# Why do Academic Scientists Engage in Interdisciplinary Research ?[ϕ]

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**Abstract :** This article provides a first empirical study of the determinants of the propensity to which academic scholars tend to perform interdisciplinarity research. For that purpose we introduce a measure of interdisciplinarity as the diversity of their research production across scientific domains. Our dataset concerns more than nine hundred permanent researchers employed by a large French university which is ranked first among French universities in terms of Impact. As expected we find that the traditional academic career incentives do not stimulate interdisciplinary research while having connections with industry does. The context of work in the laboratory (size, colleagues' status, age and affiliations) strongly affects the propensity to undertake interdisciplinary research.

**Key words :** Economics of science, Academic incentives, Interdisciplinary research, Laboratory, University.

**JEL classification :** L31, 031, 032, 034, 038.

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# 1 Introduction

As emphasized by Gibbons et al. (1994) the production of interdisciplinary knowledge is one major issue to be dealt with in the "knowledge-based society". Two main reasons came up to claim social interest in such kind of research as compared to more standard disciplinary research. First, it has been argued that research performed in an interdisciplinary context is likely to be more creative : Mixing people with different backgrounds and/or ideas from different fields would be likely to generate "breakthrough" research results. Secondly, interdisciplinary research has been emphasized as being more likely to lead to applicable results (Schmoch et al., 1994), because it is more friendly to problem-solving approaches (Foray and Gibbons, 1996). Why interdisciplinary research becomes a real subject of interest for science policy is because anecdotal evidence highlights that some institutional barriers may unduly limit its performing. More generally it seems that the academic implicit reward system in the 'open science' does not provide sufficient incentives for performing interdisciplinary research as regard to its social value. Therefore, the interest in interdisciplinary research is now broadly widened among scholars and policy makers. It increasingly becomes an important criterion taken into account in public funding processes both in the EU framework and NSF funding programs.

Although an abundant literature substantially improved our understanding of interdisciplinary research (Morreale and Howery, 2002 ; Ziman, 1997 ; Qin et al., 1997 ; Schmoch et al., 1994 ; Sanz-Menéndez et al, 2001 ; Tomov and Mutafov, 1996 ; Morillo et al., 2001), it remains a difficult and quite fuzzy concept (Klein, 1990 and Acutt et al., 2000). For the purpose of this study, we propose and make use of two new measures. The first one is labelled the *degree of multidisciplinarity* of a research unit. It measures the diversity of disciplinary professional affiliation of permanent researchers of academic laboratories. The second one is the *degree of interdisciplinarity* of an academic researcher publication production : It accounts for the diversity of a researcher's publications over scientific domains.

The main originality of our contribution is that we specifically developed a methodology that allows us to study the determinants of interdisciplinary research performing by academic researchers (i.e. the degree of *interdisciplinarity*). Despite the acknowledged importance of interdisciplinary research, there has been no systematic analysis of the determinants of interdisciplinary research. Only a few monographs dealt specifically with such an issue

(Grupp, 1994; Laudel and Gläser, 1998 and Morreale and Howery, 2002). That is unfortunate because scholars as well as science policy makers and managers still wonder about the incentives and the factors that influence the setting of academics' research agendas, particularly those that lead academic researchers to undertake interdisciplinary research. Porter and Chubin (1985) argued that it is the absence of appropriate data which constitutes a barrier to the systematic study of this phenomenon.

We have been able to overcome such a difficulty thanks to an original dataset that precisely informs about the research behaviors of more than nine hundred academic scientists over the period 1995-2000 during which they were employed by a large French University, namely the Université Louis Pasteur (ULP) in Strasbourg. This university is ranked first among French universities (in terms of impact) by the European Report on Science and Technology (2003). These data allow us to take into account both individual researchers characteristics (age, status, publications impact and strategy) and the characteristics of the laboratories to which the researchers are affiliated including colleagues' age, status, the presence of non-permanent researchers, the multidisciplinarity of the lab, the funding structure (public and private support).

Two series of determinants of interdisciplinary research will be considered. On the one hand, we will study whether the academic reward structure (accomplishment and reputation based career paths) do provide incentives or distract scholars from performing interdisciplinary work. There are strong expectations that the generalized peer-review evaluation system in science which is mainly based on disciplinary affiliations, might lead to strong incentives toward disciplinary research as suggested by Ziman (1997) and Sanz-Menéndez et al. (2001). On the other hand, we wonder whether the organizational design and the funding structure of the research units (and characteristics of colleagues in laboratories) affects the propensity to undertake interdisciplinary research as suggested by Ziman (1994, 1997).

If interdisciplinary research performing is acknowledged as a socially valuable task, providing evidence that may contribute to understand the institutional factors and the incentives which sustain or impeach such behavior becomes thus a relevant policy issue that is addressed in this paper. It is organized as follows. The next section reviews and discusses the various measures of interdisciplinarity and multidisciplinarity. It provides the definitions that will be further used in the study. The third section describes the dataset, the variables and the methodology employed. The results are presented in the fourth section.

# 2 Measuring interdisciplinarity

Numerous notions and concepts have been introduced and discussed in the philosophy and sociology of science literatures so far (Piaget, 1972 ; Gibbons et al., 1994 ; Ziman, 1994). Reviewing all these works extends far beyond the purpose of this study. We here restrict our attention to the indicators that have been proposed in the literature to assess the degree to which research is interdisciplinary. These indexes are reviewed in a first subsection, while the second subsection presents the measures that will be further used in the paper.

## 2.1 Literature review

As suggested by Sanz-Menéndez et al. (2001) a simple and useful manner to categorize the various measures of interdisciplinarity is to separate the ones applied to research groups based on team composition from the ones applied to the research outcomes. The former are from now on labeled as *measures of multidisciplinarity* while the latter will be referred to as *measures of interdisciplinarity.*

### Multidisciplinarity

Multidisciplinarity is a notion that refers to research patterns of a given team, community or institution and is observed through the affiliation of researchers to different disciplines. Sanz-Menéndez et al. (2001) interviewed researchers in order to assess the disciplinary diversity of team members and to give a qualitative appreciation of the degree of multidisciplinarity of their team. More precisely, the interviewed researchers were requested to assess the "disciplinary diversity" of their research team in a four items intensity scale. Moreover, the interviewees were asked to give a qualitative appreciation of the interdisciplinarity of their research teams by listing up to five colleagues (mentioning their disciplines and specializations) employed in the research team with whom they are currently working.

Nguyen Thi and Lahatte (2003) proposed two indicators of multidisciplinarity of university laboratories, which are the ratio of the number of fields (subdisciplines) to which researchers affiliated to the lab are associated over the average number of fields in university labs. Carayol and Matt

(2004) first introduced a measure of team multidisciplinarity as the diversity of researchers affiliations into subdisciplines. It makes use of Shannon's entropy measure which accounts for the relative weights of subdisciplines in the lab. For example, if one thinks of a laboratory the researchers of which are affiliated to two different disciplines, it is clearly not the same to have all researchers but one affiliated to one subdiscipline or to have half researchers affiliated to each subdiscipline. The latter situation is likely to be more multidisciplinary. The entropy measure accounts for that difference being at its maximum when the population (here researchers in the lab) is uniformly allocated into the various categories identified *ex ante* (the fields).

**Interdisciplinarity**

Interdisciplinarity measures go beyond the simple observation of the presence of research personnel from different disciplinary backgrounds in common institutions, but characterizes the research outcomes directly. One can identify two main approaches for measuring such interdisciplinarity.

The first approach makes use of the journals classification according to subject categories provided in the Journal Citation Report (JCR) produced by the Institute for Scientific Information (ISI). This method relies on the co-assignation of journals into the different research domains as defined in the JCR. Empirical studies have explored the interdisciplinary structure of research programs or scientific disciplines. For instance, Rinia et al. (2001) used publication data that resulted from research programs in physics. The interdisciplinarity of the programs was measured by the percentage of papers published in non-physics journals. Moreover, knowing that journals can be associated to several categories, Morillo et al. (2001) measured the degree of interdisciplinarity of a scientific discipline as the share of its mutli-assigned journals.

The second approach goes down to the articles as the subject of analysis. It makes use of information provided in the Science Citation Index (SCI) also produced by the ISI. Interdisciplinarity is measured through the co-occurences of items, such as authors' affiliations, citations or references. The more frequent the co-occurences of different fields or disciplines in authors' affiliations, in the citations received or in the references mentioned, the more intensive the relationships or the exchanges between disciplines.

The authors' affiliation-based analysis identifies the institutions of authors and associate them to disciplines. Qiu (1992) defined an annual degree of interdisciplinarity of journals as the share of interdisciplinary co-authored papers. Such articles are identified as the ones written by researchers associated to different disciplines. The author also used a similar indicator for studying the evolution of interdisciplinarity of one single discipline (Information and Library Sciences) over a 20-year period. Schummer (2003) proposed to measure interdisciplinarity in the domain of Nanoscience and Nanotechnology as the "number of disciplines involved by authorship in at least 5% of the total number of papers".

The citation and reference analyses are the most frequently used method among studies of the second approach. They measure flows of information between papers (Qin et al, 1997), journals (Porter and Chubin, 1985 ; Morillo et al., 2001), or disciplines (Qin et al, 1997). For instance, Tomov and Mutafov (1996) have proposed an interdisciplinary index of journals using both references and citations. Moreover, Sanz-Menéndez et al. (2001) measured interdisciplinarity of researchers through interviews asking them to indicate the five journals that are their main reference journals [1].

### 2.2 Interdisplinarity and Multidisciplinarity : Definitions

In this subsection we propose two measures which make us of the entropy notion introduced by Shannon. It is a simple function of a discrete distribution which is maximal when the population is uniformly distributed and minimal when the all elements of the population are in the same state.

As in Carayol and Matt (2004), we propose to measure the degree of multidisciplinarity of a laboratory as the entropy of the distribution of permanent researchers over the set of subdisciplines. It is computed as follows :

$$Lab.multidis_i = -\sum_{i \in L_i} \frac{n_{ij}}{n_i} \log\left(\frac{n_{ij}}{n_i}\right) \quad (1)$$

with $n_i$ the number of permanent researchers in $i$'s laboratory and $n_{ij}$ the number of researchers in $i$'s laboratory that are affiliated to subdiscipline $j$. It corresponds to the lowest disciplinary level of aggregation as reported by the OST classification applicable in France (cf. OST, 1996)[2]. According to that classification, there are 73 subdisciplines.

[1] We should also mention that Morillo et al. (2001) proposed to use the Chemical Abstracts database to build indicators. The degree of interdisciplinary of a given field is then the percentage of the multi-assigned documents over the 80 sections classification defined in the Chemical Abstracts.

[2] There are several institutional classifications in the French system each one being designed for peer evaluation purposes in different research institutions. Three of them have

We propose a measure for the extent to which an agent $i$'s research production is interdisciplinary. It is the diversity of $i$'s publication occurrences over the scientific domains. It is computed as follows :

$$Interdisc_i = -\sum_j p_{ij} \log(p_{ij}) \tag{2}$$

with $p_{ij}$ the share of $i$'s publications in the domain $j$. It is computed as follows :

$$p_{ij} = \frac{1}{\#P_i} \sum_{a \in P_i} \phi(j, r_a) \tag{3}$$

where $P_i$ is the set of $i$'s publications, $\#P_i$ is its cardinal and $r_a$ is the journal in which article $a \in P_i$ has been published. The function $\phi(\cdot,\cdot)$ is defined as follows : $\phi(j, r_a) = 1\{j \in d(r_a)\} / \#d(r_a)$ with $1\{\cdot\}$ the indicator function and $d(r_a)$ the set of domains to which $r_a$ is associated by JCR journal-domains classification. The cardinal of this set, $\#d(r_a)$ is thus the number of different domains to which the journal $r_a$ is associated. $d(r_a)$ is itself a subset of the set of all domains $D$, the cardinal of which $\#D$ is equal to 170 in the JCR classification scheme. It should be noticed that this definition allows us to take into account the internal interdisciplinarity of journals as evidenced by their multi-assignation to domains.

# 3 The dataset and methodology

In a first step we present our data collection and our dataset. The second subsection presents the model.

## 3.1 Data set

The data concern the research activity between 1993 and 2000 of a single university : the University Louis Pasteur (ULP) located in the Strasbourg area (France). ULP has an old tradition of fundamental research and a long-term standing of scientific excellence. its researchers have received numerous

to be considered for our study ; The first one is the CNU (the National Council of Universities) classification according to which university scholars are associated. The CNRS and the INSERM classifications allow us to characterize fulltime researchers who are associated to these institutions and who are working in our laboratories. At the most disaggregated level, the three different classifications do not perfectly match. Therefore, a standardization work was carried out for the purpose of our study. The detailed classification we realized can be produced upon request to the corresponding author.

national and international scientific prizes, including Nobel Prizes. Overall, ULP is one of the largest French universities in terms of research. The Third European Report on Science & Technology Indicators 2003 ranks ULP first among French universities and 11th among European universities in terms of impact. Active researchers count one Nobel laureate, eleven members of the Institut Universitaire de France and eleven members of the French National Academy of Science. The university research capacities are reinforced by a close-knit with the major national research bodies such as the National Center for Scientific Research (CNRS) and the National Institute for Health and Medical Research (INSERM) present in the Strasbourg area. Research and teaching activities cover a wide range of subjects : Medical Sciences, Mathematics, Computer Science, Physics, Chemistry, Life Sciences, Geology, Geophysics, Astronomy, Engineering Sciences. Human and social sciences are also present with Economics, Management, Geography, Psychology and Educational Sciences.

We collected the variables from administrative reports completed for the 1996 contractual affiliation round[3]. 1,460 permanent researchers were reported in these documents : They were all present in 1996. A similar document exists for the 2001-2004 period. Thus we had information about which permanent researchers were still present in the university in 2000. We then excluded all permanents that were not on that list. Thereby we ensure that none of the permanent researchers moved to another university or retired. At the end of the process, 1,134 permanents remained among whom 908 were fully informed on the variables of interest. According to the classification of permanent researchers disciplinary affiliations, we found 52 (out of 73) different subdisciplines.

The published articles of each permanent researcher in our database were also collected using SCI, SSCI and Arts and Humanities ISI databases. More than 26,000 publication occurrences were recorded over the 1993-2000 per-

[3] Such a round occurs every four years. All laboratories (and also Faculties and Institutes) have to produce a standardized document, which is usually divided into two distinct parts : A précis of the past four years and a project for the next four ones. The data cover the period from 1993 to 2000, which may be separated into two four-year sub-periods : 1993-1996 and 1997-2000, which represent respectively what was achieved during the four-year periods before and after 1996 (i.e. the new affiliation contract). These documents are evaluated through standard peer review procedures conducted by both the Ministry of Research and Education and funding agencies such as the CNRS and INSERM whose support is expected.

iod. We matched this table with our restricted list of permanent researchers and kept only the occurrences that were published over the period 1995-2000 for which we are sure they were employed by the university[4]. This amount includes some double counting as ULP researchers frequently co-authored papers. By dividing each occurrence by the number of co-authors we obtain the effective (normalized) scientific contribution of each author considered (an author is necessarily a permanent researcher). In addition each publication item was associated to the impact factor of the reviews in which it was published. That information was obtained for the 5,750 reviews reported in the ISI-Journal Citation Report (JCR). It gives us thus the opportunity to correct for impact publication performance. This dataset also reporting the domains, i.e. each journal is attached to one or more of 170 scientific domains.

Moreover we have information on all the laboratories to which these permanent researchers were affiliated (laboratories variables). We recorded 79 distinct laboratories in 1996 for which we have complete and reliable information. We are thus able to attach to each individual scientist the variables characterizing their laboratories or colleagues (other permanent researchers) in labs. The number of permanent researchers in the lab is the single variable which accounts for the size of the lab. All other variables are proportions. When the variables characterizing the labs were computed from information on permanent researchers, we always excluded the researcher who is analyzed (the average age of colleagues, their positions, their scientific productivity). Some additional information on the labs were collected in the 1996 research reports. We were thus also able to introduce more variables on labs. We include data on types of personnel which are often not included in empirical analyses : Some 1,230 Ph.D. students, 710 post-docs and 1,120 non-researchers (administrative staff and technicians) were reported in year 1996. Lastly we were able to collect precise information about funding of the laboratories (excluding wages). We have data on regular public funding for the period 1996-2000. We collected information about the contractual funding over the whole 1993-2000 period. The latter was broken up by source of funding : Public funding at the European, national and local levels, and private ones.

### 3.2 The model

[4]Or by the national research institutes (CNRS and INSERM) but working within the university laoratories.

Let us now turn to our econometric model which aims at explaining the individual interdisciplinarity entropy (*Interdisc*$_i$) for our population of 908 permanent scholars and researchers for whom we have complete information. A closer look of the data informs us that a non-negligible share of this variable variables is null : 90 zero (818 are strictly positive). A null degree of interdisciplinarity arises when the research occurs in one single field. The research is then strictly disciplinary. Kernel density estimates displayed in Figure 1 show the specific density we have. In order to account for the qualitative change between being strictly mono-disciplinary and publishing in more than one field of research, we perform a (left censored) Tobit model with a known cutoff due to Amemiya (1973) which is of the form :

$$y_i^* = \mathbf{x}_i' \boldsymbol{\beta} + \varepsilon_i \tag{4}$$

where $\mathbf{x}_i$ is the vector of independent variables, $\boldsymbol{\beta}$ the vector of its associated coefficients, $\varepsilon_i$ is the error term[5]. $y_i^*$ is assumed to be the unobserved level of commitment to interdisciplinary research, from which the interdisciplinary entropy measure which is the really observed dependent variable ($y_i =$*Interdisc*$_i$) is obtained as follows :

$$\begin{cases} y_i = y_i^* \text{ if } y_i^* > 0 \\ y_i = 0 \quad \text{if } y_i^* \leq 0 \end{cases} \tag{5}$$

This specification gives the opportunity to model that below a certain level of commitment no publication item is recorded outside the main research area. Such a threshold may be due to dedicated work that is implied by coping with publishing and passing peer review processes in scientific journals of different fields.

The log-likelihood which will be maximized is the following :

$$L = \frac{1}{2} \sum_{i \in S} \ln \left[ \frac{y_i - \mathbf{x}_i' \boldsymbol{\beta}}{\sigma} + \ln 2\pi\sigma^2 \right] + \sum_{i \notin S} \ln \Phi \left( \frac{-\mathbf{x}_i' \boldsymbol{\beta}}{\sigma} \right) \tag{6}$$

with $S$ the set of individuals $i$ which are uncensored (have a non null dependent variable $y_i > 0$) and $\Phi(\cdot)$ the normal cumulative density function.

The set of independent variables is given by the following vector :

$\mathbf{x}_i = ($*Impact*$_i$, *Age*$_i$, *junior*$_i$, *fulltime*$_i$, *Inter*$_i$, *Indus*$_i$, *Lab.Pub*$_i$, *Lab.Imp*$_i$,

[5]The error terms are assumed to be independent $N(0, \sigma^2)$.

$Lab.perm_i,\ Lab.age_i,\ Lab.fulltime_i,\ Lab.junior_i,\ Lab.phd_i,$
$Lab.postdocN_i,\ Lab.postdocF_i,\ Lab.nonres_i,\ Lab.multidisc_i,$
$Lab.funding_i,\ Lab.contractualPub_i,\ Lab.contractualPriv_i).$

Precise definitions of the variables are to be found in Appendix. Descriptive statistics on these variables are presented in Table 1.

# 4 Results

The estimation results are presented in Table 2. Below we first present and discuss the effects of individual variables and then those of the collective variables.

### 4.1 Individual factors

We find that *Age* is not significant. Several configurations (introducing cohorts of age, age square ...) were tested but the results remained the same. We expected a positive effect of age because of two simultaneous effects. First, younger researchers might dislike interdisciplinary research agendas because they are likely to be more risky and their reputational rewards are likely to be delayed (even if they may be spread over a longer period of time). Secondly, experience vehicled through age might be an important factor for having acquired the broad view which is required for spreading research over several fields. The absence of a such positive effect of age may be due to a simultaneous counterbalancing cohort effect[6] : researchers of the latest cohorts would tend to be more disciplinary oriented. Nevertheless, we found no evidence (even anecdotal) of such cohort effect in the literature to support this statement. It should be noticed that it is only when the promotion-related variable *Junior* was removed that *Age* became (weakly) significant. This shows, as suggested in Knorr et al. (1979) and Carayol and Matt (2004) for publication performance, that when one controls for position related variables, the age tends to become non significant.

*Junior* has a negative and significant coefficient : Since this dummy variable means not yet promoted, we find, on the one hand, that it is once they have been promoted that researchers tend to engage more strongly in interdisciplinary research. Before promotion researchers tend to concentrate

[6]See Stephan (1996) for a discussion of the importance of cohort effects in academic publication productivity.

their research agendas within well delineated fields. This may be due to career concerns. The evaluation of researchers is mostly done within scientific domains. Thus disciplinary works which generate easily identifiable scientific accomplishments tend to be better rewarded. Consequently, researchers expecting to increase their probability of being promoted may be likely to select well specified topics and methods in their main research areas and delay publications in other fields. Moreover, interdisciplinary research may be more risky and require longer term research (Schmoch et al., 1994). Thus researchers may prefer to wait until the promotion is awarded to undertake such research, when they are less pressured by academic career constraints.

*Fulltime* is strongly significant and exhibits a positive coefficient : Researchers that occupy full-time research positions undertake more interdisciplinary research. This may be explained as follows. Full-time researchers do benefit from a larger amount of time to be devoted to research. In the meantime interdisciplinary research might require a stronger commitment in research because it is likely to occur in larger projects whereas in more disciplinary research, tackling the "next problem at hand" strategy might be sustainable. Full-time researchers are not subject to the same time constraints as scholars that face teaching duties as well as research ones, and therefore they are more likely to perform interdisciplinary research.

The average impact factor is not significant. This means that people who publish in different fields do not significantly differ in terms of average impact of their publications. If one assumes that impact proxies quality, then there are no effects of the researchers abilities on his or her propensity to undertake interdisciplinary research.

On the contrary, having published at least one paper with a researcher employed in industry makes a major difference for undertaking interdisciplinary research : The dummy *Indus* is strongly significant and positive. This tends to corroborate the idea suggested by Foray and Gibbons (1996) that interdisciplinary research agendas and sensitivity to applications through problem solving approaches are strongly connected.

The results also show that interdisciplinary research is discipline-specific (most discipline dummies are significant). This might be explained by the large differences in the scope of disciplines, the abilities of agents to move between domains and to master them. Interdisciplinary research is not uniformly encouraged, facilitated and feasible among all scientific disciplines (Ziman, 1997). Moreover, the density of the SCI domains classification coverage is also not uniform across disciplines. An obvious illustration of that is for instance the extreme difference in the number of subdivisions in Mathematics and in the Medical Sciences (Qin et al., 1997). Consequently, the coefficients of discipline dummies should rather be understood as controls for such measurement biases.

### 4.2 Laboratories variables

About the effect of the context of work, we find that the size of the lab plays negatively on interdisciplinarity. It is within smaller labs that researchers tend to visit a higher number of distinct research areas. Researchers in larger labs tend to focus on fewer research areas. Smaller labs thus seems to provide a more favorable context of work for performing interdiscipinary research. In larger labs, disciplinary specialization tend to prevail and scholars tend to concentrate their work in given fields.

Colleagues' age plays positively on interdisciplinarity. Researchers tend to benefit from colleagues' experience in undertaking diverse research purposes. This result highlights that colleagues interact in the selection process of research agendas. This statement is strongly reinforced by the following results. Researchers undertake more interdisciplinary research when their colleagues are less promoted and older. This might indicate that researchers benefit from more 'open minded' interactions with older and unpromoted colleagues who stimulate them to engage in more varied research domains. We have also found that interdisciplinary research is less likely in labs which have a high ratio of Ph.D. students per permanent researchers. Ph.D. students seem to be more attracted by labs having a strong disciplinary orientation.

One important effect concerns the distribution of colleagues between various domains (degree of *multidisciplinarity* of the lab), i.e. having distinct reference (and evaluation) communities. Ziman (1997) argued that interdisciplinary research is hindered by institutional frontiers that usually correspond to disciplinary ones. We indeed find that the integration of researchers having different disciplinary backgrounds inside a common research unit stimulates the diversity of individual research production.

The funding structure of the lab also affects the propensity to perform interdisciplinary research. We find that recurrent public funding has no impact while contractual funding, both from private and public sources, has significant and positive effects. When their lab attracts larger amounts of non recurrent funding, researchers tend to perform more interdisciplinary research. Funding agencies as well as private firms tend to be more interested in problem-solving approaches. Scholars in labs having built channels to such sources of funding are more likely to engage in applications oriented and problem solving approaches and thus in interdisciplinary research.

# 5 Discussion and conclusion

Interdisciplinary research has received much attention in the literature in recent years. However, there has been no systematic analysis of the determinants of interdisciplinary research performing. In this paper, we propose two measures : the degree of *multidisciplinarity* of a laboratory as the diversity of researchers' institutional affiliations and the degree of *interdisciplinarity* of a researcher's scientific production as the diversity of his/her articles in terms of the domains in which they have been published. Secondly, we study the factors that influence the propensity to undertake interdisciplinary research. This study bears on a population of more than nine hundred academic researchers who were employed by the university Louis Pasteur in Strabourg over the period 1993-2000.

We find some specific evidence of no or negative incentives provided by the academic reward systems toward performing interdisciplinary research. Young (and non-promoted) researchers who are more inclined to respond to academic incentives (because they are likely to be delayed in their career paths) do not specifically engage in (tend to dislike undertaking) interdisciplinary work. This tends to indicate that the tension between problem-driven interdisciplinary work and discipline-based academic career structure persists. The norms of originality and the necessity to publish in the advisable disciplinary journals, on which the main criteria for enrolment or promotion of researchers are based, encourage disciplinary work having narrow topics and methods and discourage the acquisition of knowledge and more generally the openness to and the collaboration with scholars from other fields or disciplines. The rewarding mechanisms tend to favor narrowly drawn projects with specific goals that have to be achieved within short periods. The lack of time and the high risk of such projects while young researchers need some success create an entry barrier for young researchers into interdisciplinary programmes. This is consistent with the finding that full-time researchers are more likely to have interdiciplinary research production : Relaxing the time constraint stimulate the extension of the scope of research. Therefore, it is rather a strong commitment to research which stimulates interdisciplinary research.

We also find that a multidisciplinary research environment strongly stimulates individual interdisciplinarity. Even if having multiple disciplines working side-by-side in research units does not always bring out interdisciplinary research, we nevertheless find that it facilitates interdisciplinary research. Our result also shows that researchers tend to benefit from colleagues' experiences (through colleagues' ages) for undertaking diversified research purposes. The disciplinary diversity of research members and the density of the communication are thus some keys to interdisciplinary research (Gibbons et al., 1994). The size of the lab also appears as an interesting factor for interdisciplinary research : small size favors individual interdisciplinarity while bigger size favors specialization.

Connections with industry, both by co-authoring or by receiving private funds is strongly correlated with interdisciplinary research. This tends to corroborate the idea suggested by Foray and Gibbons (1996) that interdisciplinary research agendas and sensitivity to applications through problem solving approaches are strongly connected. The estimations also reveal that contractual funding whether received from private or public sources stimulates interdisciplinary research while recurrent one is not significant. This result confirms the influence of the funding structures of the lab on the propensity to perform interdisciplinary research as strongly highlighted in the literature (Ziman, 1994 ; Caswill, 1997 ; Schild et al., 2002). Contractual funding thus tends to widen the scope of academic research purposes. The societal needs vehicled through such contractual funding tend to favor the flexibility of researchers in the choice of research methodology as well as in the allocation of their attention.

These results offer some first clues for policy makers to favor interdisciplinary. Nevertheless it should still be taken cautiously at this stage and some more investigations should be further provided on this dataset and on some other ones.

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# Appendix : The variables

· $Interdisc_i$ : is the dependent variable $y_i$ and is given in equations (2) and (3) .

· $Age_i$ : $i$'s age in year 1996.

· $Fulltime_i$ : dummy variable equal to one if the permanent researcher has a full-time research position in year 1996 and zero if he occupies a teach-&-research position.

· $Junior_i$ : dummy variable equal to one if the permanent researchers remained 'un-promoted' (as Assistant Professors or Researchers) in year 1996 and zero otherwise (Professors or Director of Research)

· $Imp_i$ : average impact of $i$'s publication occurrences over 1995-2000 window (Impact Factor of the journals).

· $Inter_i$ : share of $i$'s publications that were co-authored with at least one author which mentioned an address outside France.

· $Indus_i$ : dummy variable being equal to one, if at least one of $i$'s publications were co-authored with at least one author which mentioned a company as a professional affiliation.

· $Lab.perm_i$ : the number of permanent researchers of the laboratory to which $i$ belongs. It embodies our single laboratory size variable. All other quantities relating to the lab will be given in shares if directly connected to permanent researchers, and per permanent researcher otherwise.

· $Lab.age_i$ : the average age of colleagues in the lab (other permanent researchers).

· $Lab.fulltime_i$ : share of full-time researchers among colleagues.

· $Lab.junior_i$ : share of un-promoted among colleagues in the lab.

· $Lab.Pub_i$ : productivity of colleagues over the larger 1993-2000 period, which corresponds to the average publication performance of colleagues, corrected for coauthorship.

· $Lab.Imp_i$ : average impact factor of colleagues' publication.

· $Lab.phd_i$ : average number of PhD students per permanent of the lab.

· $Lab.postdocN_i$ : is the average number of National post-docs per permanent of the lab.

· $Lab.postdocF_i$ : is the average number of Foreign post-docs per permanent of the lab.

· $Lab.nonres_i$ : stands for the number of non-researchers per permanent researchers in the lab.

· Lab.$multidisc_i$ : is the degree of multidisciplinarity of i's laboratory and is given in equation (1).

· $Lab.funding_i$ : gives the amount (in thousand Euros) of public recurrent funding per permanent researcher per year over the period 1996-2000.

· $Lab.contractualPub_i$ : corresponds to the amount (in thousand Euros) of contractual public support per permanent over the largest period 1993-2000.

· $Lab.contractualPriv_i$ : stands for to the amount (in thousand Euros) of contractual received from private sources per permanent over the largest period 1993-2000.

· $Discipline1_i$ : dummy variable equal to one if the scientific discipline to which the agent is affiliated is Mathematics, $Discipline2_i$ stands for Physics, $Discipline3_i$ stands for Chemistry, $Discipline4_i$ is for Earth Sciences, $Discipline5_i$ is for Engineering Sciences, $Discipline6_i$ is for Biology, $Discipline7_i$ is for Medicine and $Discipline8_i$ stands for Social Sciences and Humanities.

Table 1. Descriptive statistics on the variables

| | Mean | Std. Err. | Min | Max. |
|---|---|---|---|---|
| Interdisc | 1.273 | 0.633 | 0 | 2.618 |
| Imp | 3.204 | 2.349 | 0 | 16.016 |
| Age | 44.872 | 9.102 | 26 | 74 |
| Junior | 0.562 | | 0 | 1 |
| Fulltime | 0.504 | | 0 | 1 |
| Inter | 0.303 | 0.303 | 0 | 1 |
| Indus | 0.277 | 0.448 | 0 | 1 |
| Lab.pub | 3.186 | 1.834 | 0 | 9.328 |
| Lab.imp | 3.223 | 2.072 | 0.363 | 12.718 |
| Lab.perm | 36.454 | 26.433 | 2 | 79 |
| Lab.age | 51.794 | 3.481 | 41.625 | 66 |
| Lab.fulltime | 0.468 | 0.258 | 0 | 0.937 |
| Lab.junior | 0.576 | 0.135 | 0 | 1 |
| Lab.phd | 0.841 | 0.470 | 0.118 | 3 |
| Lab.postdocN | 0.108 | 0.192 | 0 | 1 |
| Lab.postdocF | 0.400 | 0.632 | 0 | 5.125 |
| Lab.nonres | 0.797 | 0.839 | 0 | 6.35 |
| Lab.multidisc | 0.806 | 0.404 | 0 | 1.845 |
| Lab.funding | 59.170 | 41.331 | 5.417 | 189.375 |
| Lab.contractualPub | 441.505 | 425.699 | 0 | 5265.644 |
| Lab.contractualPriv | 398.002 | 599.401 | 0 | 2267.652 |
| Discipline1 | 0.056 | | 0 | 1 |
| Discipline2 | 0.120 | | 0 | 1 |
| Discipline3 | 0.154 | | 0 | 1 |
| Discipline4 | 0.072 | | 0 | 1 |
| Discipline5 | 0.067 | | 0 | 1 |
| Discipline6 | 0.361 | | 0 | 1 |
| Discipline7 | 0.091 | | 0 | 1 |
| Discipline8 | 0.078 | | 0 | 1 |

Table 2. Estimations for the Tobit model given in (4) and (5) : With 90 zero observations and 818 non-zero observations.

| Dep var: Interdisc | Coef. | Std. Err. |
|---|---|---|
| Age | -0.000 | 0.003 |
| Junior | -0.146*** | 0.0458 |
| Fulltime | 0.187*** | 0.0456 |
| Impact | 0.003 | 0.0138 |
| Inter | 0.127 | 0.078 |
| Indus | 0.048*** | 0.011 |
| Lab.perm | -0.003** | 0.001 |
| Lab.age | 0.033*** | 0.009 |
| Lab.fulltime | 0.132 | 0.132 |
| Lab.junior | 0.742*** | 0.158 |
| Lab.pub | 0.005 | 0.016 |
| Lab.imp | -0.000 | 0.028 |
| Lab.phd | -0.172*** | 0.065 |
| Lab.postdocN | 0.093 | 0.136 |
| Lab.postdocF | -0.085 | 0.058 |
| Lab.nonres | -0.056 | 0.052 |
| Lab.multidisc | 0.299*** | 0.078 |
| Lab.funding | 0.0002 | 0.002 |
| Lab.contractualPub | 0.0002*** | 0.0001 |
| Lab.contractualPriv | 0.0002*** | 0.0001 |
| Discipline2 | 0.590*** | 0.154 |
| Discipline3 | 0.520*** | 0.138 |
| Discipline4 | 0.374** | 0.150 |
| Discipline5 | 0.0579 | 0.133 |
| Discipline6 | 0.5509*** | 0.142 |
| Discipline7 | 0.9123*** | 0.152 |
| Discipline8 | 0.1125 | 0.177 |
| Constant | -1.721 | 0.567 |
| Sigma | 0.5706 | 0.014 |

** and *** indicate that coefficients are statistically significant at the 0.05 and 0.01 levels respectively. Concerning Disciplines variables, coefficient should be understood as compared with *Discipline1* which is taken as a reference.

Figure 1. Distributions of Interdisc scores among researchers.

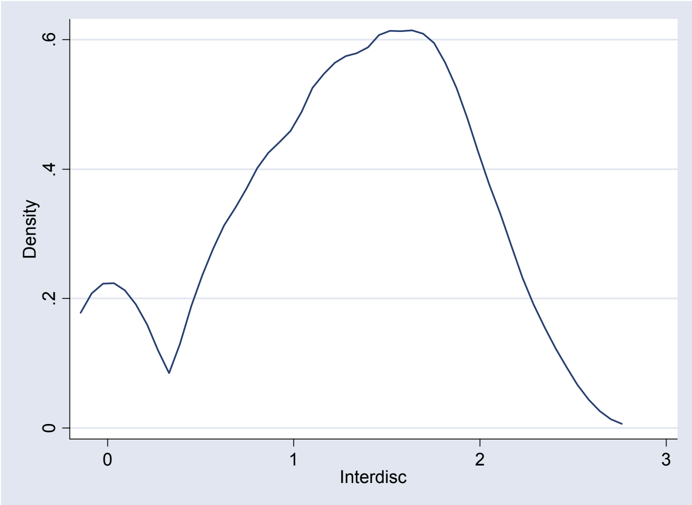


Figure 2. Two way plot of *Interdisc*×*Perf* (Publication Performance)