Proprietary vs. open-access dimension of knowledge: Illustration in a large public research organisation

Marc ISABELLE

Commissariat à l'Energie Atomique & IMRI, Université Paris-Dauphine

IMRI – Bureau A702
Université Paris-Dauphine
Place du M[al] de Lattre de Tassigny
75775 PARIS Cedex 16
Tel: +33(0)1 44 05 48 19
Email: marc.isabelle@dauphine.fr

1. Introduction

Public research systems have experienced deep transformations worldwide since the 1980s in connection with the competitiveness agenda. In European countries, they are now strongly challenged by the Lisbon strategy of the knowledge economy (a modern version of the competitiveness agenda) as prominent engines of knowledge production and dissemination. Among the changes that take place, researchers are prompted to incorporate more considerations for economic and societal needs in their activities as well as to protect more their results and to work in closer connection with private firms (Ziman, 1994; David, 2000). Some scholars advocate this new social contract for science (Gibbons, 1999) whereas others have expressed concerns about the pitfalls that may arise from this shift (Florida & Cohen, 1999; Florida, 1999; David, 2003).

In the context of increased attention paid to technological innovation as a driver of economic growth, it seems quite obvious why one would like the public research sector to work more interactively with firms and the society at large: public research organisations would be better aligned with and more responsive to firms' needs, the knowledge and technologies they develop would transfer more rapidly and effectively to firms, etc. However, for more subtle reasons, the greater relevance of public research may inadvertently produce effects that negatively hit the bottom-line of the social rate of innovation. These negative consequences can be understood in terms of departures from a normative model of how the scientific system and the market economy ought to work together (Nelson, 2004).

In this model, the function of the scientific system is essentially to build a knowledge base that is largely and freely accessible to business firms and from which they can draw for their innovative activities. This function is satisfied through a set of rules, norms and reward systems that altogether characterise the 'Republic of Science' (Polanyi, 1962; Merton, 1973). A most important one is the rapid publication of research results, which enables their use and evaluation by others and grounds the cumulativeness of the scientific enterprise. Another one is that the definition of the research agenda should take into consideration scientific goals only and not practical outcomes. As a matter of fact, the economic payoffs of basic research are largely unpredictable and it would be misleading to initiate or conversely reject a project according to its economic (ir)relevance. Incorporating more considerations for economic and societal needs encroaches upon this point while the appropriation of results (e.g. through patents) jeopardizes the scientific commons.

Concerning the alleged tension between basic research and economic relevance, Donald Stokes' contribution known as "Pasteur's Quadrant" (Stokes, 1997) pushed the debate forward by showing that basic research need not be curiosity-driven but could be use-inspired –and actually was in many cases. More generally speaking, the disconnection of fundamental research from economic and societal concerns, captured by the metaphor of the ivory tower, could well have been overestimated as well as idealised by the proponents of the linear model of science-based innovation (Nelson, 2000; Brooks, 1994; Mowery et al., 2001). One illuminating historical example of use-inspired basic research is that carried out at the Bell Labs in the 1940s in the field of solid-state physics, which had the applied purpose of searching for better amplifiers of telephone signals and eventually led to the invention of the transistor (Brooks, 1994).

However, Stokes' 2D taxonomy does not say anything about the tension between the scientific commons and the growing importance of appropriation mechanisms in the sphere of public research. As it misses this essential dimension of the normative model sketched above, I contend this taxonomy can not be operational as a tool for characterising research activities in the emerging framework of the knowledge economy. For this purpose, it has to be completed with a third dimension, that of proprietary vs. open-access research. Note that this additional dimension does not refer to intrinsic properties of the activities contemplated but is more largely related to their social organisations in terms of the objectives that are deemed legitimate by those engaged in the research, of their reward system, of the modes of disclosure and the regime of appropriability of the results (Dasgupta & David, 1994).

In this paper, a new taxonomy that expands Pasteur's quadrant with the proprietary vs. open-access dimension will first be presented and discussed. An important question immediately follows the design of the expanded taxonomy: along which of its dimensions does the global pressure for increased relevance of research unfold? The paper will report the results of a survey that used the new taxonomy to analyse the changes that are occurring in a large public research organisation: the French Commissariat à l'Energie Atomique. The CEA is of special interest as compared to its peers in France and Europe because its activities are widely distributed across the various dimensions of the new taxonomy. Its missions are essentially technological ones but many research activities are triggered by curiosity-driven factors and pursue fundamental understanding objectives on top of developing technical devices. Moreover, it has a consistent track record of patent applications and first-class scientific publications. Consequently, the CEA appears to be a propitious organisation in which to probe the expanded taxonomy.

My motivation to review and expand the existing definitions and typologies of research activities was first stimulated by the researchers and the management at CEA themselves. As a matter of fact, during a series of presentations of a study in progress dedicated to analysing the competitive advantage that the CEA could leverage from its ability for coupling internally scientific and technological research, the audience repeatedly mentioned their felt need for precise definitions of the various types of research performed at CEA. They almost unanimously agreed that the ‘fundamental’ vs. ‘applied’ research distinction was not suited anymore and preferred the terminology of scientific vs. technological research, but asked for more in-depth information about what ‘scientific’ and what ‘technological’ really meant.

The remainder of the paper is organised as follows. Section 2 reviews the various characterisations of research activities that are found in the economic literature. It also points at the need for an expanded taxonomy which is then defined and discussed. Section 3 reviews the literature about how the increased pressure for economic relevance manifests itself in the world of public research organisations. Section 4 analyses this issue on the empirical basis of a survey conducted within CEA with the expanded taxonomy. Section 5 concludes.

2. Characterising research activities

The identification of a limited set of economically relevant dimensions of research activities, for classification or modelling purposes, is a task that has long focused the efforts of many scholars. I will first review the existing literature in this field, and then motivate, present and discuss a new taxonomy that builds upon pre-existing work but also adds to it by taking into account the profound changes that research activities have recently experienced in terms of knowledge appropriation.

2.1. The existing definitions and taxonomies

A pivotal and historically-rooted question concerning the economics of research activities is their degree of exogeneity, i.e. to what extent is the research sector interconnected with the economy and through which channels? A one extreme, in the linear model view, the research sector is seen as functioning autonomously and simply feeding the economy with new scientific and technological knowledge or information. On the other hand, many departures from this exogenous model are possible, e.g. the financing of the research sector comes from the economy and may fluctuate with it, some issues tackled by the research sector may have originated in the stream of economic activities, or some research activities may be deliberately carried out to produce competitive advantages for specific economic actors.

These various forms of the exo/endogeneity of research activities have focused a mushrooming terminology. A distinction that is repeatedly mentioned is that of ‘basic research’ as opposed to ‘applied research’ but these terms also include ‘fundamental research’, ‘curiosity-driven research’, ‘blue-sky research’, ‘use-inspired research’, ‘upstream research’, ‘scientific research’ and ‘technological research’. These terms are seldom defined with enough precision. However, there have been several attempts by scholars or official bodies to provide careful definitions of some of these terms, to question their signification or to build taxonomies of research activities.

Calvert & Martin (2001) use a survey of UK and US scientists to analyse in detail the different meanings of ‘basic research’, starting from the point that the term is often invoked but the concept is rarely analysed, leading to confusion. They find most interviewees have an epistemological definition in mind when using the term ‘basic research’, i.e. they refer to the unpredictability of research, to its generality, to the theory and reductionism behind it, as well as an intentional one, i.e. basic research is driven by sole curiosity. Twice less frequent is the reference to distance from applications and four times less is the reference to the institution where the research is done (i.e. basic research is university research) as well as the norms of disclosure (i.e. basic research is published research). The least frequent association is with specific scientific fields that are implicitly considered to grow on basic research.

Official definitions of the Frascati Manual (OECD, 1994) oppose 'basic research' to 'applied research'. They rely on the epistemological, the intentional as well as the norms of disclosure references but omit the distance from application, the institutional and the scientific field references that some researchers have in mind. Thus, according to the OECD, applied research is defined as being directed primarily towards a specific practical aim or objective and its results are intended primarily to be valid for a single or limited number of products, operations, methods, or systems. Lastly, the knowledge or information derived from it is often patented but may also be kept secret. Conversely, the OECD considers basic research to be experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. It analyses properties, structures, and relationships with a view to formulating and testing hypotheses, theories or laws. Furthermore, the results of basic research are not generally sold but are usually published in scientific journals or circulated to interested colleagues.

From these definitions, it clearly appears that basic and applied research are multidimensional concepts. Hence, asking researchers whether the changes in their research environment has induced a shift towards more 'applied research' as opposed to 'basic research' won't tell much about the true nature of the shift: does it mean less theory or generality, or less room for curiosity-driven activities, or activities that are closer to applications, or more and more patented results? Introducing additional subdivisions along the linear basic / applied research axis (e.g. 'Applied technology', 'Technological research & engineering', 'Targeted scientific research' and 'Basic scientific research' as defined by Narin at al, 1976[1]) does not help much in this respect. This paper is an attempt to disentangle one-dimensional conceptions of research activities that will be combined in a new taxonomy with the purpose of better understanding which directions the pressure for increased relevance really goes.

This methodological point of view has already been adopted by Stokes (1997). Departing from the linear model of science-based innovations that emanated from Bush's influential report to the US President Roosevelt (Bush, 1945), Stokes opposed a widespread opinion according to which research activities that intended to be useful were presumably pointless in terms of fundamental knowledge generation. Building on his investigation of Louis Pasteur's research experience, he recommended that the fundamentality of research activities on the one hand (the epistemological dimension) and their utility on the other hand (the intentional dimension) were two separate dimensions and he concluded that basic research (i.e. research targeted towards fundamental understanding) could be use inspired and actually was in many cases. His 2D taxonomy largely diffused out of his book as a tool for characterising research activities and occasionally for shaping discourses about science and technology policy. In connection to this, Pasteur's quadrant has been extensively used to refer to 'use-inspired basic research'.

Figure 1. Stokes' 2D taxonomy

Considerations of use?

Quest for fundamental understanding?	No	Yes
Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
No		Pure applied research (Edison)

2.2. An expanded taxonomy: motivation and presentation

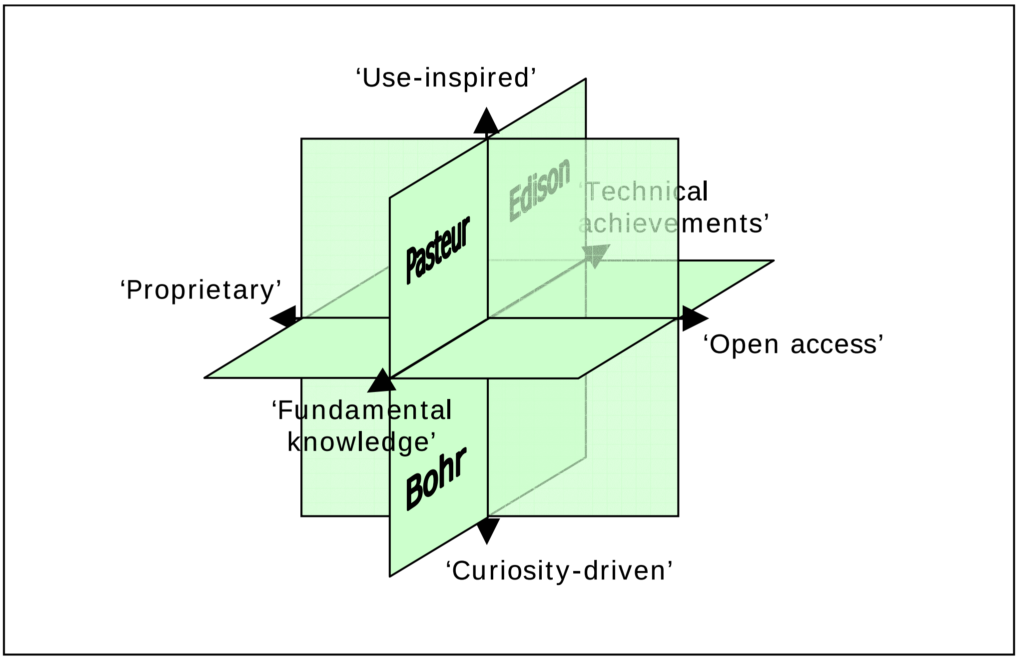
As useful as it may be, Stokes 2D taxonomy does not say anything about the ownership and control a research institution or a researcher might have on the results of its or her activities. Yet, this dimension of public research activities has deserved increasing attention by scholars and policy-makers following the reforms of public research systems of the past 25 years. These reforms first took place in the US with the Bayh-Dole act of 1980 and then diffused to Europe. In France, for example, a major law on innovation and research was passed in 1999. They have the double purpose of stimulating technological innovation and economic growth at the national level as well as of increasing economic returns from investment in public R&D (see e.g. Cohen et al., 1998; OECD, 1996). To this end, most of them strongly promote the appropriation of their research results by PROs –essentially through patenting– and their licensing to business firms.

However, the development of intellectual property instruments in the public research sector is highly controversial. As a matter of fact, some scholars have unveiled the importance of public research systems delivering freely accessible knowledge and building a knowledge-base for the national innovative capacity (Nelson, 2004). They have also pointed at the possible damages that a broad diffusion of the patenting of results emanating from public research may induce on innovation, through the fragmentation of the knowledge base (Heller & Eisenberg, 1998). So the proprietary vs. open-access dimension is essential when it comes to fully grasp the economics of how the research sector could foster the knowledge economy. To put it shortly, it may be that use-inspired basic research *à la Pasteur* has its results either published or patented, and this makes a big difference in the way these results could be used for other research or for innovation purposes, and eventually from the social welfare point of view.

Moreover, Dasgupta & David (1994) have argued that the behaviour of researchers in terms of the appropriation or publication of the results that proceed from their research lies at the core of the distinction between the scientific system and the technological system, which itself grounds the normative model presented in the introduction. More generally speaking, they contend that the social organisations that prevail in each research system are more relevant to distinguish between communities of researchers than their methods of inquiry, the nature of the knowledge obtained or the sources of their financial support. Notice however that their definition of 'the realm of Technology' and 'the Republic of Science' are normative in the sense that they bind together the various dimensions, e.g. research in the Republic of Science is meant to be curiosity-driven, to produce new fundamental knowledge and to be published. Conversely, a researcher working on a project for a firm and publishing some results can not find her place in either of the two systems…

Following the previous discussion, it appears that three disentangled dimensions of the research space should be retained. The first one relates to the epistemological category of Calvert & Martin (2001) and is concerned with the very nature of the research activities. On the one hand, there are research activities that produce 'fundamental knowledge', i.e. new understanding of the laws of nature based on theory building, reductionism and modelling. While on the other hand, there are research activities that yield 'technical achievements' for which understanding is an issue in so far as it helps in getting things work. The second dimension is the intentional one: 'curiosity-driven' research is undertaken to satisfy the curiosity and to meet the interest of the individual researcher and of the research community at large while 'use-inspired' research is undertaken with the expectation that it will be useful. Lastly, the 'open-access' vs. 'proprietary' distinction refers to the norms of appropriation of the results, of control over them and also of their disclosure. Basically, research results are published in journals and made open-access in the first regime whereas in the second they are appropriated essentially through patenting (or by being kept secret).

Figure 2. Disentangling three dimensions of the research space



2.3. An expanded taxonomy: discussion

Note that the axes in this expanded taxonomy have a different interpretation than in Stokes' 2D taxonomy. In the latter, the opposite ends of the axes express a yes / no antagonism with the consequence that the taxonomy effectively exhibits four quadrants. In the expanded taxonomy, the opposite ends of any axis are not necessarily antagonist. As my survey of researchers within CEA will reveal, some research activities may generate new fundamental knowledge and at the same time lead to technical achievements. Some may also be driven by curiosity in the sense that they are considered as areas worth exploring by scientific communities while they may also be expected to yield useful results. Contrary to what Stokes' taxonomy suggests, there does not seem to be any reason why the sets of research activities triggered by researchers' curiosity on the one hand and by the expectation to produce useful outcomes on the other hand could not overlap. Finally, taking a patent on an invention does not prevent researchers from publishing their results in academic journals afterwards.

At the end of the day, the expanded taxonomy gives rise to $3^3 = 27$ different options for characterising research activities, so it provides a much more detailed characterisation than Stokes' 2D taxonomy. Given the non-opposition between both ends of any axis, the 3D 'xyz' representation is probably not best suited to serve as a tool for representing a given research activity, a purpose for which a 'radar' representation would fit better. Yet, I chose to represent the taxonomy as it is to illustrate that it expands Stokes' 2D taxonomy. Moreover, this representation is consistent with the fact that each axis represents a homogenous dimension of the research space, i.e. (i) the motivation for the research, (ii) the nature of its outcomes and (iii) the way its results are appropriated / controlled / disclosed.

Of course, the three dimensions may be correlated in practice although they are disentangled from the logical point of view. For example, idealistic types of research activities easily find their way into the new taxonomy: 'fundamental research' refers to curiosity-driven research activities that yield new fundamental knowledge and have their results published in academic journals without paying attention to appropriation, to technical achievements nor to expectations of usefulness. Conversely, 'applied research' stands for use-inspired research activities the results of which are technical achievements that are appropriated by their inventor. For this type of research, fundamental knowledge elaboration, the curiosity of any stakeholder and the publication of research results in journals are disregarded. It is however most probable that these stylised types barely exist in reality.

As far as the intentional dimension is concerned, it is worth mentioning the ex post – ex ante difference. That considerations of use do (or do not) contribute to trigger the undertaking of a particular research activity does not imply that the research will (or won't) be useful ex post. As already mentioned, it is in the nature of research activities to be subject to high uncertainty. Some research activities that intend to be useful end up not that useful and conversely, others end up with a wide range of applications although they were by and large driven by curiosity (e.g. the discovery of radioactivity). What matters for the purpose of this paper is the intention of the researcher or research team in charge of the activities contemplated with respect to encompassing considerations of use, be it ex ante or ex post[2]. Finally, one should note that some research activities may move across the taxonomy as time passes by, e.g. go from an essentially (curiosity-driven - fundamental knowledge - open-access) position to a more (use-inspired - fundamental knowledge – proprietary) one.

3. What do we know about the expression of the increased pressure for the relevance of research?

An abundant literature has studied in the past decade the effects of the increased pressure for the relevance of public research (as referred to by Pavitt, 2001) but the results are still controversial. The main theoretical and empirical results related to the skewing problem, the tragedy of the anti-commons and the secrecy problem will now be presented in turn.

3.1. The skewing problem

A first concern is about the threat to basic research that may arise from a shift to more short-term and applied research in response to the requirements of industrial partners, known as the skewing problem (Florida & Cohen, 1999). The 'short-term' and 'applied' terms refer to the lack of room for curiosity-driven research as well as an attitude that might be incompatible with fundamental knowledge generation. Hence, the skewing problem has connections with two dimensions of the expanded taxonomy.

From the economic point of view, the skewing problem relates to the inefficiencies that may stem from the allocation of resources for research according to their anticipated economic returns, a feature that is clearly related to use-inspiration in the expanded taxonomy. The problem is that the market economy is considered a poor mechanism to allocate resources for scientific research given the serendipity of its results. Conversely, these resources would be best allocated when informed scientists themselves decide what the important subjects for scientific inquiry are (Nelson, 2004). This point clearly calls for a balance between curiosity-driven and use-inspired research, on which the various sources of financial support that are available for researchers have a great impact. Typically, recurring funding allows scientists and communities to select research themes according to their own judgment while industrial or government agency funding selects a priori research themes that are anticipated to yield practical payoffs.

The empirical evidence on these points does not deliver a definite answer. Blumenthal et al. (1986) found that researchers whose activities were supported by industry were four times more likely than others to report that their decisions to explore a particular research topic had been impacted by the expectation that it would yield commercial applications. Rahm and Morgan (two authors cited in Florida & Cohen, 1999) find a small positive relation between the involvement of academia with the industry and increased levels of applied research, although the direction of this relation remains open to question.

Also, Goddard & Isabelle (2006a) found on the basis of a survey of 130 laboratories' directors in French PROs that, because of collaboration, labs tend to step-up their 'applied research and experimental development' and, to a lesser extent, their 'oriented basic research' while this shift is only marginally accompanied by a diminution in 'pure basic research'. Addressing more specifically the issue of the returns to public R&D, Henderson, Jaffe & Trajtenberg (1998) use American universities patents' citations counts to show that some measures of the generality and of the importance of these patents have decreased since the early 1980s and that correlatively, the strong increase in university patenting triggered by the Bayh-Dole act of 1980 encompasses essentially low-quality patents.

By contrast, Ranga et al. (2003) find on the basis of publications classification and counts at the Belgian Katholieke Universiteit Leuven that there is no evidence of a shift towards applied research in connection with the involvement in university-industry linkages. In an extension of this work, Van Looy et al. (2004) compare scientists at the Katholieke Universiteit Leuven who engage in contract research with firms to those who don't, and find that the first group publishes more in applied fields without publishing less in the basic fields. Also, Hicks & Hamilton (1999) studied a very large sample of university publications and university-industry co-publications over the 1981-1994 period and found that the proportion of basic research papers did not decrease over time although that of co-authored papers between academia and researchers in firms did increase.

Two other concerns with the increased relevance of public research relate to the third dimension of the expanded taxonomy, i.e. the appropriation, control and disclosure of results.

3.2. The tragedy of the anti-commons

First, the patenting of research results may have detrimental effects on innovation. Heller & Eisenberg (1998) have shown that the fragmentation of the scientific and technological knowledge base could lead to a tragedy of the anti-commons, in the sense that the high coordination costs that must be incurred in order to gather complementary inventions scattered among many different owners, as well as the strategic behaviours of the latter, may delay or simply make it unprofitable to develop an innovation that would otherwise have been developed –i.e. had the inventions been freely available in the public domain. In the aggregate, it is the whole innovation activity itself that could be deterred. This risk is more prevalent with complex and integrative technologies (Shapiro, 2001) or where the innovation process is highly cumulative (Scotchmer, 1991).

It is only recently that several studies have been implemented to yield empirical evidence on this point, with different focuses and methodologies. Walsh, Cho and Cohen (2005) surveyed US academic scientists in the field of biomedical research in order to ascertain the extent of the “patent thicket” in upstream research. They find that patents on research inputs do not divert researchers from pursuing specific projects and only very marginally delay or modify them, one apparent reason for this being that academic scientists are barely aware of the patents that are relevant to their research. It may well be that industry scientists would tell a different story.

Murray & Stern (2006) take a different perspective and find more pessimistic results. They directly investigate the anti-commons in scientific knowledge diffusion by focusing on paper-patent pairs[3] and find a moderate drop in a paper’s citations after the associated patent is granted (more than three years later on average). They conclude that a modest anti-commons effect does exist in the sense that published findings that are associated with formal intellectual property rights have a lower cumulative scientific impact than in the absence of such intellectual property rights.

3.3. The secrecy problem

The secrecy problem (Florida & Cohen, 1999) relates to restrictions over the disclosure of research results that may be imposed by industrial partners. The question “what can (not) be published and when?” clearly relates to the ‘open-access’ dimension of the expanded taxonomy. It also connects to the ‘proprietary’ dimension in the sense that publications may be delayed to allow for patent application. These restrictions have been extensively documented in the literature.

Blumenthal et al. (1997) surveyed a large sample of scientists in the field of life science and found that participation in collaborations with private firms and commitment to the commercialisation of research results were often associated with publication delays, and that the main drive behind these delays was to allow time for filing patent applications. Cohen et al. (1994) surveyed 1056 joint university-industry research centres in the US and found that for half of them, the industrial partner could force a delay on the publication of research results while for one third, it could have some information deleted from papers prior to publication. Exploiting a similar survey for French PROs, Goddard & Isabelle (2006b) find comparable figures with the additional result that 26 per cent of respondents effectively experienced restricted information from publications.

Delayed or precluded publications are not the only form that restrictions on scientific communication can take. As a matter of fact, informal exchange between researchers is another important vector for the diffusion of scientific information, and the decision to informally share information with colleagues or on the contrary to withhold that information is another difference captured by the 'open-access' vs. 'proprietary' dimension that this paper's taxonomy adds to Pasteur's quadrant. Here again, the literature does not offer definite answers.

The survey by Blumenthal et al. (1997) did not find any significant relation between the involvement of researchers with industry and the withholding of research results. In their comparison of two distant surveys of mathematicians, physicists and experimental biologists conducted in 1966 and 1998, Walsh & Hong (2003) confirm an increased practice of secrecy among academic scientists and analyse the predictors of this trend. They find a mixed effect of the scientists' commercial activity, given that secrecy increases with industry funding but decreases with industry collaborators.

The survey of lab directors in French PROs analysed by Goddard & Isabelle (2006b) directly addresses this question of the limitations in scientific communication induced by collaboration with industry. Not surprisingly, a majority of respondents report limitations with firms other than the partner(s) but 30 per cent also experience restrictions with researchers at other PROs. A striking result is that limitations even affect communication within the lab (although to a lesser extent), whereby it is the true locus of scientific and technological knowledge production that is torn apart.

4. Empirical results

In this section, the expanded taxonomy is used to empirically analyse the changes that are occurring in the type of research performed at a large public research organisation: the French Commissariat à l'Energie Atomique. I will present the CEA and explain why it is a propitious organisation to test the new taxonomy of research activities before turning to the description of the preliminary survey and its results.

4.1. Why probing the expanded taxonomy in the CEA?

A characteristic of the French public research stems from its duality in the sense that universities coexist in approximate parity with government laboratories ("*grands organismes*" as called in France) that, as opposed to the former, are mostly oriented towards technological research in specific areas (medicine, energy, defence, NICT, etc.). The Commissariat à l'Energie Atomique is the largest of these government labs and the second largest public research organisation in France by its number of employees[4]. It has distinctive features that make it a propitious organisation to probe the expanded taxonomy. As a matter of fact, its activities are distributed over a large bandwidth on the research spectrum –from fundamental to applied research, to keep on referring to the traditional terminology– in some targeted technological areas: defence and global security, energy, information and health technologies.

Firstly, what gave birth to the CEA and subsequently defined it the best are its technological missions, often related to national strategic objectives: providing France with the nuclear weapon and developing the technological infrastructure for the French electronuclear industry (as soon as its inception in 1945); fostering technological innovations in the fields of NICT and new technologies for health since the 1980s. From this point of view, research at CEA tends to be mostly use-inspired and to a large extent aiming at technical achievements. Correlatively, CEA has a long experience of working with industry and the patent culture is more diffused there than in most other French public research organisations[5].

But in addition, CEA's technological missions rely on selected fundamental research activities that have always been preserved. This is reflected in CEA's organisation into four operational divisions: Nuclear Energy, Military Applications, Technological Research and Fundamental Research, the latter being composed of two subdivisions: Life Sciences and Matter Sciences. Moreover, the CEA has an important track of scientific records in the fields of, e.g., nuclear physics, astrophysics, particle physics, thermonuclear fusion and also in many domains of chemistry and biology. On top of these complementary missions, CEA has an established technological capacity for the design, construction and operation of large scientific instruments, from thermonuclear fusion reactors[6] to particle accelerators and satellites.

Another obvious reason why I study CEA specifically is that I can observe it from the inside given that I've been working as an economist in its Department of Economic Studies since March 2003. This position is a privileged one in the sense that I can observe and verify the information that is usually unobservable or unverifiable for the outsider. Moreover, one of my jobs there as an economist is precisely to investigate the origins, mechanisms and consequences of the transformations at stake in public research organisations and to produce targeted, accurate and serviceable information in order to help the researchers and the management anticipate and proactively react to them.

4.2. The survey and its results

In January 2006, I implemented a survey prototype directed towards selected researchers within CEA to assess the reliability of the expanded taxonomy and to test whether it could be useful as a tool to identify what directions the pressure for increased relevance of public research really goes. The sample size was of about 50 individuals and the empirical results presented here are based on the 37 answers received. 37 is not a large number so these prototype results must be interpreted cautiously. However, after controlling for various clustering effects (see below), the variability of data appears to be quite low so I contend that additional data in the future will tend to reinforce the results sketched hereafter. The questionnaire used for the survey is reproduced in Appendix 1. Its questions basically stick to the expanded taxonomy in order to characterise the research activities contemplated, the changes they undergo as well as to identify the sources of these changes. Answers were coded on a 3 point Likert scale for

Q0, Q1 and Q3 and on a 5 point Likert scale for Q2 (i.e. as 1, 2, 3, 4, 5 from the leftmost to the rightmost column).

The researchers who were surveyed are outstanding CEA researchers that were appointed 'research director' (henceforth 'RD'). This highly selective grade is specific to the CEA and was instituted in 2000. Its awarding is a priori independent of the researcher's hierarchical position in the organisation but testifies that he or she achieved major scientific or technological successes during his or her career. Thus, RDs form a network of high-skilled scientific experts whose mission is to take part in the scientific and technical appraisal of CEA's programmes, to provide assistance with respect to strategic planning and lastly to disseminate scientific and technical knowledge at the national and international levels. RDs are promoted for a five year period that can be re-conducted. In 2005, there were one hundred and nine RDs representing a wide range of scientific and technical capabilities.

A subset of about 50 RDs was selected according to two criteria: (i) they ought to be distributed across the different divisions in CEA so as to represent roughly the number of employees in each division; (ii) for any given division, their areas of expertise should be as representative as possible of the variety of specialities. Table 1 shows the distribution of the 37 respondents among CEA's five operational divisions.

Table 1. Distribution of respondents among CEA's five operational divisions

DAM	DEN	DRT	DSM	DSV	All together
27% 10	16% 6	16% 6	27% 10	14% 5	100% 37

Note: DAM = Division of Military Applications
DEN = Division of Nuclear Energy
DRT = Division of Technological Research
DSM = Division of Matter Sciences
DSV = Division of Life Sciences

As compared to the overall number of employees in each division of the CEA, the sample is biased towards an over-representation of the Division of Matter Sciences (DSM) and an under-representation of the Division of Nuclear Energy. Correlatively, basic research activities are probably over-represented in the sample while applied research activities are under-represented. In the taxonomy, this might induce a bias towards the ‘fundamental knowledge’, ‘curiosity-driven’ and ‘open-access’ types, while the ‘technical achievements’, ‘use-inspired’ and ‘proprietary’ types might be under-represented. So the sample does not mean to be representative of all research activities being conducted in CEA.

A first look at the data is provided by the next table, which exhibits usual descriptive statistics for a Likert scale-based survey, i.e. the median, the mode, the range and the inter-quartile range.

Table 2. Usual descriptive statistics associated with Likert scale variables

	Q0 Satisfaction					
Median	1,0					
Mode	1,0					
Range	1,0					
Inter-quartile range	1,0					
	Q1 Position in taxonomy					
	Technical	Fundamental	Use-inspired	Curiosity-	Open-access	Proprietary
Median	1,0	2,0	1,0	2,0	1,0	2,0
Mode	1,0	2,0	1,0	2,0	1,0	2,0
Range	2,0	2,0	1,0	2,0	2,0	2,0
Inter-quartile range	1,0	1,0	0,0	0,3	1,0	1,0
	Q2 Changes in position					
	Technical	Fundamental	Use-inspired	Curiosity-	Open-access	Proprietary
Median	3,0	3,0	2,0	3,0	3,0	2,0
Mode	3,0	3,0	2,0	3,0	3,0	2,0
Range	3,0	3,0	3,0	3,0	4,0	3,0
Inter-quartile range	1,0	0,0	1,0	1,0	1,0	1,0
	Q3 Sources of change					
	Industrial	Sources of	Assessment	Hierarchy	Other	
Median	2,0	1,0	2,0	2,0	3,0	
Mode	3,0	1,0	3,0	3,0	3,0	
Range	2,0	2,0	2,0	2,0	2,0	
Inter-quartile range	1,0	1,0	1,0	2,0	0,0	

These figures first tell that the respondents are mostly happy with the taxonomy, and this is a most confident result (the Range and the Inter-quartile range show a low variability).

Concerning the position of research activities in the taxonomy (Q1), the strongest and most confident result (inter-quartile range = 0,0) is that respondents are engaged in activities that are essentially use-inspired (median = 1,0 and mode = 1,0) despite the bias towards basic research I identified earlier. This is not a surprising feature concerning the CEA whose central missions are technological ones. Yet, another very robust result (inter-quartile range = 0,25) is that these activities are also, to a lower extent, curiosity-driven (median = 2,0 and mode = 2,0). Besides, the research activities contemplated seem to be aiming more at technical achievements than at fundamental knowledge generation as well as to be more open-access than proprietary (median = 1,0 and mode = 1,0 vs. median = 2,0 and mode = 2,0 in each case) although these results are less confident.

The identification of the changes that occurred in the past few years (Q2) shows that the research activities contemplated have turned more use-inspired and more proprietary (median = 2,0 and mode = 2,0), two results that are confident enough. This must be put in perspective with the fact that curiosity-driven activities seem to be by and large unchanged as well as activities the results of which are made open-access (median = 3,0 and mode = 3,0; for the latter, range = 4,0 indicates more dispersed extreme answers). Finally, no shift has occurred concerning activities aiming at technical achievements or activities aiming at fundamental knowledge generation (median = 3,0 and mode = 3,0), the latter result being the most robust of all (inter-quartile range = 0,0).

Lastly, the answers to the question about the sources of the changes that occurred (if any) reveal that the tracking sources of financial support has the strongest impact (median = 1,0 and mode = 1,0) and this result is confident enough. Moreover, when looking at the whole sample, there is no clear evidence that other factors have triggered the changes under scrutiny (median = 2,0 but mode = 3,0, i.e. the answer “No” has the highest response rate).

Medians and modes computed for the whole sample may hide heterogeneous responses of subgroups scattered around them. So let me now turn to the distributions of responses that are shown in the following table (the related bar charts are reproduced in appendix 2).

Table 3. Distributions of responses

		1	2	3	4	5	NR	Total
Q0 Satisfaction		70%	30%	0%			0%	100%
Q1 Position in taxonomy	Technical achievements	57%	30%	8%			5%	100%
	Fundamental knowledge	41%	54%	5%			0%	100%
	Use-inspired	81%	16%	0%			3%	100%
	Curiosity-driven	24%	62%	11%			3%	100%
	Open-access	57%	38%	5%			0%	100%
	Proprietary	35%	49%	11%			5%	100%
Q2 Changes in position	Technical achievements	14%	32%	41%	8%	0%	5%	100%
	Fundamental knowledge	0%	24%	59%	14%	3%	0%	100%
	Use-inspired	14%	54%	27%	3%	0%	3%	100%
	Curiosity-driven	0%	11%	57%	27%	3%	3%	100%
	Open-access	3%	24%	57%	14%	3%	0%	100%
	Proprietary	5%	46%	30%	14%	0%	5%	100%
Q3 Sources of change	Industrial partners	22%	32%	38%			8%	100%
	Sources of financial support	49%	32%	11%			8%	100%
	Assessment systems	16%	35%	41%			8%	100%
	Hierarchy	30%	27%	35%			8%	100%
	Other	16%	3%	73%			8%	100%

A vast majority of respondents (81 per cent) characterise their research as being essentially use-inspired. At the same time, only four respondents in this subset consider their research to be not curiosity-driven at all[7]. Moreover, two occurrences are found of research activities considered to be both essentially use-inspired and essentially curiosity-driven. So contrary to what Stokes' designation of Pasteur's quadrant as being 'use-inspired basic research' may suggest, use-inspired and curiosity-driven research are not antagonist. However, they can be considered weak substitutes since the two variables have the same value only in the two instances mentioned above. In other words, a vast majority of researchers (84 per cent) consider their research to be both use-inspired and curiosity-driven but most frequently one type dominates while the other is only of second-order importance.

A majority of respondents (57 per cent) said their research was essentially open-access while a minority (35 per cent) said it was essentially proprietary (remember though that 41 per cent of respondents belong to the ‘Fundamental Research’ divisions of CEA). Moreover, only two respondents answered that their research results were not open-access while only four said their results were not proprietary. In other words, for a large majority of respondents (78 per cent), research results are made open-access *and* appropriated. This suggests that researchers are able to sit on the fence in the sense that they manage to publish some research results (95 per cent) and to patent some others[8] (84 per cent), developing safeguards against the “secrecy problem”. Here again, though, a weak substitution exists between proprietary and open-access research since the two variables have the same value only in five instances: for 65 per cent of the respondents, research results are appropriated and made open-access with one dominating and one dominated type.

Similar results are found for the ‘Technical achievements’ / ‘Fundamental knowledge’ dimension. A majority of respondents (57 per cent) see the former as being the essential outcome of their activities while fundamental knowledge is the essential outcome for fewer respondents (41 per cent). 81 per cent indicate that their activities have both ‘technical achievements’ *and* ‘fundamental knowledge’ as an outcome, while there is a weak substitution between the two since one type of output dominates the other in most case (93 per cent of the preceding subset).

Regarding the changes that occurred in the past few years, the strongest shift in research profiles has been towards more use-inspired research (14+54=68 per cent). Other shifts towards more technical achievements (14+32=46 per cent) and more proprietary research (5+46=51 per cent) have also occurred, yet to a lower extent. When combined together, these three trends show that in the aggregate, it is the idealistic ‘applied research’ type (see subsection 2.3.) that has gained increased importance in the past years.

The antagonism between opposite ends of the taxonomy’s axes appears in this dynamic (or marginal) perspective since at the same time, 30 per cent of respondents answer that their research is less curiosity-driven, 16 per cent that it is less open-access and 16 per cent that it is less aiming at fundamental knowledge generation. More precisely, I find that use-inspiration and curiosity-drive are strong substitutes at the margin in the sense that both never experience the same shift: when one is said to be stronger, the other is said to be weaker or unchanged (and vice-versa). This strong marginal substitution feature also holds for research aiming at technical achievements vs. research aiming at fundamental knowledge generation. And likewise concerning proprietary vs. open-access research except for one researcher in the Division of Military Applications who declares that her research activities have become much more open-access and at the same time more proprietary, plus another in the Division of Technological Research the activities of whom have simultaneously become more open-access and proprietary.

Interestingly, it should be mentioned that for 27 per cent of respondents, research results are made more open-access. This answer has been made by every researcher but three in the Division of Military Applications, which is overrepresented in this subset (70 per cent). As a matter of fact, a significant part of this Division’s programmes have swung from technological to more scientific work in the past decade including from the point of view of the norms of disclosure of results, following the French decision to abandon nuclear testing in 1996. Since then, the credibility of French nuclear deterrence heavily relies on CEA's capacity to demonstrate cutting-edge scientific capabilities for simulation-based nuclear weapon design.

More generally speaking, the survey provides insights of the extent to which the self-governed scientific commons are put in danger at CEA: for a large majority of respondents, research producing new fundamental knowledge has not diminished in the past few years (84 per cent) nor has open-access research (84 per cent) nor has curiosity-driven research (70 per cent)[9]. The latter result is the more pessimistic.

When asked about the reasons for the shift in their research profile over the past few years, one respondent out of two (49 per cent precisely) answer that it is essentially the sources of financial support. It is striking that all these respondents but one consider their research as having drifted more or much more use-inspired in the past few years (subset probability of 94 per cent as compared to 68 per cent in the whole sample). The financial support motivation is also closely associated with the shifts in terms of more or much more technical achievements (subset probability of 78 per cent as compared to 46 per cent in the whole sample) and in terms of more or much more proprietary results (72 per cent vs. 51 per cent). Moreover, all respondents who said that their research had become less or much less open-access are included in these 49 per cent (subset probability of 33 per cent as compared to 16 per cent in the whole sample). The financial support motivation is also closely associated with the shifts towards less or much less curiosity-driven research (50 per cent vs. 30 per cent) and towards less or much less fundamental knowledge generation (28 per cent vs. 16 per cent).

So the story being told by these figures is that of all types of research in the sample being forced to be more use-inspired but also more proprietary and aiming at more technical achievements because of the sources of financial support they have to chase. This shift occurs at the expense of the idealistic fundamental research type (less curiosity-drive, less open-access and less fundamental knowledge generation; see subsection 2.3.). These results are summarised in table 4:

Table 4. Changes in research profiles when the sources of financial support are an essential drive for change

	Technical achievements	Fundamental knowledge	Use-inspired	Curiosity-driven	Proprietary	Open-access
More + much more	78% (46%)		94% (68%)		72% (51%)	
Less + much less		28% (16%)		50% (30%)		33% (16%)

Conditional probability compared to whole sample probability (in brackets)

It is noteworthy that this story is being told by every researcher in the Division of Technological Research, which heavily depends on non-recurring funding. But incidentally, it is also told by researchers in every division of CEA (yet only very marginally –i.e. by one researcher– in that of Military Applications where financing comes in a more regular fashion essentially through the Ministry of Defense).

Another 30 per cent take their hierarchy essentially responsible for the shifts that occurred in their research profile. This feature would probably be to a certain extent specific to the CEA where, as compared to its peers in France, hierarchy plays a much greater role. It happens that the three technological divisions in CEA (Division of Military Applications, Division of Nuclear Energy and Division of Technological Research) are over-represented in this subset (subset probability of 82 per cent as compared to 59 per cent in the whole sample). In these divisions, hierarchy is part of the ethos as well as a coordination mechanism of greater importance than in the Division of

Fundamental Research –although formal organisation charts are similar in every division. Correlatively, these researchers are mostly engaged in activities essentially aiming at technical achievements (82 per cent vs. 57 per cent) and essentially appropriating their results (55 per cent vs. 35 per cent). It is noteworthy that the responsibility put on the hierarchy is primarily associated with lower probabilities to experience no shift in research profiles (except for the shift in terms of technical achievements) but that the shifts contemplated are ambiguous (e.g. stronger probability than in the aggregate to have more or much more open-access results but also to have less or much less open-access results).

Lastly, industrial partners are said to be the essential cause of the shifts contemplated in research profiles by another 22 per cent of the respondents. The research profile of these respondents is less oriented towards essentially open-access results (subset probability of 38 per cent as compared to 57 per cent in the whole sample) and more oriented towards essentially proprietary results (50 per cent vs. 35 per cent). The shift under scrutiny is predominantly towards less or much less fundamental knowledge generation (38 per cent vs. 16 per cent). But less or much less curiosity-drive also shows (50 per cent vs. 30 per cent) as well as less or much less open-access results (25 per cent vs. 16 per cent) and more or much more proprietary results (75 per cent vs. 51 per cent). The Division of Technological Research of CEA that is heavily engaged in collaborative research with industrial partners is overrepresented in this subset (38 per cent as compared to 16 per cent in the whole sample).

5. Conclusion

The taxonomy developed in this paper expands on Stokes' "Pasteur's quadrant" and allows to better characterise research activities and to better scrutinize the changes that they undergo. The survey based on this expanded taxonomy in the French Commissariat à l'Energie Atomique delivers a broad message of hybridisation. Clearly, following Pasteur's quadrant, it appears that research at CEA is predominantly 'use-inspired basic research', i.e. it encompasses considerations of use and follows the quest for fundamental understanding; but it is also much more than this 2D taxonomy could ever tell. The survey shows that in CEA, research activities are by and large both use-inspired and curiosity-driven, producing both fundamental knowledge and technical achievements as well as both made open-access and appropriated. Notice that the basic vs. applied research distinction is practically useless to say anything about the research that is being conducted there –and, I contend, in many other places.

The survey also reveals that the increased pressure experienced by researchers to take more economic and societal needs into consideration manifests itself essentially through more use-inspiration and more proprietary results. Furthermore, the analysis shows that use-inspired and curiosity-driven research are perfect substitutes at the margin, that is in a dynamic setting. This marginal substitution feature also holds for research aiming at technical achievements vs. that aiming at fundamental knowledge generation, and for research generating proprietary results vs. research producing open-access results.

Tracking sources of financial support for research activities is considered to be the most important factor triggering the changes contemplated. When this cause is said to be essential, the shift in research profiles is even more clearly directed towards more 'pure applied' research (i.e. proprietary and use-inspired research aiming at technical achievements) and less 'pure fundamental' research (i.e. open-access and curiosity-driven research aiming at fundamental knowledge generation). This set of results highlights the impact of the changing rationale for research funding that has been taking place in Europe during the past decades (Geuna, 2001) and the importance of the composition of research funding for regulating the research sector overall. It intimates the following main policy implication of this work.

Since Nelson (1959) and Arrow (1962), it is theoretically established that the provision of resources for R&D through competitive market can not trigger a sufficient production of scientific knowledge because of its non-appropriability. Conversely, it can be anticipated that the growing contractual-oriented and competitive approach to research funding should prompt more proprietary research –as characterised by the expanded taxonomy– and this is illustrated in the findings. But there is more than that: the results presented above suggest that such competitive funding also skews research towards more directly useful projects (to a greater extent than what industrial partners do) and that it stifles the generation of fundamental knowledge.

Moreover, it appeared that researchers are able to perform various or multifaceted activities but that they can not develop them altogether: the changes that occur underscore the growth of some types of activities at the expense of other types. Accordingly, it is very important for policy makers to strike a balance between recurring and non-recurring funding for public research according to a choice that should be made explicit in terms of the relative volumes of fundamental and applied research. From this point of view, the consequences of the creation in 2005 of the French "*Agence*

Nationale de la Recherche" (ANR), a funding agency for research that will increase the volume and proportion of project-based financing, will deserve particular attention.

Methodological issues are raised by this study. First of all, the CEA is a government lab and as such, it differs from university research in many respects –in particular, it is presumably much more concerned with economic, industrial and societal needs. Secondly, the dataset that is used consists in self-reported information about one's research activities, the reliability of which can be tenuous given their important emotional dimension. For example, it may not come as a surprise that not any researcher said her activities were not use-inspired at all –an answer that could be emotionally associated with being useless. Lastly, the results must be considered cautiously since they are based on a survey prototype that covers a sample of very limited size. They will be further consolidated and validated only with the extensive survey that will be carried out shortly.

6. References

Arrow K., (1962), "Economic welfare and allocation of resources for invention", in R. Nelson (ed.), *The Rate and Direction of Inventive Activity*, 609-625, Princeton: Princeton University Press.

Blumenthal D., Epstein S., Maxwell J., (1986), "Commercializing university research: Lessons from the experience of the Wisconsin Alumni Research Foundation", *New England Journal of Medicine*, 314(25), 1621-26.

Blumenthal D., Campbell E., Anderson M., Causino N., Seashore-Louis K., (1997), "Withholding research results in academic life science: evidence from a national survey of faculty", *Journal of the Academic Medical Association*, 277(15), April 16, 1224-1228.

Brooks H., (1994). "The relationship between science and technology", *Research Policy*, 23, 477-486.

Bush V. (1945). *Science, the Endless Frontier. A Report to the President*, U.S. Government Printing Office.

Calvert J., (2002), "Making academic research useful. Scientists' responses to changing policy demands", *Paper presented to the NPRNet Conference "Rethinking Science Policy"*, 21-23 March, SPRU.

Calvert J., Martin B.R., (2001), "Changing conceptions of basic research?", *Background Document for the OECD Workshop on Policy Relevance and Measurement of Basic Research*, Oslo, 29-30 October.

Cohen W., Florida R., Goe W.R., (1994), *University-industry research centers in the United States*, Carnegie Mellon University.

Cohen W., Florida R., Randazzese L., Walsh J., (1998), "Industry and the Academy: Uneasy Partners in the Cause of Technological Advance", in R.G. Noll (ed.), *Challenges to Research Universities*, http://brookings.nap.edu/books/0815715099/html/index.html

Dasgupta P., David P.A., (1994), "Toward a new economics of science", *Research Policy*, 23, 487-521.

David P.A., (2000), "The Political Economy of Science", in H. Lawton Smith (ed.), *The Regulation of Science and Technology*, London: MacMillan.

David P.A., (2003), "The Economic Logic of "Open Science" and the Balance between Private Property Rights and the Public Domain in Scientific Data and Information: A Primer", *SIEPR Discussion Paper*, No. 02-30.

Florida R., (1999), "The Role of the University: Leveraging Talent, Not Technology", *Issues in Science and Technology*, Summer, 363-73.

Florida R., Cohen W.M., (1999), "Engine or infrastructure? The university role in economic development", in: L.M. Branscomb, F. Kodama, Florida R., (eds), *Industrializing Knowledge. University-Industry Linkages in Japan and the United States*, Cambridge: MIT Press.

Geuna A., (2001), "The Changing Rationale for European University Research Funding: Are There Negative Unintended Consequences?", *Journal of Economic Issues*, 35(3), 607-32.

Gibbons M., (1999), "Science's new social contract with society", *Nature*, 402, 81-84.

Goddard J.G., Isabelle M., (2006a), "How do public laboratories collaborate with industry? New survey evidence from France", *Working Paper IMRI n°06/02*, June.

Goddard J.G., Isabelle M., (2006b), "Managing intellectual assets within knowledge-based partnerships: Insights from a survey of public laboratories collaborating with industry", *Working Paper IMRI n°06/03*, July.

Godin B., (1996), "Research and the practice of publication in industries", *Research Policy*, 25, 587-606.

Heller M., Eisenberg R., (1998), "Can Patents Deter Innovation? The Anticommons in Biomedical Research", *Science*, Vol. 280, 698-701.

Henderson R., Jaffe A.B., Trajtenberg M., (1998), “Universities as a source of commercial technology: a detailed analysis of university patenting, 1965-1988”, *The Review of Economics and Statistics*, 80, 119-27.

Hicks D., Hamilton K., (1999), “Does university-industry collaboration adversely affect university research?”, *Issues in Science and Technology*, 15(4), 74-75.

Larsen M.T., (2005), “Does industrial relevance in public science come at the expense of basic research?”, Paper presented at the DRUID Winter Conference, Aalborg / Rebild Bakker, January 27-29.

Merton R.K., (1973), *The Sociology of Science: Theoretical and Empirical Investigations*, Chicago: University of Chicago Press.

Mowery D.C., Nelson R.R., Sampat B.N., Ziedonis A.A., (2001), “The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh–Dole act of 1980”, *Research Policy*, 30, 99-119.

Murray F., Stern S., (2006), “Do formal intellectual property rights hinder the free flow of scientific knowledge? An empirical test of the anti-commons hypothesis”, *Paper presented at the Druid Summer Conference*, Copenhagen, June 18-20.

Narin F, Pinski G., Gee H.H., (1976), “Structure of the biomedical literature”, *Journal of the American Society for Information Science*, 27, 25-45.

Nelson R.R., (1959), “The Simple Economics of Basic Scientific Research”, *Journal of Political Economy*, 67(3), 297-306.

Nelson R.R., (2000), “Knowledge and innovation systems”, in OECD, *Knowledge Management in the Learning Society*, Paris: OECD.

Nelson R.R., (2004), “The market economy and the scientific commons”, *Research Policy*, 33, 455-71.

OECD, (1994), *Main definitions and conventions for the measurement of research and experimental development (R&D). A summary of the Frascati Manual*, Paris: OECD.

OECD, (1996), *The knowledge-based economy*, Paris: OECD.

OST, (2003), *Rapport sur les indicateurs relatifs à la propriété intellectuelle dans les organismes de recherche publique et dans les établissements d’enseignement supérieur*, Paris : OST.

Pavitt K., (2001), “Public policies to support basic research: What can the rest of the world learn from US theory and practice? (And what they should not learn)”, *Industrial and Corporate Change*, 10(3), 761-779.

Polanyi M., (1962), “The Republic of Science: Its Political and Economic Theory”, *Minerva*, 1(l), 54-73.

Ranga L.M., Debackere K., von Tunzelmann N., (2003), “Entrepreneurial universities and the dynamics of academic knowledge production: A case study of basic vs. applied research in Belgium”, *Scientometrics*, 58(2), 301-20.

Scotchmer S., (1991), “Standing on the Shoulders of Giants: Cumulative Research and the Patent Law”, *Journal of Economic Perspectives*, 5, 29-41.

Shapiro C., (2001), “Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting”, in A. Jaffe, J. Lerner, and S. Stern (eds), *Innovation Policy and the Economy*, Cambridge: MIT Press.

Stokes D.E., (1997), *Pasteur’s Quadrant: Basic Science and Technological Innovation*, Washington D.C.: Brookings Institution Press.

Van Looy B., Ranga M., Callaert J., Debackere K., Zimmermann E., (2004), "Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect?", *Research Policy*, 33, 425-41.

Walsh J.P., Cho C., Cohen W.M., (2005), "Patents, Material Transfers and Access to Research Inputs in Biomedical Research", *Final Report to the National Academy of Sciences' Committee on Intellectual Property Rights in Genomic and Protein-Related Inventions*, September.

Walsh J.P., Hong W., (2003), "Secrecy is increasing in step with competition," *Nature*, 422, 24 April, 801-802.

Ziman J., (1994), *Prometheus Bound: Science in a Dynamic Steady State*, Cambridge: Cambridge University Press.

7. Appendix

7.1. Questionnaire used for the survey

Q0 *Are you pleased with this taxonomy?*

❑ Yes ❑ More or less ❑ No

Why? type your comments here…

Q1 *Please position your research activities in this taxonomy:*

	Yes essentially	Yes to a lower extent	No
Technical achievements	❑	❑	❑
Fundamental knowledge	❑	❑	❑
Use-inspired	❑	❑	❑
Curiosity-driven	❑	❑	❑
Open-access results	❑	❑	❑
Proprietary results	❑	❑	❑

Q2 *Has this position changed in the past few years?*

	Much more	More	Unchanged	Less	Much less
Technical achievements	❑	❑	❑	❑	❑
Fundamental knowledge	❑	❑	❑	❑	❑
Use-inspired	❑	❑	❑	❑	❑
Curiosity-driven	❑	❑	❑	❑	❑
Open-access results	❑	❑	❑	❑	❑
Proprietary results	❑	❑	❑	❑	❑

Q3 *Have these changes (if any) operated under the pressure of:*

	Yes essentially	Yes to a lower extent	No
Industrial partners	❑	❑	❑
Sources of financial support	❑	❑	❑
Evaluation systems	❑	❑	❑
Hierarchy	❑	❑	❑
Other (please develop…)	❑	❑	❑

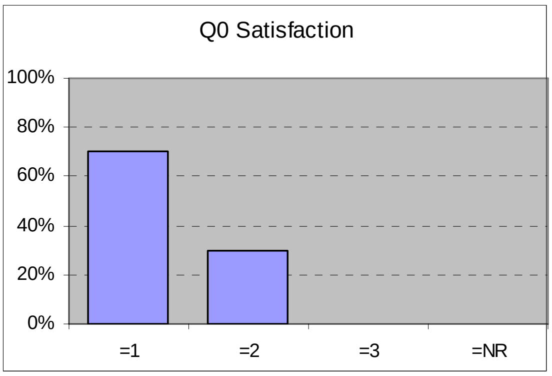
Q4 *Additional information:*

Division : ☐

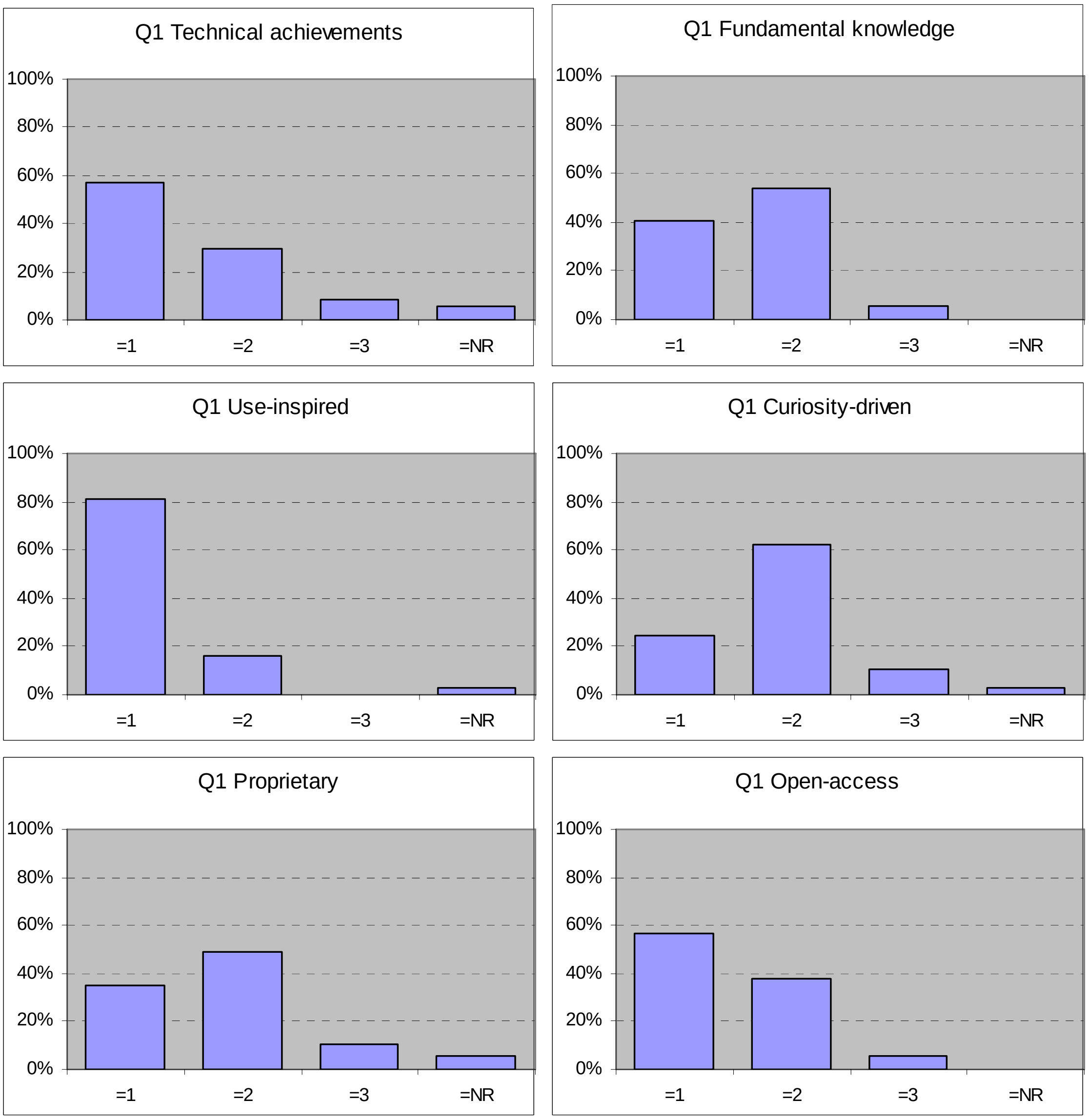
Research fields : Field 1 Field 2 Field 3 Field 4

(use the following link to the Dewey Decimal Classification Index: http://www.scit.wlv.ac.uk/wwlib/browse.html)

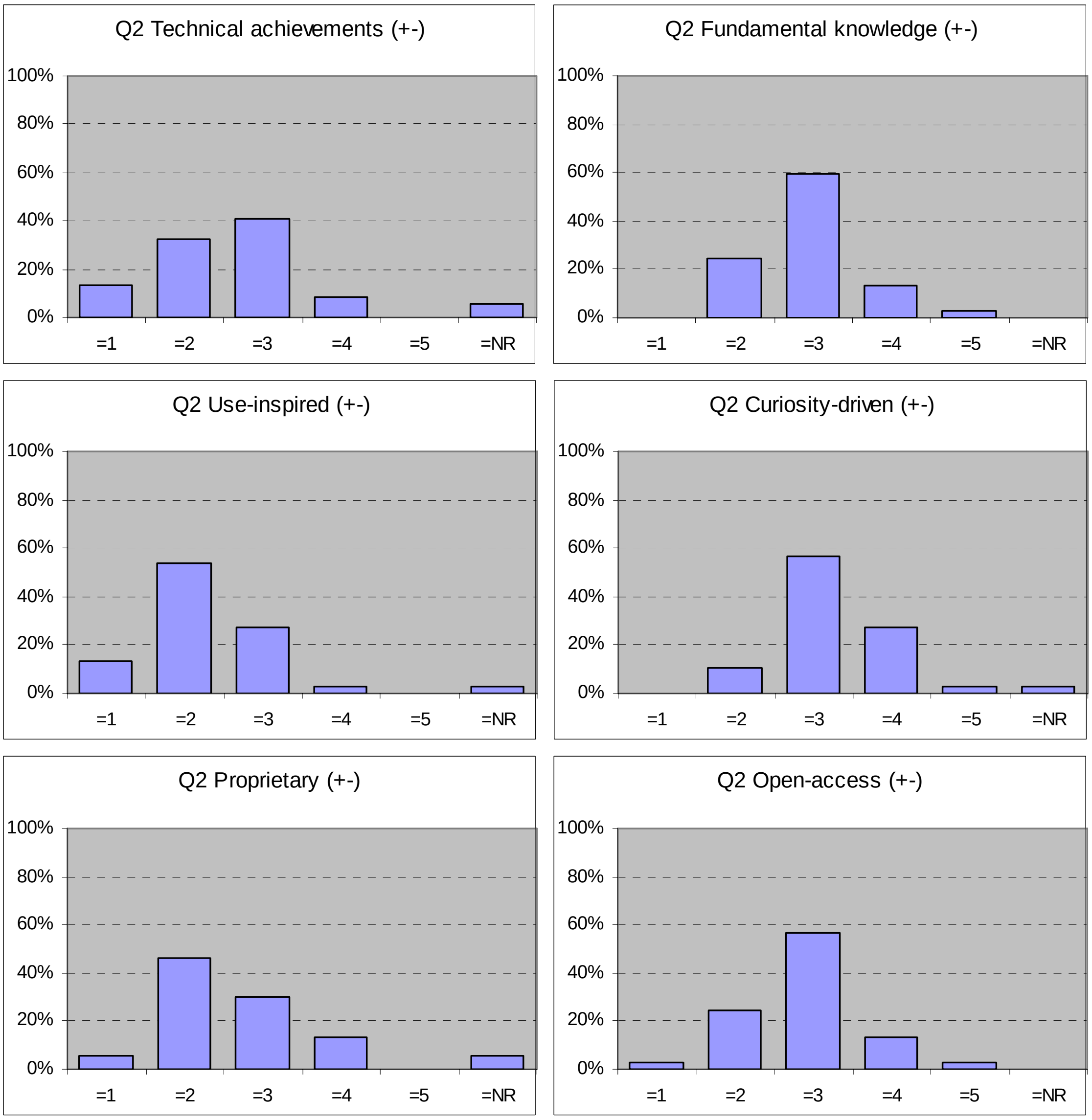
7.2. Bar charts of responses



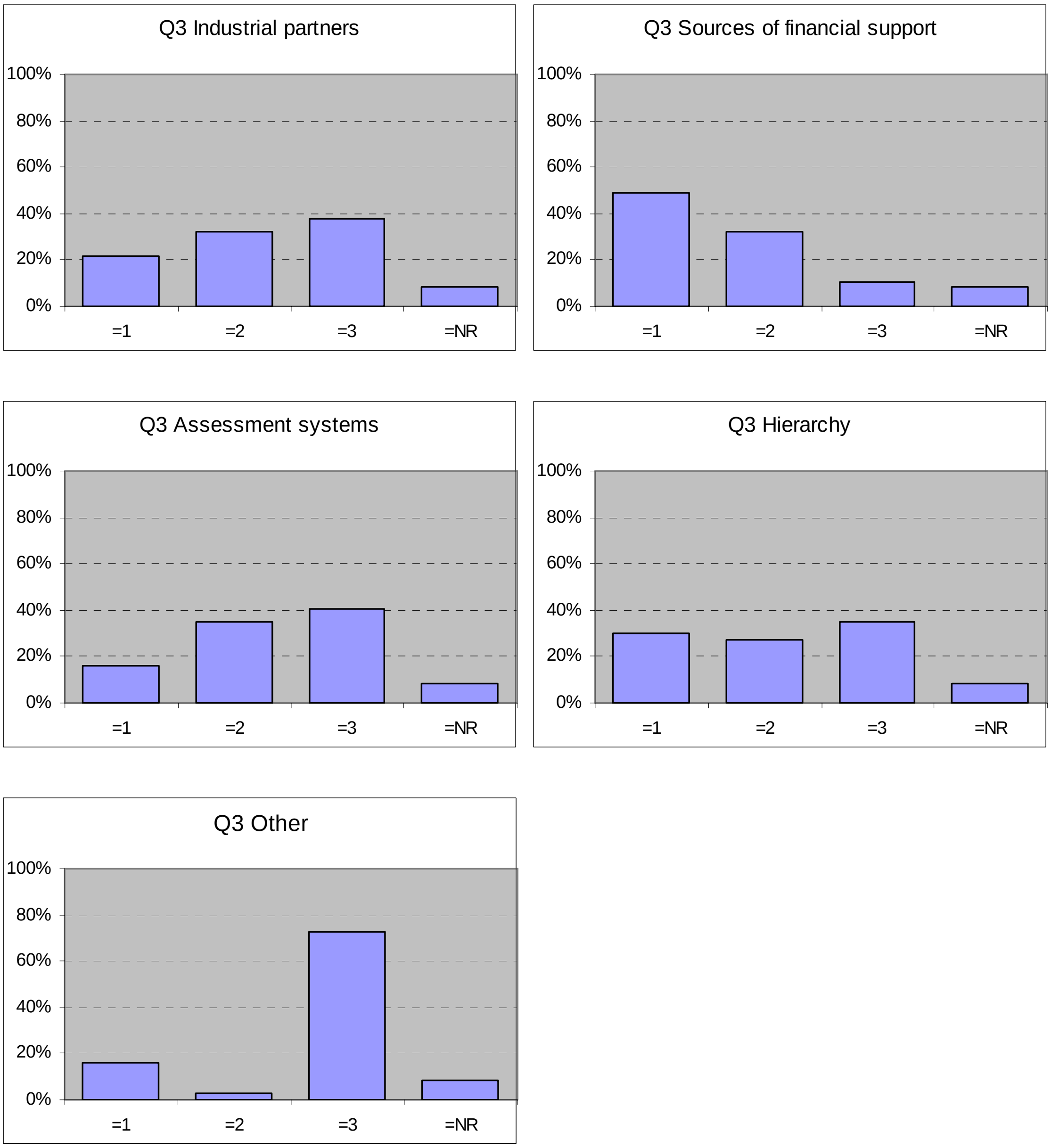
1 Yes 2 More or less 3 No



1 Yes essentially   2 Yes to a lower extent   3 No



1 Much more 2 More 3 Unchanged 4 Less 5 Much less



1 Yes essentially   2 Yes to a lower extent   3 No

---

[1] Variations of this four-level subdivision have been used among others by Godin (1996), Ranga et al. (2003), Van Looy et al. (2004) and Larsen (2005).

[2] The true motivations of researchers may not be that easy to identify. Calvert (2002) shows that in order to compete for funding, researchers may present their activities as use-inspired although their considerations for use are only marginal.

[3] Notice that their methodology has close connections with the extension of Pasteur's quadrant set forth in this paper.

[4] The CEA had 14 910 employees as of December 31, 2006; the CNRS (Centre National de la Recherche Scientifique) ranks first with 26 078 employees.

[5] According to a study by OST (2003) on the 1997-2001 period, the CEA was the most actively patenting public research institution in France.

[6] CEA's commitment to provide strong assistance for the design, construction and operation of the International Thermonuclear Experimental Reactor (ITER) is said to have played a significant role in the decision taken recently by the international community to have it built in France close to one of CEA's locations in the Provence region (Cadarache research centre).

[7] Note that no respondent in the whole sample considers her research to be not use-inspired at all; once again, this result is not surprising in the case of the CEA the missions of which are predominantly technological ones.

[8] Or to patent results before publishing them; results may also keep them secret in the case of defense-related activities.

[9] Note moreover that the changes in terms of fundamental knowledge generation are significantly correlated with those in terms of open-access and of curiosity-driven research (correlation coefficient of +0,7 for both).