Explaining the balance between publications and patents as outputs from public-private collaborative R&D: An empirical study on French data

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Abstract

R&D collaboration between firms and public research organizations (PROs) is considered a key component of national systems of innovation. A direct benefit from these collaborations is the production of new scientific and technological knowledge, which is disseminated essentially through publications and patents. In this paper, we empirically address the issue of the economic factors shaping the publishing and patenting patterns in public-private R&D collaborative settings by drawing on the data from a survey conducted among laboratories of the largest French public research organizations in the chemistry and life sciences fields. We consistently find that consortia collaborations tend to discard patents while they are supported by the development of new product innovations. Moreover, the proportion of post-docs in the laboratory's workforce is correlated with more patents than publications. This result is original and highlights the key role played by post-docs for the production of commercially relevant knowledge in French public-private R&D partnerships. It stresses the need for more explicit human resource management tools and policies directed towards this fraction of the knowledge production workforce.

Keywords: University-Industry Collaboration, Knowledge and Technology Transfer, Public-Private Research Partnerships, Economics of Science, France

JEL Classification: L33, O31, O32

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1.   Introduction

The past 25 years have seen a surge in the number of collaborative arrangements between public research organizations (henceforth PROs) and firms (Cohen et al., 1998; Mansfield and Lee, 1996; OECD, 2002) and in the importance of intellectual property therein (Kortum and Lerner, 1998; Henderson, Jaffe and Trajtenberg, 1998). Knowledge and technology transfer as well as the commercialization of research results have gained increased attention as activities allowing PROs to leverage additional financial resources and lift the rate of innovation in the economy. Patents and licensing of intellectual property appear to be important mechanisms in this context (Thursby et al., 2001; Thursby and Thursby, 2003) and in PROs specifically, the number of patents applications and licensing revenues have increased sharply (Nelson, 2001; Thursby and Thursby, 2002).

These trends have led practitioners and policymakers to assume that public-private R&D collaboration will automatically result in an increase in applied outputs and industrial productivity growth, and therefore that policy and strategy should concentrate on reducing transactions costs and incentive-related obstacles for such joint activities. Yet the fact is we don't have hard evidence on the prevalence or value of different outputs generated by public-private collaborative R&D. Indeed, many studies from the US and the EU show that the channels for knowledge and technology transfer are often informal, and rely on research papers and technical reports, consultancy, telephone conversations, informal meetings with industry personnel, seminars, workshops, and symposiums (Cohen et al., 1994; Meyer-Krahmer and Schmoch, 1998).

What is the balance between basic and applied outputs in situations where PROs work with firms, and can it be influenced by policy? The literature is far from reaching an agreement about the factors conducive to achieving different results, which is critical for the design and evaluation of these public programs. This is an important area for research, as the resources to foster public-private research interactions continue to grow in volume (e.g., the 6th Framework Program at the EU-level and many national programs using matching grants), and one of the conditions to access these programs is that cooperating researchers at laboratories and firms specify the likely deliverables.

A great concern has also been expressed in the recent years regarding the potential conflicts between the commercialization of knowledge by PROs and the orientation / pace / availability of new knowledge generation (Stephan and Levin, 1996). This issue can be addressed by looking at the balance between publications and patents, which are the standard outputs respectively in the Republic of science and in the realm of technology (Dasgupta and David, 1994). A set of studies has recently yielded some evidence that there is mutual reinforcement rather that conflict between publication and patent productivity (Azoulay, Ding and Stuart, 2006; Van Looy, Callaert and Debackere, 2006; Carayol and Matt (2004) for the French case) but they use the public research lab or individual researcher as the unit of analysis. We complement these studies by taking a different perspective, that of the public-private R&D collaboration itself, i.e. the very centrepiece of the policy debate concerning reforms of public research systems.

This paper will explore the factors shaping publishing and patenting patterns within public-private R&D collaborative settings.[1] Specifically, we will indicate what public lab characteristics, what modalities and outcomes of collaborative R&D are correlated with publishing and patenting propensities, based on an econometric analysis that uses the data from a survey of 130 French public laboratories in the chemistry and life sciences fields. Our aim is to identify the idiosyncratic determinants behind publishing and patenting within public-private R&D collaboration, as well as the factors explaining the balance between the two. It is worth anticipating that lab respondents in our sample consider publications to be more frequent outputs of collaboration than patents, and our analysis allows us to pinpoint certain policy variables that appear to shift this balance.

Among the various hypotheses that we set forth to guide our empirical analysis, our estimations bear support for the following: (i) Collaborative R&D that take the form of bilateral joint research projects are predisposed towards generating more publications and more patents but are neutral vis-à-vis the balance between the two; (ii) R&D consortia, i.e. multilateral research partnerships, are less prone to produce patents and consequently are correlated with more publications than patents; (iii) R&D collaboration that produce applied research outputs such as new products, new processes and prototypes are more likely to co-produce patents; new products also tend to discard publications and as such are correlated with a balance that favours patents over publications; (iv) The composition of human resources in labs influences this balance in a significant way, particularly the availability of post-docs is positively associated with a tendency for patenting.

The structure of the paper is the following. In the next section, we discuss the related literature, focusing on past studies about the feedbacks and tensions between patenting and publishing as outcomes of collaborative R&D. Section 3 describes the survey, introduces the dependent and independent variables, and formulates hypotheses for each. In Section 4, we put forward our econometric model and main results. The concluding section discusses the paper's implications for human resource management of public labs and for evaluating outcomes from public-private collaborative R&D.

2.   Literature review

The topic of productivity in science has gained increased attention in the economics literature in the past fifteen years (Diamond, 1986; Levin and Stephan, 1991). A specific and controversial sub-question is that of scientific and technological production (its rate, direction, quality) in the context of collaborations between scientific institutions and firms. Such collaboration could skew public research agenda towards more short-term and applied subjects (Blumenthal et al., 1986), could impose restrictions of the dissemination of research results (Blumenthal et al., 1997) and could be conducive to a detrimental fragmentation of the scientific and technological knowledge base as a result of generalized appropriation practices (Heller and Eisenberg, 1998). Since publication is the standard for new knowledge

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[1] We focus on papers and patents because they are two different ways of articulating / codifying scientific and technological knowledge. Conversely, we chose not to put licenses on balance with papers because they pertain to commercial agreements and not to repositories of S&T knowledge.

dissemination in the scientific system and patent its counterpart in the technological system, most of these issues can be addressed by analyzing the publication and patent productivity patterns in various contexts. Many determinants of both paper and patent production have been identified on theoretical and empirical grounds, and at different units of analysis. We now recall the main results starting at the macro level and then going to the institutional, laboratory and finally individual levels.

A first global pattern found in most studies is that papers are far more frequent than patents, despite the strong increase in academic patenting (Agrawal and Henderson, 2002). An obvious reason is that most patentable research is also publishable, while the reverse is not true given that we expect only new knowledge with commercial value to be subject to patenting. Moreover, for a given piece of such knowledge, the financial cost of the publication process is lower than that of the patenting process in terms of the filing procedure, the maintenance, the possible extensions, etc. On the other hand, the frequency difference between publications and patents should be mitigated by the strong economies of scope when writing a paper and a patent for the same piece of new knowledge.[2]

At the institutional level, a number of studies point at a series of possible reasons for the increase in academic patenting of the past decades. The expansion of public research performed in Pasteur's quadrant (Stokes, 1997) is one of them. Such research activities aim at the generation of new knowledge and at the same time intend to yield useful results, possibly with associated patents (Stephan et al., 2005). Besides, formal as well as informal incentives for patenting and licensing are now prevalent in many research institutions. In France for example, following a major law on research and innovation passed in 1999, the major PROs have implemented financial schemes for researchers whose inventions are licensed to firms. Also, the number of patents granted to PROs has become a standard for public evaluation.

Other factors have been identified as possible determinants of either the patent or the publication output (or both) at the research lab level. First of all, the profile of a lab's activities along the basic - applied research spectrum is crucial since basic research is less suited for patentability. Other intrinsic factors relate to the disciplines contemplated. In computer sciences, for example, software are protected by copyright rather than by patent (especially in Europe), meaning that copyrights would be a better proxy of outputs in this sector. Another example comes from the life sciences, which quasi-automatically fall into Pasteur's quadrant and as such are more prone to patenting on average. Notice that our sample is largely composed by labs active in the chemistry and life sciences fields, where patents are widely used, whereas ICT labs are a small proportion of the sample (11%).

The former determinants of publication and patent patterns at the lab levels are essentially exogenous. On the contrary, a series of other factors are directly related to the research strategy of the lab. First, several authors have stressed that a form of learning process may be at play regarding the patenting activity of public research labs. More precisely, this learning unfolds within the interaction between laboratories and their technology transfer offices, which assess the commercial potential of the technologies disclosed by labs and decide to patent or not (Siegel, Waldman and Link, 2003). As a result, the efficiency regarding patent production may be positively related to the past patenting experience of the lab or the TTO.

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[2] Owen-Smith and Powell (2003), for example, notice that academic inventors often disclose their inventions to technology transfer offices by transmitting an article manuscript.

The lab's decision to engage in collaborations with firms may itself have an impact on its patent and publication output. Such collaboration may direct the lab towards research subjects where the results are more likely to be patentable (Agrawal and Henderson, 2002). The lab may also derive additional value from its patents by using them as bargaining chips with firms. On the other hand, publications can be hindered as a result of contractual provisions negotiated by industrial partners to allow for the firm to file a patent application, or to protect the competitive advantage gained by the firm from specific research results (Blumenthal et al., 1997). In their survey of 511 joint university-industry research centres in the US, Cohen et al. (1994) 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. The same questions were asked in our survey and the responses are of the same magnitude (Goddard and Isabelle, 2006b).

Lastly, paper and patent productivity have been analyzed at the individual level. A strong fixed effect appears to be at play, which Stephan et al. (2005) call "the right stuff" and that has to do with individual motivation and ability. Strong heterogeneity amongst individual productivity in science was first identified by Lotka (1926) who found that half of papers were published by 6% of scientists. His empirical law has been confirmed since (Price, 1986) and skewed distributions were also found regarding the production of patents (Narin and Breitzman, 1995; Ernst, Leptien and Vitt, 2000). An additional important result along these lines is that patent and publication rates tend to be correlated at the individual level (Azoulay, Ding and Stuart, 2006; Van Looy, Callaert and Debackere, 2006). This result shows despite the fact that patents and publications could be substitutes at the level of the individual research production function because the time and efforts allocated to either of the two is (at least partially) lost for the other output (Azoulay, Ding and Stuart, 2005).

Scientific and technological productivity may also be related to age through two different mechanisms. Firstly, a cohort affect can be anticipated whereby young researchers would be more open towards the patent culture than their older colleagues (Stephan et al., 2005), resulting in a higher patent productivity. Secondly, several studies have found a life cycle effect both in paper and patent production, which can be explained in terms of dynamic reputation-based and monetary incentives in academic carrier. On the side of publications, researchers face strong incentives to publish in the early stages of their careers in order to get tenured positions, but the reputation-based rewards tend to decrease as the remaining activity period shortens (Levin and Stephan, 1991). On the side of patents, Stephan et al. (2005) suggest that incentives would increase for older researchers since patents could generate a stream of revenues after they retire. However, researchers also admit they file patents because they think it increases the visibility of their academic work (Owen-Smith and Powell, 2001), and this could translate into similar incentives profiles than for publications, i.e. stronger incentives to patent in the early than in the late carrier.

This review of the determinants of publication and patent production in public research at the global, institutional, laboratory and individual levels allows us to pick the presumably most informative variables in our dataset about public - private collaborative R&D in France in order to build a model for explaining the balance between publications and patents in this context. In the discussion, it will also help identify the variables that we omitted because we lacked the information in the dataset.

3.   Survey data and descriptive statistics

In 2004, a detailed questionnaire was sent to around 1,800 laboratory directors in the major French government research bodies (CNRS, CEA, INRA, INRIA, INSERM, Institut Pasteur and Institut Curie). The purpose of this survey was to build a comprehensive dataset about collaborations between public research laboratories and firms in France, with a focus on the management of intellectual property. The survey was meant to include the population of all public research labs active in one of the following S&T fields: life sciences, chemistry and ICT. Laboratories from government research bodies were targeted because of their historically important role in the French innovation landscape.[3]

A characteristic of the French public research system stems from its duality, in the sense that universities coexist in approximate parity in terms of human resources with the government laboratories that were surveyed (known as "grands organismes"; see Table 1 below for a brief description). The former traditionally bear the missions of higher education and basic research while the latter are mostly oriented towards technological research as well as knowledge and technology transfer in specific areas (agriculture, medicine, energy, defence, NICT, etc.). However, the two types of organizations are frequently intertwined, as in mixed research units (Unités Mixtes de Recherche, henceforth UMRs) which themselves are public collaborative structures co-funded and co-supervised by universities and government labs.

The dataset we examine features responses from 130 collaborating labs. Collectively, this group has 875 industrial partners and account for almost 6,800 personnel, between permanent researchers and professors (30%), doctoral and post-doctoral students (24% and 6% respectively), engineers (13%) technicians (23%) and administrative staff (4%). In terms of S&T fields, 52% of responding labs have a specialization in life sciences, 37% in chemistry and 11% in ICT. The distribution by size of the labs is indicated in Figure 1, which shows a wide variation and, notably, four outlier "megalabs" with 250+ members. There are 63 mixed research teams (UMRs) between universities and government laboratories.

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[3] This is evidenced by patenting and licensing statistics. In France, they filed close to 600 national patents and 600 European patents in 2000, amounting to roughly 6% and 8% of all French applications for such patents (OST, 2003). They also had more than 3 000 active license agreements at the end of 2001 (including licenses on patents, know-how, software, databases, biological materials, etc.), generating close to € 100 M (ibid.).
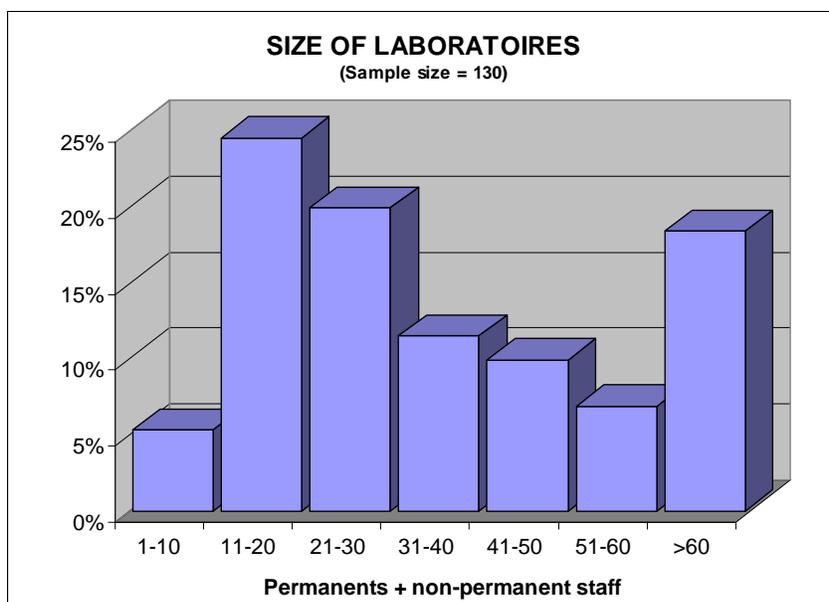
SIZE OF LABORATOIRES
(Sample size = 130)

Figure 1

The low response rate (7.2%) registered was in part a result of the length of the questionnaire and in part because of the timing of the survey, which coincided early 2004 with the mass resignation of laboratory directors opposed to budget cuts for research in government plans. Consequently, our results should be viewed as indicative rather than conclusive about patterns of collaborative R&D. We investigated potential sample biases by comparing the affiliation of the responding labs with the total employees in French PROs. The sample seems to be quite acceptable in that dimension. The distribution of labs among the various PROs is the following: CNRS (48%), CEA (25%), INSERM (18%), INRA (15%), Institut Pasteur (2%), Institut Curie (2%) and INRIA (2%). This is similar to the overall composition of employees in these PROs (shown in Table 1 below) except for an overrepresentation of INSERM labs in our sample as well as of labs from the CEA located in the Provence region and working in the field of chemistry.

	CNRS	CEA	INRA	INSERM	INRIA	Institut Pasteur	Institut Curie
Employees (2004)	26080	14910	8840	4823	1031	1793	750
Fields of research	Very broad range	Defense Energy ICT Health techn[ies]	Food & nutrition Agriculture Environment	Biology Medical science	Computer science Control	Biology	Cancer

Table 1

The survey was very comprehensive regarding the collaborations that public labs have with firms. Lab directors were asked as much as 157 questions regarding the modalities,

benefits and outcomes of collaborations, the management of intellectual property therein, the impact of collaborations on research activities as well as some characteristics of their lab. We now introduce the different variables that are included in the econometric models and present descriptive statistics.

We build econometric models to explain the frequency of publications and patents as outputs of public-private collaborative R&D, as well as the frequency difference between publications and patents (dependent variables). *Publications* is the perceived frequency of publications on a four-point Likert scale (1=never, 2=rare, 3=frequent, 4=very frequent). More precisely, to increase the number of useful observations, we define *Publications* as Max (*LabPublications*, *Co-publications*). It is usually equal to the frequency of publications issued from the lab's collaborations with firms (*LabPublications*). But if this information is missing and the *Co-publications* response exists, then *Publications* equals *Co-publications*, i.e. the frequency of publications co-authored with researchers in the firm. Note that the frequency of publications may be underestimated for the additional points since *LabPublications* ≥ *Co-publications*. Similarly, *Patents* is the perceived frequency of patents as outputs of collaboration (again, from 1 to 4).

We construct an indicator of the balance between publications and patents within public-private R&D collaboration using other proxies for the frequency of publications and patents. We transform *Publications* (respectively *Patents)* into a dummy *Publications2* (respectively *Patents2*) with value 1 if the frequency is 3 or 4 (frequent or very frequent); but 0 otherwise (rare or never). Based on this, the proxy variable *Publish>Patents* equals 1 if *Publications2 > Patents2* in which case publications are relatively more frequent; and 0 otherwise.[4]

Figure 2 shows how respondents rate the frequency of occurrence of different outputs. Publications are the number one output, with over 60% of respondents stating that collaboration with industry frequently or very frequently produces publications. Patents, like other outputs associated with the legal appropriation and exploitation of research results (licenses of different kinds and copyrights) are not as pervasive (rate of frequent + very frequent slightly over 20%). This gap between publication and patent productivity has been identified by several studies at different levels of analysis in PROs (see literature review). We find it also shows at the level of public-private R&D collaborations, although we would expect these collaborations to value more applied outputs.

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[4] We also tried two other indicators. The first is a dummy variable that takes a value of 1 if *Publications > Patents*; and 0 otherwise. The second is defined as *Publications – Patents* + 4 , which goes from 1 if patents occur much more frequently than publications to 7 if publications do so. The results we present below are qualitatively the same as those when we run maximum-likelihood probit regressions using these alternative indicators.
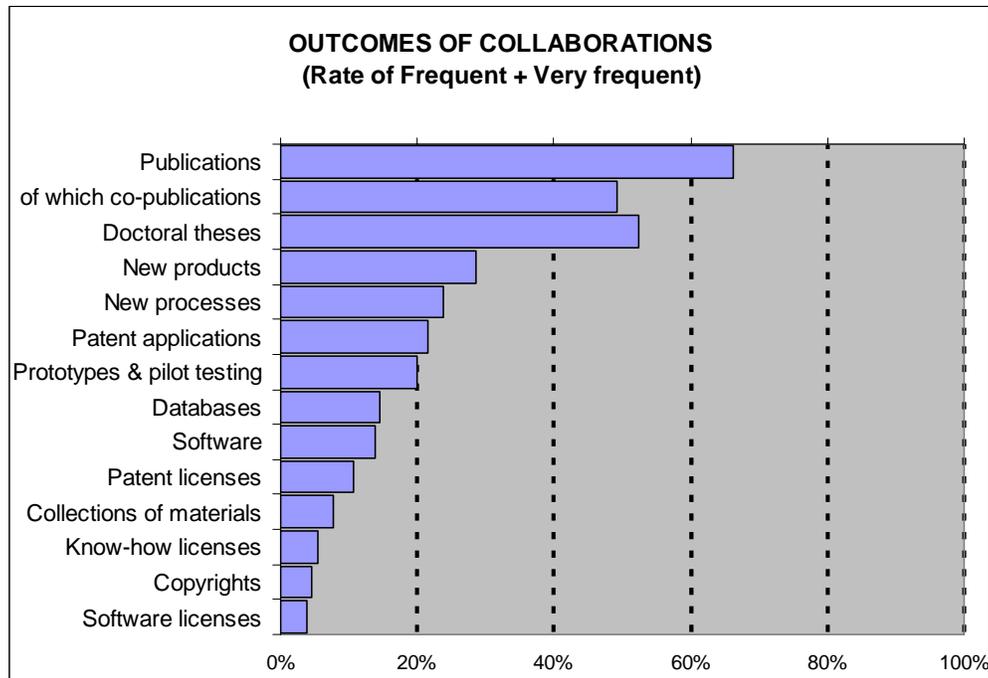
OUTCOMES OF COLLABORATIONS
(Rate of Frequent + Very frequent)

Publications · of which co-publications · Doctoral theses · New products · New processes · Patent applications · Prototypes & pilot testing · Databases · Software · Patent licenses · Collections of materials · Know-how licenses · Copyrights · Software licenses

Figure 2

Our econometric models aim to estimate the correlation of patent and publication outputs, and the balance thereof, with respect to the following independent variables. They were selected on the basis of the results identified in the literature review, and also in an attempt to optimize the use we could make of the information available in our dataset. We now describe them in turn and then we present the descriptive statistics for all variables.

1.   Modalities of public-private collaborative R&D

JointResearch is the perceived frequency (1-4) of joint research as a modality of R&D collaborations with firms. Lab directors indicated that joint research was the most frequent modality (frequent or very frequent for 66% of responses). We anticipate that joint research projects, a closer form of interaction deliberately aiming at the production of new knowledge and technologies (as compared to informal exchanges or consulting for example) has a positive correlation with both outputs.

Consortia is defined as the maximum between the perceived frequency (1-4) of R&D consortia generally speaking and European R&D consortia specifically as modalities of R&D collaborations with firms. The variable is defined in this way to increase the number of useful observations as the information regarding consortia is sometimes missing while that concerning European consortia is provided (note that the frequency of consortia may be underestimated for the additional points since European consortia are a subset of all types of consortia). Consortia were ranked 4th in terms of perceived frequency by lab directors (frequent or very frequent for 37% of responses) behind joint research, informal contacts and contract research. Our hypothesis is that collaborating in consortia will be negatively

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correlated with patenting propensities, and thus bias the balance towards publications. The reason is that consortia can entail significant transaction costs with respect to the negotiation of intellectual property rights that create hurdles for appropriation.

2.   Outputs of public-private collaborative R&D

Products, *Processes* and *Prototypes* measure the perceived frequency (1-4) of new products, new processes and prototypes / pilot designs as outputs of public-private R&D collaborations. As shown in Figure 2 above, together they form a second group of outputs as measured through their perceived frequency (rate of frequent or very frequent between 20% and 28%) behind the group composed of publications, co-publications and doctoral theses, i.e. the traditional outputs of research activities. These applied-research outputs are expected to be correlated with patent frequency.

3.   Management of intellectual property within public-private collaborative R&D

Secret measures the perceived frequency (1-4) of total secret requirements by the industrial partner about the outcomes of R&D collaborations. This requirement was indicated to be frequent or very frequent by 25% of lab directors, a somewhat strong figure. This variable should be negatively correlated with publication frequency given the limit it imposes on researchers' freedom to publish results in a timely and inclusive manner.

ManagementPRO is the frequency (1-4) with which the PRO (or its Technology Transfer Office) is responsible for managing the lab's R&D collaborations and technology transfer activities. The questionnaire listed other possible managing units such as private firms, IP consulting firms, etc. Lab directors indicated that their TTO was the most frequent institution responsible for collaboration and technology transfer with firms (frequent or very frequent for 84% of responses). Our hypothesis is that this will tend to increase publications frequency and decrease that of patents, pushing the balance towards publications, given the relative lack of experience of French TTOs and potential conflicts of interests with researchers as compared to external specialists.[5]

Coownership is the frequency (1-4) of co-ownership as one possible arrangement for the allocation of intellectual property stemming from R&D collaborations. Other arrangements listed in the questionnaire were sole ownership of the industrial partner, sole ownership of the PRO, and separated ownership of each other's results. Co-ownership is by far the most frequent arrangement (indicated to be frequent or very frequent by 71% lab directors). We hypothesize *Coownership* should be negatively correlated with patenting owing to the aforementioned transaction costs of deciding on a formula for appropriation and exploitation of results (Hagedoorn, 2003).

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[5] These conflicts of interest lie at the core of a model of technology transfer developed by Jensen, Thursby and Thursby (2003). They examine the interplay of the university administration, the TTO and the faculty with a game-theoretic dual agency model where both the faculty and the TTO are agents of the administration. They find that in the sub-game between the inventor and the TTO, the latter's objectives in executing a license must take into account the interests of the faculty (i.e. the TTO is also an agent of the inventor), a result they confirm empirically.

4.   Workforce profile of the research lab

ProportionPhDs and *ProportionPostdocs* are equal to the number of PhDs (resp. of postdoctoral fellows) in the lab divided by the total number of employees. These variables are included with the anticipation that they would capture both cohort and life-cycle effects in scientific and technological productivity. We expect them to be positively correlated with publications as a result of the life-cycle effect (theses and papers can be jointly produced; post-docs have an incentive to publish in order to establish their reputation). We also expect them to be positively correlated with patents as a result of the cohort effect by which younger researchers would be more open to the patent culture and more aware of the patenting process. Also, their relatively low wages and influence in lab decisions would mean that they could be directed to work on patenting-related activities, which would also be positively correlated.

5.   Lab characteristics used as control variables

LogEmployees is the Logarithm of the number of employees of the lab. This variable is introduced to capture returns to scale in scientific and technological production at the lab level, which might pass on to the level of collaborative arrangements that labs have with firms. Our expectation concerning the effect of this size variable is undetermined since to our knowledge, only elementary results are available concerning scale effects at the laboratory level.[6]

      LogIndustrial is the Logarithm of the number of industrial partners of the lab. For several reasons identified in the literature review, we expect the number of industrial partners to be positively correlated with patents frequency (impact in terms of more applied research themes; value of patent as a bargaining chip; learning curves regarding the patenting process) and negatively with publications frequency (various restrictions on labs' publishing activities). The correlation with the balance between publications and patents should also be negative.

      Academic is the number of PROs that have a stake in the lab (>1 for mixed research units). In France, the institutional mix is usually considered a signal of scientific excellence (Carayol and Matt, 2004). So we expect that *Academic* will be positively correlated with publications frequency. But we also anticipate that the transaction costs related to negotiations over intellectual property increase with the number of parties that can voice their interest, and thus *Academic* should be negatively correlated with patents frequency, and positively correlated with the balance between publications and patents.

      Lifesciences and *Chemistry* are dummy variables for the S&T field that will allow controlling for fixed productivity effects at the disciplinary level. Similarly, *PRO_CNRS*, *PRO_CEA*, *PRO_INRA*, *PRO_INSERM* will allow controlling for fixed effects at the institutional level.

      The descriptive statistics for all variables is presented in Table 2 below:

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[6] At higher levels of aggregation, the evidence is more conclusive. For example, Adams and Griliches (1998) have found that the research production function follows diminishing returns to scale at the university level but constant returns to scale at the aggregate level.

Table 2. Summary statistics

	Variable	Type	No. obs.	Mean	St. dev.	Mode	Median	Range
Dependent	*Publications*	Discrete	126	2.90	0.84	3	3	1-4
	Patents	Discrete	120	1.95	0.96	2	2	1-4
	Publish>patent	Discrete	119	0.54	0.50	1	1	0-1
Independent	*Jointresearch*	Discrete	125	2.79	0.85	3	3	1-4
	Consortia	Discrete	117	2.38	0.98	3	3	1-4
	Products	Discrete	120	2.02	0.91	1	2	1-4
	Processes	Discrete	120	1.87	0.89	1	2	1-4
	Prototypes	Discrete	116	1.72	0.95	1	1	1-4
	Secret	Discrete	128	1.98	0.93	2	2	1-4
	ManagementPRO	Discrete	122	3.52	0.79	4	4	1-4
	Coownership	Discrete	124	2.90	0.91	3	3	1-4
	ProportionPhDs	%	124	0.22	0.14	0.00	0.22	0-0.53
	ProportionPostdocs	%	124	0.08	0.08	0.00	0.06	0-0.41
Control	*LogEmployees*	Real	126	3.51	0.88	2.8	3.35	1.6-6.7
	LogIndustrial	Real	127	1.42	0.92	1.5	1.39	0-4.9
	Academic	Integer	130	1.74	0.84	1	2	1-5
	Lifesciences	Dummy	130	0.52	0.50	1	1	0-1
	Chemistry	Dummy	130	0.37	0.48	0	0	0-1
	PRO_CNRS	Dummy	130	0.48	0.50	0	0	0-1
	PRO_CEA	Dummy	130	0.25	0.43	0	0	0-1
	PRO_INRA	Dummy	130	0.15	0.35	0	0	0-1
	PRO_INSERM	Dummy	130	0.18	0.38	0	0	0-1

4. Econometric models and results

We run maximum-likelihood ordered probit regressions for the dependent variables *Publications, Patents*, and a binary probit for *Publish>Patents*. These regressions include all independent variables related to the modalities of collaboration, outputs, management of intellectual property, and workforce profile, plus the control variables. The results for these estimations are presented in Table 3. In the rest of this section, we discuss the statistically significant results and their sensitivity to alternative specifications, and try to evaluate how well they conform to the hypotheses outlined before and to the results that have been found by previous literature. We start by discussing the model with publications frequency as the

dependent variable, then address patents frequency, and finally open up the discussion to the balance between these two outputs.

Table 3. Regression results

	Publications	*Patents*	*Publish>patent*
Constant			-0.18
Jointresearch	0.37 **	0.71 ***	0.05
Consortia	0.03	-0.31 **	0.39 **
Products	-0.34 *	0.64 ***	-0.79 ***
Processes	-0.20	0.32 *	-0.24
Prototypes	0.33 **	0.29 *	0.00
Secret	-0.01	-0.13	0.25
ManagementPRO	0.12	0.29 *	0.19
Coownership	-0.11	0.04	-0.01
ProportionPhDs	2.00	2.47 *	1.73
ProportionPostdocs	2.60	13.38 ***	-8.58 ***
LogEmployees	0.25	0.56 ***	-0.22
LogIndustrial	0.06	0.16	0.05
Academic	0.10	-0.22	0.36
Lifesciences	0.11	0.49	0.56
Chemistry	1.13 **	0.49	0.33
PRO_CNRS	0.53	0.38	-0.08
PRO_CEA	0.30	1.07 *	0.15
PRO_INRA	1.35 **	0.43	0.45
PRO_INSERM	0.72	0.92	-0.47
Pseudo-R^2	0.18	0.43	0.29
LR statistic	47.1 ***	113.0 ***	42.1 ***
Number of observations	107	107	107

*** Significant at 1% level; ** significant at 5% level; * significant at 10% level

4.1.   Publications frequency

The results for this estimation indicate that the frequency of joint research is positively correlated with publications frequency, as we anticipated. As a matter of fact, within the highly diverse set of channels of interaction between public laboratories and firms (informal

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contacts, technology transfer agreements, technical assistance, consulting, etc.), such bilateral collaborative research appears to be the modality through which two partners can jointly run R&D projects of common interest and eventually co-produce publications. Notice in particular that multilateral R&D projects that take the form of consortia are not significantly correlated with publication rates.

Publications frequency is negatively correlated with the frequency of the development of new products, although not with a strong significance. This result, which we did not anticipate, can be interpreted in the light of the relatively strong and highly significant correlation of new product development with patents frequency. Actually, publications are usually withhold or delayed to allow for patent application, with a direct negative impact on publication rates. At the same time, this interpretation is not supported by another result, which is a significant positive correlation between both publications and patents frequency with the frequency of prototypes.

Concerning the controls, chemistry labs have a significantly higher propensity to publish on the course of collaborations with firms than the omitted category, i.e. ICT labs. Moreover, labs that are affiliated to INRA, a French PRO dedicated to food & nutrition, agricultural and environmental research, have a significantly higher propensity to produce publications out of their R&D collaborations with firms than the omitted category, which includes INRIA, Institut Pasteur and Institut Curie.

4.2.   Patents frequency

The frequency of joint research, which was found to be positively related with publications frequency, has also a positive correlation with patents frequency; this correlation is stronger and more significant than for publications. Once again, this is consistent with the view that gaining highly valuable outputs such as patents from R&D collaboration requires close modalities of interaction such as joint research. The opposite is true of the frequency of consortia as a modality of public-private R&D collaboration. This result, although less confident, concords with the view we presented above that patents are difficult to manage within public-private consortia, a modality of collaboration that typically involves a large number of partners from diverse institutional origins (Cassier and Foray, 2002; Foray and Steinmueller, 2003).

The frequency of products as an output of public-private R&D collaborations has, as expected, a significant positive correlation with patents frequency. We know from Levin et al. (1987) that product innovations are more prone to patentability than process innovations for which protection by secrecy is more common, and indeed the results show a weaker and less significant correlation of patents frequency and process innovations. A correlation of the same magnitude is also found between the frequency of prototypes and patents frequency.

Interestingly, we find that labs for which technology transfer activities and collaborations with firms are managed by the mother PRO or its Technology Transfer Office tend to get a higher frequency of patents out of their R&D collaborations, which is contrary to what we hypothesised. This result would seem to refute our assumptions related to the lack of experience of French TTOs and to their potential conflicts of interests with researchers. The view it supports is rather that of TTOs being an organizational structure of technology transfer activities that is more efficient than alternatives such as specialized private firms, IP

consulting firms, or regional public centres and non-profit associations dedicated to technology transfer activities as they exist in the French landscape and as they appeared in the questionnaire. Debackere and Veugelers (2005) mention several comparative advantages of TTOs: they locate the responsibilities for transfer activities close to research groups (decentralisation), thereby reducing the asymmetric information problem typically encountered in the market for scientific and technological knowledge; they provide a responsive administrative support for financial, legal and IP issues to researchers who can thereby focus their efforts on R&D; and they secure a sufficient level of autonomy in the PRO for developing relations with industry.

Looking at control variables, we find that patents frequency is correlated with the size of the lab in terms of its number of employees: larger labs are more prone to get patents out of their R&D collaborations with firms. We are facing three difficulties in interpreting this result. Firstly, given that patents frequency is coded discretely (1-4), we can not infer any elasticity value from the coefficient on *LogEmployees* in the regression and thus we can not conclude to increasing or decreasing returns to scale. Secondly, only a fraction of the lab's workforce is an input into its R&D collaborations with firms, and the partnering firm may also commit resources into the collaboration. Thirdly, although it would seem intuitive that most outputs from R&D collaborations are positively correlated with the lab's size, this is not the case for publications frequency, as shown in the first model. Another control variable has a significant correlation with patents frequency: labs that are affiliated to CEA, a French PRO dedicated to defence, energy, ICT and health technologies have a higher propensity to produce patents out of their R&D collaborations with firms than the omitted category. The CEA was also found to be the most actively patenting PRO in Europe by Debackere and Veugelers (2005).

Our last result reveals that the patent output is more frequent when labs are supplied with a larger proportion of PhDs and more especially of post-docs in their research teams. Results from previous works have left the question open since the life-cycle effect and the cohort effect presumably play against each other. Younger researchers would be more open to the patent culture and more aware of the patenting process (cohort effect), whilst they would face less incentives as well as a higher opportunity cost than their older and tenured colleagues to disclose inventions and file patents (life-cycle effect). According to our result, it would seem that the cohort effect dominates the life-cycle effect. However, there appears to be something specific to post-doctoral positions in terms of patent productivity since the coefficient is much stronger and much more significant than for PhDs. Similar results were found by Carayol and Matt (2004) in their study of 80 laboratories of the University Louis Pasteur in Strasbourg, France. They suggest that post-docs are dedicated to invention activities as a result of "their weak autonomy in research agenda selection or of their early involvement in a career path turned toward research in industry."

4.3.   Balance between publications and patents frequency

Public labs that frequently collaborate with firms on the basis of consortia tend to have a balance of collaborative outputs bent towards publications, or rather bent away from patents. This follows directly from the difficulty to manage intellectual property in consortia (and specifically public-private consortia) that was stressed while commenting the *Patents* regression. The other modality of collaborative R&D, i.e. joint research, is not found to be

significantly correlated with the balance between publications and patents although it was positively correlated with both outputs and had a stronger and more significant coefficient on patents.

Another result that passes on directly from the *Publications* and the *Patents* regression is the negative correlation between the frequency of new products as an output of public-private collaborative R&D and the balance between publications and patents. It follows from the widespread use of patents to appropriate new products, and from the associated detrimental effect we mentioned on publication rates. Neither the *Processes* nor the *Prototypes* variables have a significant correlation with the balance between publications and patents although they were found to be correlated with publications and patents frequency. Specifically, the positive correlations of *Propotypes* with both publications and patents frequency seem to neutralize themselves in the balancing model.

Lastly, the proportion of post-docs in the staff of the lab is negatively correlated with the probability that publications are more frequent than patent. This variable was found to be positively correlated with patents frequency, with a relatively strong magnitude and a high significance, but not with publications frequency. Notice that no control variable has a significant correlation with the balance between publications and patents frequency.

5.   Conclusions

The survey we have at our disposal for public laboratories affiliated to French PROs indicates that R&D collaborations between public labs and industry yield publications more often than patents[7] and gives us some clues about what the underlying reasons are. Overall, the original results we can infer from our econometric models is that consortia collaborations make it difficult to negotiate on patents; and that post-doc seem to be a highly productive human resource within public-private R&D collaborations in terms of patents.

An issue we have not tackled in this paper is the direction of the causality between patent outputs at the R&D collaboration level and the proportion of post-docs in the public lab workforce. In line with most of the assumptions we made (cohort and life cycle effects), it could actually be that post-docs have a high scientific and technological productivity and that they are an important input for public-private R&D collaborations, at least in France. But in their analysis of labs of the Italian National Research Council, Bonaccorsi and Daraio (2003) propose another explanation for the correlations we find that inverts the sense of the causality. According to the 'attractiveness' hypothesis they develop for post-doc positions, which they consider pre-recruitment situations, the more prestigious labs – those that have stronger S&T productivity indicators – attract more and smarter candidates for post-doctoral fellowships and they can leverage more resources for them. A virtuous circle would then be at play

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[7] As we argued in Goddard and Isabelle (2006a), this small fact of itself could lead to questions about the reliance on patents as a proxy for knowledge output in the context of public-private partnerships, which applies as much to the economic literature, as well as to policy actions to promote collaboration that specify patents as the main expected outcome.

between the attraction of talented young researchers, institutional prestige and resource availability.

The relatively weak correlation between the proportion of PhDs in the lab and productivity indicators at the collaboration level could also be explained in this framework. As Carayol and Matt (2004) suggest, PhDs and post-docs are allocated to public labs through different channels: the latter seem to favour the lab's reputation and performance in terms of publications and patents, while PhDs seem to value personal contacts with professors during the late stage of their graduate studies.

More sophisticated econometric techniques applied to a more comprehensive dataset would be necessary to assess the sense of the causality between the post-doctoral workforce in public research labs and the patent productivity when these labs collaborate with firms. Whatever the sense of the causality, this original result highlights the key role played by post-docs for the production of commercially relevant knowledge in French public-private R&D partnerships. It stresses the need for more explicit human resource management tools and policies directed towards this fraction of the knowledge production workforce.

A limit of our paper is the possibility of a sample bias, which we can not check easily given the very limit amount of information that we have concerning non-responding labs. So once again, our results must be considered as informative rather than conclusive. Also, we have not been able to include in our regressions all the variables that we anticipated to have an impact on the production of patents or publications within public-private R&D collaborations, because the information was missing in our database. Two important omitted variables are the profile of the lab's activities along the fundamental / applied research spectrum, and the labs experience of the patenting process that could be captured e.g. trough its existing stock of patents.

To conclude, we believe this paper can pave the way for a broader international comparative analysis of public-private collaborative R&D. The survey in itself is already a standard since both our survey for France and the survey used by Meyer-Krahmer and Schmoch (1998) for Germany were largely inspired by the Carnegie Mellon survey designed by Cohen et al. (1994). It is also in the process of being transposed to Belgian universities. We would warmly welcome and support further transpositions to other European countries. With the Europe-wide comparable surveys that could result from such efforts, we believe our methodology could also set a standard in order to asses the scientific and technological productivity of public-private R&D collaborations. Of course, for this purpose we would need to add in the regressions a set of country-specific variables such as characteristics of the legal framework for intellectual property in public research organizations, the R&D intensity of firms in the country (the demand-side for R&D collaborations), etc. We hope scholars from other countries will jump on-board this challenging task!

References

Adams, J. and Z. Griliches, (1998), "Research Productivity in a System of Universities", *Annales d'Economie et de Statistique*, 49(50), p.127–162.

Agrawal, A. and R. Henderson (2002), "Putting Patents in Context: Exploring Knowledge Transfer from MIT", *Management Science*, Volume 48, pages 44-60.

Azoulay, P., Ding, W. and T. Stuart (2005), "The Impact of Academic Patenting on the Rate, Quality, and Direction of (Public) Research," *NBER Working Paper* 11917.

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

Bonaccorsi, A. and C. Daraio (2003), "Age effects in scientific productivity. The case of the Italian National Research Council (CNR)", *Scientometrics*, 58(1), p.35–48.

Carayol, N. and M. Matt (2004), "The exploitation of complementarities in scientific production process at the laboratory level", *Technovation*, 24, p.455-465.

Cassier, M. and D. Foray (2002), "Public knowledge, private property and the economics of high-tech consortia", *Economics of Innovation and New Technology*, 11(2), p.123-132.

Cohen, W.M., R. Florida and R. Goe (1994), "University-Industry Research Centers in the United States," *Report to the Ford Foundation*, Mimeo, Carnegie Mellon University.

Cohen, W.M., R. Florida, L. Randazzese, and J. Walsh (1998), "Industry and the Academy: Uneasy Partners in the Cause of Technological Advance," in Roger Noll (ed.), *Challenge to the Research University*, Washington, DC: Brookings Institution.

Coupé, T. (2003), "Science is golden: academic R&D and university patents", *Journal of Technology Transfer*, 28, p.31-46.

Dasgupta, P. and P.A. David (1994), "Toward a New Economics of Science", *Research Policy*, Volume 23, p.487-521.

Debackere K. and Veugelers R. (2005), "The role of academic technology transfer organizations in improving industry science links", *Research Policy*, 34, p.321-342.

Diamond, A.M. (1986), "The life-cycle research productivity of mathematicians and scientists", *The Journal of Gerontology*, 41, p.520-525.

Ernst, H., Leptien C. and J. Vitt (2000), "Inventors Are Not Alike: The Distribution of Patenting Output Among Industrial R&D Personnel, *IEEE Transactions on Engineering Management*, 47(2), p.184-199.

Foray, D. and W.E. Steinmueller (2003), "On the economics of R&D and technological collaborations: Insights and results from the project Colline", *Economics of Innovation and New Technology*, 12(1), p.77-91.

Goddard, J.G. and M. Isabelle (2006a), "How do Public Laboratories Collaborate with Industry? New Survey Evidence from France", *Working Paper IMRI*.

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

Hagedoorn, J. (2003), "Sharing intellectual property rights – an exploratory study of joint patenting amongst companies", *Industrial and Corporate Change*, 12(5), p.1035-1050.

Henderson, R., A.B. Jaffe and M. Trajtenberg (1998), "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965–1988," *Review of Economics and Statistics*, Volume 80, pages 119-127.

Jensen, R., J. Thursby and M. Thursby, (2003), "Disclosure and licensing of university inventions: 'The best we can do with the s**t we get to work with' ", *International Journal of Industrial Organization*, 21(9), p.1271–1300.

Kortum, S. and J. Lerner (1998), "Stronger Protection or Technological Revolution: What is Behind the Recent Surge in Patenting?," *Carnegie-Rochester Series on Public Policy*, Volume 48, pages 247-304.

Levin, R.C., Klevorick, A.K., Nelson, R.R. and S.G. Winter (1987), "Appropriating the Returns from Industrial Research and Development", *Brookings Papers on Economic Activity*, 3, 783-820.

Levin, S.G. and P.E. Stephan, (1991), "Research productivity over the life cycle: evidence for academic scientists", *American Economic Review*, 81, p.114-132.

Lotka, A.J. (1926), "The Frequency Distribution of Scientific Productivity," *Journal of Washington Academy of Science*, 16(12), p.317-23.

Mansfield, E. and J.-Y. Lee (1996), "The Modern University: Contributor to Industrial Innovation and Recipient of Industrial R&D Support," *Research Policy*, Volume 25, pages 1047-1058.

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

Meyer-Krahmer, F. and U. Schmoch (1998), "Science-Based Technologies: University-Industry Interactions in Four Fields," *Research Policy*, Volume 27, pages 835-851.

Narin, F. and A. Breitzman (1995), "Inventive Productivity," *Research Policy*, 24, p.507-519.

Nelson, R.R. (2001), "Observations on the Post-Bayh-Dole Rise in University Patenting", *Journal of Technology Transfer*, Volume 26, pages 13–19.

OECD (2002), *Benchmarking Industry-Science Relationships*, Paris: OECD.

Owen-Smith, J. and W. Powell (2001) "To Patent or Not: Faculty Decisions and Institutional Success at Technology Transfer," *Journal of Technology Transfer*, 26(1/2), p.99-114.

Owen-Smith, J. and W. Powell (2003) "The Expanding Role of University Patenting in the Life Sciences: Assessing the Importance of Experience and Connectivity," *Research Policy*, 32, p.1695-1711.

Price, D.J. De Solla (1986), *Little Science, Big Science... and Beyond*, New York: Columbia University Press.

Siegel, D.S., Waldman, D. and A. Link (2003), "Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An Exploratory Study," *Research Policy*, 32, p.27-48.

Stephan, P.E., Gurmu, S., Sumell, A.J. and G. Black (2005), "Who's Patenting in the University? Evidence from the Survey of Doctorate Recipients", Forthcoming in the *Economics of Innovation and New Technology*.

Stephan, P.E., Gurmu, S., Sumell, A.J. and G. Black (2002), "Individual Patenting and Publication Activity: Having One's Cake and Eating it Too", Prepared for presentation at the NPRNet Conference, March 23, University of Sussex, Brighton, UK.

Stephan, Paula and Sharon Levin (1996), "Property Rights and Entrepreneurship in Science," *Small Business Economics*, 8(3), p.177-188.

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

Thursby, J.G., R. Jensen and M.C. Thursby (2001), "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities," *Journal of Technology Transfer*, Volume 26, pages 59-72.

Thursby, J.G. and M.C. Thursby (2003), "Industry/University Licensing: Characteristics, Concerns and Issues from the Perspective of the Buyer," *Journal of Technology Transfer*, Volume 28, pages 207-213.

Thursby, J.G. and M.C. Thursby (2002), "Who is Selling the Ivory Tower? Sources of Growth in University Licensing," *Management Science*, Volume 48, pages 90-104.

Van Looy, B., J. Callaert and K. Debackere (2006), "Publication and patent behavior of academic researchers: Conflicting, reinforcing or merely co-existing?," *Research Policy*, 35, pages 596-608.