], with specific criteria different from those used by the Ministry of Research. The aim was to *identify* the means and resources, and to *rank* the platforms according to practical operational criteria. The RIO distinguished "operational" platforms that were already functioning as a matter of routine, from ones that were still in a phase of construction and therefore considered to be "emergent". The RIO's conclusions[12], submitted to the Ministry of Research and the partners of the coordination at the beginning of 2002, highlighted the weaknesses of a system undermined by the lack of staff devoted to infrastructure, and by problems of funding the equipment (procurement, maintenance and renewal of machines) due to rapid obsolescence, especially when it came to platforms not benefiting from the support of the National Science Fund. In 2003 a process of dialogue was initiated between the research organizations, the ministry, the genopoles and the universities, to allocate posts to the platforms identified by the RIO and to finance their equipment. The first division of work between the actors emerged: the public research organizations provided positions for engineers and technicians (43 positions for 19 platforms); the universities provided research and teaching posts (five); and the RNG provided temporary contracts as well as grants for running costs and equipment. Certain platforms (regional or national) received direct support from the ministry via the National Science Fund.

In 2003 the RIO coordination, in cooperation with the NGN and with the support of the Ministry of Research, updated the platform census. This exercise took place in a public context that differed from that of 2001. First, a "platform charter" had been drawn up in 2002 by the RIO coordination. This charter defined platforms and set criteria for their identification. It also laid down the conditions for their funding and the employment of their specialized staff. These criteria were: the degree of openness to users outside the site; the mode of management (the focus was on the modalities of evaluation and the formalization of the service supply: conditions and rates of access); the technological evolution of means; the

[10] Bioinformatics, transcriptomics, proteomics, structural genomics, and functional exploration of genes.

[11] Genomics (sequencing-genotyping, transcriptomics, proteome); imagery (in vivo, cellular and electronic microscopy); animal houses and functional explorations; databanks and collections; structural biology; and bioinformatics.

[12] Out of 280 applications examined in 2001, the census identified 80 platforms considered to be operational, 37 emergent platforms, and 49 mutualized biological resource banks.

presence of training; and the existence of a body responsible for ensuring that the charter was adhered to. Approval by the RIO (in the form of a label) was henceforth contingent on compliance with this charter.

A new ministerial typology of platforms was also created, which classified them according to the scale of their activities and their *degree of openness* to the scientific community: "local technical platforms" (*plateaux techniques de site*), associated with the *Instituts fédératifs de recherché* projects, whose perimeter of openness and modes of management were defined locally; "regional platforms", open to large projects and to the regional community (genopole platforms are typical of this category); and "national platforms" (*plate-forms à vocation nationale*), including the national resource centres (Genoscope and CNG, then the Grenoble proteomics centre, and the Centre for the production of long oligonuclotides at Nice-Sophia Antipolis). The aim of this classification was to limit the ministries' budgetary support to regional and national platforms only, and to encourage public research organizations to participate more actively in coordination and provision of resources (funds, jobs), especially for the local platforms. These new arrangements in the labelling process were part of a more general movement of concentrating means and grouping together research and educational structures devoted to genomic research. This was illustrated by the creation in 2002 of the public interest grouping CNRG (*Consortium national de la recherché en génomique*), with an initial budget of €28m in 2004.

This movement was accompanied by an ex post evaluation of the genopoles' efficiency. Three audits were carried out at the ministry's behest, by the European molecular biology organization, the firm Ernst & Young, and the CNRG's scientific council. In all three cases the conclusions and recommendations were fairly similar, i.e. in favour of better identification of existing means through more operational categories for distinguishing resources. They advised against spreading resources out too widely and recommended the concentration of platforms. The insufficiency of dedicated staff (especially technicians and engineers) was highlighted as a major weakness. The updating of the RIO census in 2003 corresponded to these issues and restricted the label. It suggested grouping together facilities, on the basis of the geographic and/or thematic proximity of certain sites.

The institutional construction of platforms was thus the outcome of a real investment of form (Thévenot, 1986) by a series of actors (ministry, research organizations, universities, genopoles, laboratories, etc.). Each of them contributed with their own rationales to the elaboration of the technical and social forms of the platforms, and then organized themselves collectively and cross-cuttingly to try to coordinate their actions.

Investing in the creation, financing, consolidation and stabilization of an efficient network of platforms was envisioned by public authorities as a means to control and reduce costs of access to and acquisition of knowledge. The idea was to set up institutions which could act as intermediaries, and help codify knowledge and accelerate its circulation. These institutions were meant to standardize and link various technical elements, in order to give general thematic orientations an operational scientific content, based on an integrated biological approach. Another aim was to promote efficient forms of cooperation in the production of new knowledge, which would increase returns to scale of scientific as well as socio-economic research. Finally, the public authorities wanted to develop a policy which would achieve the coherence of all the properties of the research process in the life sciences.

As for the laboratories, the inclusion in institutional arrangements was seen as a means to take advantage of the attendant resources. They hoped to benefit from competitive advantages in international scientific competition, at the expense of losing part of their autonomy when it came to scientific orientation, due to greater dependence on equipment and funds outside the institutions but still under their supervision.

B – Empirical forms of heterogeneity of platforms

Public policies have gradually defined the characteristics of the systems from which they expect an efficient coupling between research and instrumentation. The research platforms were constituted from sets of instruments and associated competencies, researchers, and engineers and technicians working on the design and implementation of experiments, the validation of protocols and even the development and co-development of technologies, organized with a view to answering research questions (possibly from different disciplines) in fields of application targeted to a greater or lesser degree. The empirical analysis carried out on six public and private platforms shows however that this definition is only the shell of a wide range of apparatus with varied institutional forms, management approaches, and relations with the research laboratories. This heterogeneity is historically shaped by the specificity of the local contexts in which the platforms are set. It varies with their position along the chain of research products and the relationships of coordination set up.

The platforms are distinguished first by their institutional affiliation. Some were created and approved by laboratory consortiums, especially on the incentive of the 1999 call for proposals on genopoles (Marseille-Nice transcriptome pole, Rhône-Alpes proteomic platform). They face the difficulties of coordination between the stakeholders governed by distinct norms and rules. Others are the property of a research foundation (Pasteur), which facilitates their integration into a specific research policy. These platforms nevertheless share the characteristic of not having the obligation to perform economically in often emergent, narrow, demanding markets that are constantly being redefined. It is these markets that start-ups and spin-offs such as Eurogentec, ProteinXpert and Ipsogen challenge, even though they have been able to benefit from start-up funds and various forms of public aid, and can take advantage of the strong links that they often maintain with the laboratories from which they spun off (RoBioMol, Ipsogen).

Management rules also differ. Platforms created by public consortia have rules that the RIO label has tried to standardize by differentiating principles of access, services and rates, according to the nature of the users: internal or external researchers, or private clients. By clarifying the norms of exchange, these rules mark the exteriority of the platforms in relation to the teams that created them, and the pre-eminence of steering committees representative of the entities participating in the selection of projects. Yet they tend to be ill-defined, partially fictive and barely constraining. For instance, rates applied to outside users are frequently reduced to the marginal cost of the products used. The small number of outside clients often limits services to inside users, and the rules of access are respected less when the platform remains so closely linked to the scientific team that set it up. Partnership agreements with firms are not always clearly formalized. In the final analysis, management rules often appear inefficient, whether they apply to the type of users, serving as a barometer for the activity, or boosting the autonomy of the platforms concerned. In contrast, the Pasteur Institute has developed a far more sophisticated approach in which it uses a precise typology of these platforms. In homogeneous technological domains they take charge of activities that present a potential for repetition, because they offer routinized services which nevertheless require an intensive technology watch, or because they are no longer exploratory but in the process of being routinized in the medium term. These platforms are clearly detached from the laboratories, and are identified and run by their own scientific management. It differentiates their resources and rules of access, service and organization, depending on whether they are oriented mainly towards exploitation or exploration (analytical activities freely available versus co-design of technical material and experience by engineers and research teams), and depending on the research strategies and the partnership in which they are set. Finally, the scientific management leaves it up to each platform to formalize these rules specifically.

The management of human resources differs substantially from one platform to the next, in terms of recruitment, job allocation or career prospects. In private firms we witness cautious recruitment and career management in the core activities. Eurogentec, for instance, whose business model is based on production and sales rather than on a complex technology and costly development, organizes its human resources around two key competencies: those of experienced technicians who guarantee reliable and rapid production, and those of salespersons –mostly doctors– capable of perceiving, interpreting and anticipating research tendencies in genomics, who practice a technology watch for their clients, and who keep their competencies up-to-date by on-going education. On the other hand, the human resources management of public research institutions is ill-suited to the fluidity, reactivity and cross-cutting approach required by the rapid transformation of research facilities' activities. This is especially true as regards the functioning of the genopoles, for the Ministry of the Economy and Finance prohibits the recruitment of any new staff. In terms of the decree on the application of the 1999 law on research and innovation, it is mandatory to set up a legal structure (such as a limited liability company) within genopoles or local authorities, to be able to develop innovative activities and recruit the required scientific and technical staff. The difficulty of recruiting –except for temporary positions, a very small number of which will be turned into permanent positions– makes the operation of large facilities difficult and uncertain. In the absence of a stable workforce of qualified staff, researchers have difficulty maintaining and transferring the skills acquired on platforms within their own organizations. The latter are unable to identify the specific functions entrusted to platform staff, and lack the means to attract skilled staff. The problems of human resources management are therefore posed in terms of recognition of careers –which are moreover parameterized differently depending on the organization –but also in terms of intellectual property and authoring publications on the research carried out on the platforms. The lack of positions and experienced dedicated staff thus reduces the beneficial effect of the equipment. In contrast, its status as a foundation and its hierarchical organization with a unity of command enable the Pasteur Institute to combine an organized and differentiated management of activities with a specific approach to personnel and career management, in line with its strategies of co-evolution of research and common resources, and their predictable evolution.

Finally, platforms differ empirically in their dynamics of attachment to or detachment from the laboratories that promoted them. Thus, spin-offs frequently preserve strong ties with the laboratory from which they came (e.g. Ipsogen with the Paoli Calmettes Institute, a regional cancer centre in Marseille), which may be formalized to a greater or lesser degree in a partnership. They expect from them a scientific watch and development potential that is indispensable for their visibility, quality image, certification, client relations and, finally, their long-term competitiveness. After their creation they can formalize their new partnership with the public laboratories from which they spun off, by creating a new platform with them (Protein'Expert, RoBioMol and the LIM in Grenoble). The detachment can grow, within certain limits, with the degree of routinization of activities. Thus, Eurogentec, a private platform that reached maturity on stabilized technologies, has varied scientific intelligence apparatus (networks of sales representatives, scientific committee, partnerships) but remains clearly outside research itself. Public operators theoretically have a large degree of latitude for governing the dynamics of attachment or detachment of platforms, whose survival is more or less independent of their economic performance. The example of the Pasteur Institute shows that it is possible to generate this dynamic, to set up or close down a platform, to situate it in a service relationship or one of co-production with laboratories, depending on the procedures allowing for the standardization of the demand. But the analysis of public platforms shows that this dynamic of attachment-detachment sometimes proceeds from self-organization, due to the failure to respect missions and rules established in collaboration, or the lack of clarity of those rules. In these circumstances a degree of confusion reigns between scientific collaboration and service provision, stemming more from deadweights in response to policy statements than to an intrinsic necessity of the organization (e.g. the transcriptomics platform of the Marseilles genopole).

2. Organization of platforms and research dynamics

A – Contrasting and ambiguous modalities of performance

The empirical diversity described above results in contrasting modalities of performance, linked to the way in which research is coupled to instrumentation on the platforms. The discriminating criteria that can be used to analyse these typical forms of coupling and their consequences in terms of organization and governance, depend less on the legal status of the entities concerned (private firms, public or semi-public platforms) or their organizational form (hierarchical or networked), than on the main type of activity that takes place or the nature of the relationships that are formed there. It is thus possible to interpret the heterogeneity of the platforms and their performance in relation to two variables. The first takes into account their positioning (up or downstream) in the chain of research products, depending on their degree of proximity to or distance from the commercial sphere (generic knowledge with multiple destinations, R&D, exploitation of results in routinized practices, services for research, and niche markets). The second variable integrates the characteristics of the relations of cooperation and/or competition formed through the platforms.

The typology proposed by Hatchuel, Le Masson and Nakhla (2004) is illuminating here for an analysis of the nature of the activities deployed on the different platforms. These authors distinguish two main profiles. The first, called a "shared analytical device" or DAP[13], is characterized by a focus on essentially routine analytical activities whose main function is to exploit the results of scientific research. The researchers, engineers and technicians are familiar with the services delivered, the validation protocols and the equipment. The second profile, called a "shared experimental device" or DEP[14], revolves around experimental activities of an exploratory nature. The services and validation protocols often have to be designed within the research framework, and the instruments can be developed specifically to meet the needs of research underway. In the former case, as the technologies and their uses for research are stabilized, a strong division of work, possibly from a distance, is possible. In the latter case, as the technologies and their uses are evolving, the research subjects, protocols and technologies are designed and adjusted in the same framework as research projects. In other words, this case requires the organization of a strong coupling between the development of technologies and services, and the design of research objects, which demands a real cognitive and geographic proximity.

This analytical framework reveals two main poles of activity: one consisting of commercial valorization of the knowledge production system; the other consisting of co-production, in which the partners mutually benefit from their cooperation, so that the exchange cannot be limited to its strictly commercial dimension. Empirically, each platform can be deployed across the entire spectrum between the DAP and the DEP, as each activity organizes the exchange as a service or co-production of services.

The private-sector market is par excellence the place where platforms target productive and commercial models enabling them to exist economically. This is evident in those firms that are able to meet the challenge of producing appropriable and rival knowledge by developing a mass offer of customized services at commercial rates, defined on the basis of scientific competitive intelligence and exploitable on standard equipment, in a DAP. The Eurogentec

[13] D*ispositif d'Expérimentation Partagé*
[14] *Dispositif d'Expérimentation Partagé*

strategy, for instance, is based on the development of this type of service offer. But here the firm is positioned in research and innovation networks that already exist, where the identity of the actors and knowledge produced is clearly identified (Callon, 1999). It tries to minimize the economic risks by diversifying its clientele and avoiding an R&D activity whose profitability is deemed too random. Doing little innovation, it aims above all to differentiate itself on service quality criteria (delivery times, quality of samples), by developing commercial engineering enabling it to build up a close relationship with a client network throughout the world, and identifying new services to develop to meet their needs. This production model, based neither on instrumentalized design nor on research activities, nevertheless remains fragile. Given the rapidity of standardization, even the commodification of technologies and competencies used, competition with other private firms (suppliers of bundles of services, such as Affymetrix), and with subsidized public platforms, is strong and the margins are weak.

This form is however not peculiar to private firms. Public platforms can very legitimately adopt it if they sell their services at market prices. This is the implicit instruction given by the standards of the RIO, which encourage them to distinguish the rates of public services according to the nature of the users –as if the public partners were by nature co-producers of scientific and technical innovation, and private users were client users of standard services. Frequently, however, public partners request the platforms to meet their needs for standard analysis. They benefit from transfers of public resources at "slashed prices", which introduces the conditions of disloyal competition with private producers of similar services. These situations are found primarily on RIO-labelled multi-organization platforms, whose rationale is often that the initial pooling of resources is indispensable to meet such costly and complex needs in the coupling of research and instrumentation. The public authorities anticipated that these public resources would rapidly be compensated by the profits generated through the growth of an internal and external demand, directly triggered by this new supply policy. However, when tested, the model revealed a twofold illusion in this projection. First, it was somewhat paradoxical to simultaneously implement two policies, one oriented towards the economic profitability of an internalized service offer, while the other was aimed at the exteriorization of that same offer in the form of a spin off. Second, when it was not accompanied by the creation of steering devices specifically adapted to the characteristics of each platform, this policy left the management of the production, cooperation, service-delivery and performance-evaluation processes de facto up to processes of self-organization. But because RIO-labelled public platforms are thus embedded in the laboratories that created them, and because the policies of their supervisory authorities remain largely opaque, there is necessarily a certain confusion as to their organizational positioning, the functions expected from them, and the accounting and compensation of their costs, as well as the evaluation of their performance. These processes have also proved to be unsuited to accompanying the dynamics of the positioning of platforms. They have not made it possible to evaluate the advantage of perpetuating them by deciding which types of scientific equipment and which types of services needed to be organized as platforms, which could be entrusted to the market, and which should rather be incorporated into laboratories. We consequently often find that engineering skills and equipment are rapidly obsolescent, and that the research teams that use them have difficulty renewing their research capacities based on the instrumentation. This results in the under-utilization of most of the platforms studied. Of the six cases analysed, only three, Pasteur, RoBioMol and Eurogentec –none of which belong to the category of multi-actor public platforms– attest to a high performance (equipment saturated, customer satisfaction, co-publications with lead users on exploratory activities).

The second main model of activity is found in platforms that receive public funds. The market's incapacity to produce uncertain public goods justifies such funding, which supports the hybridization of research and technology. The public platforms in question can thus rationally be considered as cost centres at the service of an internal coupling between research and instrumentation, and not as profit centres. An example is the mutualized management witnessed at the Pasteur Institute[15]. The Institute's platforms are entrusted to a specific division responsible for the management of technologies and scientific equipment. They focus only on those activities that have development potential for several users. The rules of operation and performance evaluation depend on the nature of each platform's activities. Routine activities are for example managed freely and evaluated according to the criteria of regular production systems (in terms of deadlines, queues, user satisfaction, rates, etc.). Exploratory activities, on the other hand, are carried out in partnership, with for example the organization's highly specialized research teams, as well as suppliers of instruments, depending on the rules governing access, rates, and publication, specified in advance. For the research teams, the platforms provide resources and competencies that are particularly valuable, as operational knowledge is still largely uncodified in instruments, protocols and techniques, and therefore largely incorporated in the platform staff. For the platforms, these exploration partnerships make it possible to test the uses of new instruments and to codify the knowledge and services that could be proposed to other research teams. For the designers of instruments/facilities –often large firms like Varian, Perkin-Elmer, Affymetrix or Xenogen– the advantage of such partnerships is huge since they allow for cooperation with top-level research teams that work on original research questions, leading to the exploration of possible new uses for new instruments and new markets. When these conditions are met, the partnership is cemented by the availability of highly specialized free-of-charge equipment, and by the instrument designers' investment in the construction of the research programme.

At Pasteur the rules of organization concern not only the conditions of access to the facilities, the financing or the rates, but also the management of competencies, priority rules, the range of services offered, and the links with research programmes. They make it possible to manage a business model based on a combination of routine tasks and experimental devices linking platforms and research teams. In this respect the heavy involvement of users is a key element enabling the platforms to be adaptable. This management thus produces a virtuous circle that generates learning rents for partners at rates that cannot legitimately be set by the market, and which are embedded in other modes of shared valorization (original scientific publications for research teams; patents and new competencies for platforms; exploration of the potential of new facilities for equipment designers).

Although the definition of clear rules of organization (access, priority, funding) constitutes a favourable condition for the smooth functioning of platforms, it does not suffice to explain the properties of Pasteur's model. This type of virtuous circle is also based on another element generally neglected in public policies on platforms: the crucial role played at Pasteur by a development engineering that allows for facilities to be put into service. This development engineering plays an important part in the identification of those activities that have a potential for generalization of scientific research, that is, those which are likely to stimulate cooperation and generate positive externalities for the Institute's other research teams[16]. When this potential for generalization is exploited, the platforms codify knowledge and participate in the consolidation of research and innovation networks by making the knowledge accessible to a large number of users within the Institute, or even to outside users and for open-source software in bioinformatics, developed in collaboration with the Institute's most specialized

[15] The Institute is a private foundation in the public interest (statutes amended in 2003), whose mission encompasses research, training and public health. It is funded one third by the state, one third by own income from its activities, and one third by bequests and income from its property.

[16] This work was carried out for example in the field of dynamic imagery. After an exploratory phase with instrument lead users of the Pasteur Institute, it is now disseminated among many users, with the support of the platform.

teams (e.g. for automatically annotating the genome). The development of such engineering implies a specific and flexible management of competencies, generally lacking in French public institutions. The careers of the technicians and engineers of these platforms are thus managed in a specific way, different to that of the researchers, whose assessment is based on the platforms' own performance criteria. Pasteur, for instance, provides concrete evidence that the materiality of the platforms is not sufficient unto itself; the instruments that they bring together are not "transparent", non-problematical objects. They depend on an organization that builds them in relation to the nature of their expected uses, and enables them to retroact on the goals pursued. This still means that different notions of performance can apply at different stages of their trajectory, depending on whether they are evolving towards exploration or exploitation.

It is more surprising that similar configurations are found on private platforms, in two types of situation. The first situation combines private platforms and public research teams, which act as lead users. The platform's engineering activity is then closely linked to cutting-edge research aimed at identifying services with a high value added that answer new research questions. The proximity of the platform and of these research teams can favour partnerships, even if examples in the US show that it is not necessary for this proximity to be geographic; it is above all cognitive and organizational. RoBioMol, which entered into selective partnerships with local teams to provide them with ad hoc services in the framework of new research and assay protocols, is an example of this model. Even though the firm has been able to perpetuate its activity, it remains modest in size, which seems to be a more general characteristic of this type of model when the production of these niche services is not coupled with instrumentation design. Unlike the preceding model based on the commercial exploitation of standardized services to research in the framework of stabilized research and innovation networks, this model is based on the co-production of specific services (non-codified knowledge) in the framework of emergent networks. This is the case of Ipsogen, whose partnership with the Paoli Calmettes Institute led to a Phase 1 of clinical trials of its predictive genetic test of responsive patients. In this respect, it is important to emphasize the fragility of this economic model that depends on close partnerships with scientific research whose private yields are uncertain, or with clinical research whose exploitation is subject to the agreement of the public health authorities and the CNAM (the national health insurance fund).

In the second situation the private platforms develop an offer in bundles, based above all on the co-design and joint sale of instruments and services (maintenance, supply of reagents, training, etc.). The possibility of implementing this type of strategy nevertheless seems to be reserved for a small number of large groups, mostly US (Affymetrix, Varian, Xenogen, etc.). These firms are capable of exploiting a technological trajectory (based on a catalogue of instruments and services) to generate learning rents from technical standards, and of exploring new potential markets in partnership with innovative users, for whom they adapt the instruments and services proposed. This model thus makes it possible to generate rents for instrument designers and their users, and to reinforce lineages of innovation around instrumentation (Hatchuel, Le Masson and Nakhla, 2004). Although this strategy makes it possible to combine a logic of exploiting mature technologies in the framework of constituted networks, with a logic of exploration of new technologies in the framework of emergent networks, it is difficult to replicate, for it implies the development of design capacities and a sufficiently large critical size to absorb the high costs of such design.

B – Governance, the condition of performance

How can the gap between the expected effects of public policies on platforms and their observable effects be explained? How is the variability of observed results the outcome of particular institutional arrangements? What conclusions can be drawn from the conditions of efficacy of platform management?

The typology proposed by Hatchuel, le Masson and Nakhla (2004) enables us to relate the various platform models discussed above to the governance models adapted to them, by distinguishing the platforms according to their core activity. The creation of learning rents by the platforms, which base their longevity on their ability to co-evolve with the demand, is governed by a capacity for differentiated management of a range of activities –routine or exploratory–, each of which requires specific forms of organization and partnership. It is not enough for a coalition of research teams to grasp the opportunities for funding afforded by their institutions and the public actors, to set up a lasting platform. Several of the platforms studied are the product of ad hoc alliances between public laboratories, without specific management by public institutions. Theoretically, they allow for a mutualized management of human resources and equipment, thus favouring economies of scale and work on exploratory research questions which would not otherwise have met an effective demand. In practice, these theoretical advantages are nevertheless rarely exploited. The functioning of platforms is soon confronted with the instability of the coalitions from which they stem, the difficulties of shared management of facilities and human resources, and the tensions spawned by commitments made regarding the opening up to users, which enter into conflict with the units' research logic. Due to the absence of shared reflexivity it has not been possible to elucidate the common missions that the partners wanted to give their platforms. Even if initially, for each partner, the participation in the funding more or less implicitly had the objective of organizing the global coupling of multiple research activities with multiple instrumental activities, not all of them are necessarily interested in the same combinations. Consequently, the platforms thus created are used by the laboratories from which they were created, according to their own needs. The RIO label that most of them have received has not led to agreed strategies on their orientations or their future. It follows that self-organization by the researchers prevails, even though it does not seem to be compatible with the inevitable professionalization of the management of platforms and the renewal of relations with users. In this respect the rigidity and compartmentalization of the rules of public management are a crippling obstacle to the adaptation of engineering skills and the renewal of instruments. We clearly see the limits of this model of quasi-autonomous organization of platforms, based on service provision, itself linked to the routinization of technologies. It seems hardly permanent, for it is dependent on restrictive conditions in a world of rapidly renewed technical and scientific innovation. Moreover, it is unable to ensure the co-evolution of questions on instrumentation and research in an environment whose managerial rigidity, combined with the absence of an autonomous policy, produces a vicious circle. In this context the rapid obsolescence of equipment and skills causes clients to turn away and to prefer outside service providers.

The examples in which this co-evolution was established, as at the Pasteur Institute, are on the contrary based on a collective governance structure involving the Institute's management, its scientific divisions, its scientific teams (the potential users), and the managers of the platforms. The Institute uses the flexibility stemming from its status as a private foundation to enable it to apply a sophisticated management model. This simultaneously plays on different levels of intervention and organization to combine flexibility and mutualization of resources. The rules of organization, which concern the conditions not only of access to the equipment, funds or rates, but also skills management, priority rules, the range of services offered and the links with research programming, make it possible to manage a model based on a combination of routinized activities and experimental devices linking platforms and research teams. In this respect the users' strong involvement is a key element allowing for the adaptation of platforms. This specific management of equipment, competencies and human resources generates learning rents for the partners (co-publications, exploration of new common research questions, renewal of the instrumentation and services proposed, etc.).

Conclusion

Platforms were invented to cope with new constraints of reactivity and cooperation, which established research institutions were unable to meet. Very directly linked to the change of the scientific production regime triggered by the molecular revolution, along with its hidden promises in the economic domain, the institution of these new systems demanded financial investments in expensive technical instrumentation, as well as investments in form to nurture collaboration between technological and scientific competencies. The platforms therefore rapidly targeted a coupling between, on the one hand, the dynamics of research questions and instruments in an environment with a high level of innovation, and, on the other, the construction of new collectives able to control experimental devices and complex facilities. Their emergence was more the symptom of a need for new organizations than a ready-made organizational solution. This is what the authors and operators of public policies failed to see, institutionally and cognitively surrounded as they were by the established structure of the public research landscape. It was likewise what public firms sometimes failed to perceive. As a result they soon revealed the fragility of their economic model and managed to survive only by developing implicit or explicit intra- or inter-organizational links.

Everything happened as if the promoters of the platforms considered that the modalities of their establishment had solved the problem of interfaces between research and instrumentation, thus making it unnecessary to think about the conditions and variety of their performance. There were two reasons for this: first, the fact of there being only one label concealed the heterogeneity of the platforms and the conditions of their performance; second, the habit of seeing scientific equipment as transparent tools at the service of research concealed the organizational work required. Put to the test of the market, private firms soon discovered this reality. Public organizations shed their duties as supervisory authorities by bringing together instruments and human resources in platforms, and by accompanying their creation with an announcement of general norms for access, service and rates. They were clearly unable to take into account their diversity and to take charge of their coordination. Hence, they disregarded what the platforms' capacity for exploitation, and above all for exploration, owed to the fact that scientific instruments function as real epistemic machines that generate knowledge, channel and focus research activities, pose problems, and help to solve them. They thus deprived themselves of reflection on the possibility of managing the co-evolution of instrumentation and research questions that would make it possible to capitalize on learning rents in a context of very intense scientific competition.

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