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The determinants of scientific research agenda: Why do academic inventors choose to perform patentable versus non-patentable research?

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Abstract

This paper explores the determinants of scientific research agenda. By using an original dataset that includes extensive information about 269 French academic inventors, we analyze why scientists choose to perform patentable versus non-patentable research. Usually economic studies tackle this problem by using the number of invented patents as a proxy of researchers' willingness to perform patentable research. The originality of the paper is that, in addition to the number of invented patents, we rely on a survey-base dependant variable that indicates whether or not scientists acknowledge orienting deliberately their research towards patentable areas. Our results indicate that past experience with respect to patenting activity matters: academic inventors who have already experienced a successful technology transfer are more inclined to orient their research towards patentable domains. Similarly, the institutional environment plays an explanatory role, whereas conversely, scientific discipline, age and individual research performance do not seem to affect the decision to orient research towards patentable areas. Yet, age and scientific performance positively influence the number of patents scholars effectively invent.

Keywords: University, patent, scientific agenda, technology transfer, academic inventors.

JEL Classification: O3

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1. Introduction

Patenting in academia is a thorny, if salient issue. On the one hand, developed economies face a greater involvement of universities into commercial activities, going hand in hand with the creation or reinforcement of structures dedicated to technology transfer, and the evolution of national legal framework towards higher financial returns for university research. On the other hand, the emergence of this “third mission” of universities gives rise to fundamental concerns (Siegel *et al.*, 2007). The literature that analyzes the impact of university patenting highlights four main threats (recently summarized in Baldini, 2008): threat to scientific progress due to restrictions on sharing and using new knowledge; threat to basic research due to changes in the remuneration structure of scientists; threat to teaching activities (for similar reasons); and threat to industry facing more difficulties to get access to knowledge created by universities (Fabrizio, 2007). In the present contribution, we choose to focus on the second threat and to investigate the selection process of scientific research agenda.

The recent upsurge of patents in science (Henderson *et al.*, 1998; Mowery *et al.*, 2004) is likely to affect the way scientists select their research contests (Stephan, 1996). Specifically, the introduction of patents within the “republic of science” (Palanyi, 1962) may reduce incentives to invest in upstream, far from the market research, generating a crowding-out effect of basic research in favour of more applied (and potentially patentable) research. In turn, this eviction effect might seriously damage long term growth rate (Nelson 1959; 2004). If plausible, all those relations remain however assumptions, the exact nature of the consequences of patents on scientists research agenda remaining unclear yet.

In such a context, exploring the determinants that influence scientists’ choice of a research contest sounds necessary. Few papers already address the issue of scientists’ motivations to perform patentable research. Among them, Baldini (2008) and Baldini *et al.* (2007) provide some original empirical investigations of the factors explaining the (Italian) faculty members’ decisions to patent or not. The present paper is positioned upstream in the questioning process. We try to understand the factors that affect the decision of scientists to orient their research towards more or less patentable areas. For this purpose, we use an original dataset composed of 269 French academic inventors, i.e. academic professors who are also inventors of at least one European patent. Via a survey administered in spring 2008, we collected in depth personal and professional information about those academic inventors.

Based on this survey, we estimate two different econometric models. In a first negative binomial regression we explore the determinants of the number of patents invented by each academic inventor. It is indeed usual in the literature to proxy the willingness of researchers to orient their research towards patentable fields by the number of patents they have invented (Van Looy *et al.*, 2006; Azagra Caro *et al.*, 2006; Carayol, 2007; Stephan *et al.*, 2007). Then, in a second logistic regression, we look for the variables that influence scientists declared choice to orient their research towards more or less patentable domains. To do so, we rely on an original dichotomised dependent variable (built on one specific question of the survey): whether or not academic inventors acknowledge orienting their research towards patentable scientific areas.

We deliberately introduce this second regression so as to enrich the first step of analysis and to be able to really understand the willingness of scientists to reorient their research due to patent

considerations. Such a methodological choice allows us to cope with some of the drawbacks of studies that are exclusively based on whether or not researchers have effectively been granted patents. It is indeed not because a scientist has been granted a patent that he deliberately orients its research toward patentable areas. The patent can be an unexpected outcome of his research as well. Similarly, it is not because a scientist has not been granted a patent that he does not orient its research towards patentable areas. Here we are therefore able to compare results based both on revealed preferences (number of patents invented by each scientist) with declared preferences (scientist's declared decision to orient its research towards patentable areas).

Our results indicate that scientists who belong to labs that are used to massively patent their research, who have already experienced successful technology transfer or, on the contrary, who already have been obliged to reorient their research due to a risk of patent infringement are more likely to orient their research towards patentable areas. Conversely, experience of publication delay directly attributable to past patent application, age and scientific performance (measured by the number of past publications) do not affect the willingness of scientists to look for patents. Yet, age and scientific performance positively affect the number of patents invented by scholars, suggesting that the number of invented patents and the willingness to orient its research towards patentable areas do not have similar determinants.

The rest of the paper is organized as follows. Section 2 reviews the existing literature on the determinants of scientific research agenda and builds the assumptions to be tested. Section 3 provides detailed information on the methodology and data selected for the study. In section 4 we conduct the econometric analysis and discuss the results. Section 5 concludes.

2. The problem of problem choice and the patent issue

2.1 Patenting university research and the choice of scientific contest

Most of the time scientists are free to choose their scientific contest. This freedom is an axiom of the “republic of science”. To ensure the efficiency of the process, no central regulator should constrain scientists to work on some specific topic (Polanyi 1962). In such a loosely-guided context, an important issue for researchers deals with the “problem of problem choice” (Carayol and Dalle, 2007), i.e. with scientists' choice of their own research agenda.

The literature in economics of science has shown that scientists select the research they want to perform according to three main criteria: gold, puzzle and reputation, with an important weight given to reputation and puzzle considerations (Stephan, 1996). This specific objective function induces scientists to choose not the more remunerating problems to solve but the more challenging ones from an intellectual point of view. This, in turn, intends to encourage scientists to devote time and resources to undertake basic research, which is more highly valued by the scientific community, and less time and resource to undertake applied research, less considered by peers. Hence, the tacit functioning of the “republic of science” ensures – although in an imperfect manner- that scientists have incentives to perform basic research, even though this kind of research yields, at least in the short run, weak monetary benefits to scientists.

The introduction of patents within the “republic of science” may reduce those incentives to devote time and resources to perform basic research and increase the advantages associated to applied research¹. By definition patents reward applied research. Theoretically, basic research hardly lead to patent since they consist in research undertaken without any application in mind, while an invention must involve an industrial application to become patentable. It is therefore possible that the opportunity to patent university research induces a crowding-out effect of basic research in favor of more applied research. Since the latter becomes more rewarded, scientists may prefer to engage more resources to do applied, patentable research and less to undertake basic, non patentable research.

Yet, Thursby *et al.* (2007) show that this crowding-out effect of basic research may not necessarily occur. Indeed, scientists decide to share their available time between four main activities: (1) basic research; (2) applied research; (3) teaching; and (4) leisure. Hence, even though the introduction of university patent might lead scientists to prefer applied research, this may not be detrimental to basic research and teaching activities provided that scientists simultaneously decide to devote less time to leisure. Furthermore, Thursby *et al.* show that if applied research results in both additional applied and basic knowledge (which is the case in some specific scientific areas), the introduction of university patent can exhibit an even more positive effect (see also Thursby and Thursby (2009) and Perkmann and Walsh (2009) for a similar point of view).

Empirical studies do not provide converging results on this crowding-out hypothesis. On the one hand, when the outcome of basic research is measured by the number of publications, the existence of an eviction effect is rejected. Researchers and labs who patent the most are also those who publish the most, which tends to indicate that researchers who are engaged in patentable activities do not renounce to basic research (Thursby and Thursby, 2002; Breschi *et al.*, 2005; Van Looy *et al.*, 2006; Carayol, 2007; Stephan *et al.*, 2007). For instance, Thursby and Thursby (2002) show that changes in the universities’ propensity to patent are more important to explain the growth of university patenting and licensing than eventual changes in faculty research direction.

On the other hand, a bundle of empirical studies also tend to suggest that academic patenting and licensing shift the focus of academic research away from basic to more applied topics. Henderson *et al.* (1998), for instance, find that the quality of academic patent, measured by the number of forward citations, tend to decline since the early 80s’. A possible interpretation of this finding is a shift of US universities toward more applied research (with a less rich scientific content). Yet, Mowery *et al.* (2004) do not find evidence of such a quality decline. Azoulay *et al.* (2006) find that university patenting may induce scientists to shift their research focus on topics of more commercial interest. Czarnitzki *et al.* (2009) take into account the heterogeneity of patenting activities and find out, by using German data, that patents owned by non profits organizations such as universities do not decrease publication performance whereas patents owned by firms do.

¹ Similarly, university patenting may reduce the incentives to spend time and resources on education. Since teaching becomes relatively less rewarded than doing patentable research, university professors may tend to reduce the time they devote to teaching (Geuna and Nesta 2006). But this question is out of the scope of the present paper.

In short, patenting activities may impact the scientific agenda, but the literature does not provide a clear-cut conclusion on the nature and intensity of this impact. It is therefore important to explore the variables that may affect scientists' choice of their research contests, and more particularly the factors and motivations that lead researchers to undertake patentable research. Indeed if the literature flourishes on the potential detrimental impact of academic patenting on science and on its potential positive impact on technology transfer, almost nothing exists on the origins of the decision to patent for a scientist. Understanding why faculty members engage into patentable research areas would however provide interesting avenues to design appropriate incentives to catalyse the three complementary missions of university simultaneously.

2.2 Why do scientists choose to engage into patentable research?

We explore here the variables that might explain scientists' willingness to devote time and resources to perform patentable research. We distinguish between contextual explanatory factors (disciplinary, organisational, institutional, etc.) and individual explanatory factors (characteristics of the scientist, past behaviours, subjective perception) (Figueiredo Moutinho *et al.*, 2007).

Contextual explanatory factors

The literature presents sometimes patenting activities as being in some cases a necessary evil, enforced by the context. Within a given professional (more or less patent-friendly) environment, the scientific discipline at stake can be the first explanatory variable of scientists' behaviours. Indeed, scientific and technological domains are characterized by diverse levels of patenting opportunities and by heterogeneous strategic values associated to patenting (Griliches, 1990). Among others, scientific disciplines affect (i) the size of the gap between academic research and industrial applications and (ii) the effectiveness of patents as means of protecting inventions (Schild, 2004). As a consequence, researchers belonging to different research areas might experience different propensity to patent and different patent productivities (Stephan *et al.*, 2007). Thus, the first hypothesis we want to test is the following:

Scientific discipline plays a decisive role in scientists' willingness to engage into patentable research areas (H1)

Another part of the institutional environment of the researcher which might affect his research agenda is the characteristics of the organisation he is member of. Bercovitz and Feldman (2003) talked about "observational learning" in order to stress that the individual choice to engage into patentable activity is often influenced by the social context in terms of tolerance and support of patenting activities. Being aware of patenting experiences of colleagues may influence one's perception of patents. Hence, the culture at work within the lab might shape the faculty members' choice to patent. The nature of the institution and its history might also affect the incentives of its members and the priority order they assign to their different professional missions. This point is confirmed by Carayol (2007) who concluded that labs characteristics largely affect individual patenting production in universities, and by Callaert *et al.* (2009) who stress important differences with respect to patenting activities between universities and engineering/technical schools. Concretely, we expect that:

Scientists working for universities and labs actively engaged into patenting activities are more willing to orient their research in patentable activities (H2)

If academic patenting is function of the institutional context, Bercovitz and Feldman (2003), Thursby and Thursby (2002) and Oven-Smith and Powell (2001) also stress that academic patenting is above all strongly influenced by scientists' attitudes. More precisely individual characteristics are decisive, whatever the institutional environment.

Individual explanatory factors

First, the scientist's personal characteristics matter. Among them gender proves influent. Female scientists have been found to patent less than their male counterparts (Breschi *et al.* 2005; Thursby and Thursby, 2005). Link *et al.* (2007) also found that male scientists are more likely to be involved in informal technology transfer from university to industry. However Bunker *et al.* (2005) precised that the quality and impact of women's patents equals or even exceeds the men's ones. Besides, age might also affect patenting behaviour. Life cycle models exhibit the age of scientists as a significant explanatory factor (Levin and Stephan, 1991; Thursby *et al.*, 2007). Since basic research mostly yields benefits in the long run, via the increase in the researcher's scientific reputation and its potential professional promotion, older scientists should assign less importance to this type of research and be ready to focus on activities, such as patenting, that generate more short-run benefits. Similarly, since the career of youngest researchers strongly depends upon their publication performance, those researchers should be less inclined towards applied and/or patentable activities. Moreover, older (more senior) researchers benefit from a wider experience which allows them to more easily assess the value and publication/ patent potential of their research results, and in turn leads them to be less concentrated on publishing. Similarly and strongly correlated with age, it can be expected that tenured scientists are more likely to be involved in patenting and technology transfer activities (Link *et al.*, 2007). It can thus be expected that all things being held equal:

The probability for a researcher to orient its research towards more patentable activities increases with his age and varies with gender and academic position (H3)

The scientific performance of the researcher might also influence its attitude towards patentable research activities. Most empirical studies emphasize a positive link between patenting and publishing activities in quantitative terms. Breschi *et al.* (2004) explain this positive link by the existence of a "resource effect" (patent gives scientists more resource and therefore allow them to perform better science) and of a "individual productivity effect" (since patents and publications are two outcomes of research activities, best researchers, who produce more knowledge, are more likely to be granted more patents and more publications than less productive researchers). Yet, even though most productive scientists are more likely to be granted patents, they may not deliberately orient their research towards patentable domains. On the contrary, those researchers' strong reputation due to good performance in basic research ensures them with a comfortable expectation of future earnings, thus removing the burden of having to ensure their living, via patenting for instance. Our fourth hypothesis can therefore be stated as follows:

More productive researchers (in terms of number of publications) are not more willing to orient their research towards patentable domains than less productive ones (H4)

The nature of the motivation of the researcher can also explain his more or less important inclination towards patenting activities. As emphasized above, researcher's motivation depends upon three elements: reputation, gold and puzzle solving. Being the inventor of a patent might result into financial reward since the university shares royalties with the inventors. Thus, being involved into patentable research areas might be seen as a way to increase both revenues (through direct licensing or the creation of a spin-off based on the patent) and reputation. Incidentally, OECD report confirms that patenting at university has a positive influence on researchers' careers and earnings (OECD, 2003).

Therefore, one can expect that researchers who grant more importance to immediate earning are more willing to engage into patentable activities. Conversely an important "taste of science" (scientists being mostly interested by puzzle solving) should clearly orient scientists toward basic research (Levin and Stephan, 1991) and as a consequence, divert them from patentable research. Notice that this view is sometimes simplistic. Patenting can be a new challenge for scientists and it can also participate to increase their reputation (Baldini *et al.*, 2007). But in general it can be expected that:

Scientists primarily motivated by immediate earnings are more willing than those primarily motivated by puzzle solving (who have a strong "taste of science") to orient their research towards patentable activities (H5)

Lastly, the opinion of the researcher on the potential drawbacks and advantages of patent may also affect its decision to invest time and energy in patentable research topics. Some researchers have a very negative image of patents, while others, more entrepreneurial ones, are patent enthusiastic. The literature concludes that past experiences in patenting influence the perception of the process: those researchers who have never been involved in patenting attribute a higher value to the difficulties associated to this activity than those who have already patented (Figueiredo Moutinho, 2007). But past patenting activities may also have been very successful, revealing the importance of patent to help technology transfer for instance. Such positive experience should induce researchers to look for patents again. On the other hand, past patenting experiences may have been disappointing, leading to publication delay (Liebeskind, 2001; Cohen *et al.*, 2002, this problem being even more accurate in Europe, where the US "grace period" does not exist), interdiction of publication, litigations, less time for research, etc. Going one step further, Owen-Smith and Powell (2001) conclude that if scientists have had negative experiences with technology transfer offices, they invest less time in future patenting processes. So we expect that:

Scientists who have a positive opinion on patents are more willing to engage into patentable activities than those who have a negative image of patents (H6)

Researchers who have already experienced a successful episode of technology transfer due to a patent are more willing to orient their research towards patentable activities (H7)

Researchers who have already experienced important delay of publication due to past patenting experience (H8a) or who have already been involved in a patent litigation

(H8b) or who have been blocked in their research by an existing patent (H8c) are less willing to orient their research towards patentable activities

To summarize, we raised in this section hypotheses on the determinants that affect scientists' willingness to engage into patentable research areas. Some of them refer to researchers' individual characteristics whereas others rather suggest that the decision to select patentable research areas is function of the context surrounding scientists. In the next part we detail the dataset we use to test those assumptions empirically.

3. Methodology and data

3.1 The French context for academic patenting

As in most developed countries, French public research organizations are actively engaged in patenting activities. In the last decade, the CNRS was systematically ranked in the top ten of French patent applicants, INSERM and INRA reaching also high rankings. Regarding French universities, they are now intensively patenting their research and there are several evidence that this trend is growing (Azagra-Caro *et al.*, 2006; Carayol, 2007; Lissoni *et al.*, 2007).

This recent change in the behavior of French universities can be attributed at least partially to the law on innovation and research passed in 1999, which puts a strong emphasis on university-industry technology transfer and, in particular, on patents. Conversely to the US case, before this law French universities were already allowed to patent their invention and, if they did, to own and manage their patent with considerable freedom. Yet, the 1999 legislation led to the creation of technology transfer offices (TTOs) and incubators in most French scientific universities (some of which already had such structures before the law was passed) and encouraged university researchers to exploit their research findings, by allowing them to create their own companies (strong provision is made to help researchers do so) and to have their inventions patented or co-patented.

Specifically, before the law it was rather common that scientists took part to patented invention, thus being included as inventors in the patent, but the university often used to leave the whole ownership to the industrial partner or to the scientist himself. Today, emphasis is placed on the fact that French universities have to retain sole ownership of the patent rights or at least share it with the firms they have collaborated with.

Thus, the law on innovation has contributed to changing the philosophy of French university researchers with respect to patenting. Rather than modifying the legal status of university patents, as was the case in the United States, the law has introduced a new strategic orientation, and has placed stronger emphasis on technology transfer and patent ownership. Nowadays, French universities' TTOs put a lot of pressure on university researchers to get their discoveries patented. This change explains why, since the law was passed, the number of university-owned patents has increased significantly.

With respect to the remuneration of individual academic inventors, the French authorities also decided in 2005 to harmonize the remuneration practices of French universities and to introduce

one set of rules that is applicable to all universities. More precisely, when a university grants a license to a firm, the revenues derived from licensing are shared following a simple principle: first, the technology transfer office is reimbursed for its expenditures. 50% of the remaining sum is shared among the inventors (up to a ceiling above which the inventors only share 25% of the remaining income) and the other half is shared among the institutions that took part in the invention process, namely the different labs and universities in which the inventors are employed. As a consequence, in the current legislative context, French academic scientists can earn a significant share of the income derived from patenting and licensing their inventions, which might motivate them to engage in such an activity.

3.2 Construction and description of the sample

Sample construction

We collected information about 269 French academic inventors through a survey conducted in spring 2008. This sample of inventors stems from a wider population of French academic inventors identified in a previous study (Lissoni *et al.* 2007). By academic inventors we mean tenured university lecturers (i.e. “Maître de Conférences” -equivalent to associate professors - and university professors) active in a French university in 2004 and designated as inventors on at least one patent application submitted to the European Patent Office between 1993 and 2005.

Matching the French university professors with the European patent inventors databases (during a European research project entitled KEINS²) allowed us to identify 1228 confirmed French academic inventors. Those are confirmed academic inventors; whenever we had doubt about a person's status as inventor (because of homonymy problems for instance) we contacted him/her by telephone or email in order to get the confirmation that s/he is both university professor and designated as an inventor in a European patent (Lissoni *et al.*, 2007).

Out of these 1228 confirmed French academic inventors to whom we sent a questionnaire by email, we collected 280 answers, corresponding to a response rate higher than 20%. Finally, out of these 280 respondents, 269 were really exhaustive and useable for our study.

Regarding the survey content, a first section was dedicated to individual information such as age, gender, status, etc. The second section was targeted at motives and impediments to patenting activity at university. The third part included questions on the consequences of the patent directly experienced by the academic inventor. We ran a pilot test of the questionnaire thanks to the help of three faculty members of our institution, which allowed us to improve the clarity and exhaustiveness of the survey³.

Profile of the academic inventors

Table 3.1 gives the profiles of the 269 respondents according to their age, gender, academic position and scientific disciplines.

² KEINS is the acronym of “Knowledge based Entrepreneurship: Innovation Networks and Systems”.

³ The questionnaire is available on request to the authors. For a more detailed description of both the sample and the methodology used to collect data, interested reader can consult Pénin (2010).

Table 3.1: Sample distribution

Characteristics		% in the sample
Age	30-40	12
	40-50	36
	50-60	28
	60-70	21
	More than 70	3
Gender	Male	90
	Female	10
Academic position	MCF	43
	PU	57
Scientific discipline	Biological sciences	15
	Chemical sciences	29
	Electronics	16
	Medical sciences	10
	Pharmaceuticals and drugs	10
	Engineering	13
	Others	7

Our respondents are mostly male (90%), University professors (57%) and over 40 years old (88% of the respondents is more that 40 years old). We find in our sample all the disciplines where universities are used to patent: electronics, biology, chemistry, pharmaceuticals and engineering (social sciences being not represented). All those figures are consistent with the sampling population of French academic inventors (Lissoni *et al.*, 2007; Pénin, 2010).

3.3 Econometric analysis

In order to investigate the determinants of scientists' willingness to perform patentable versus non patentable research, we run two different econometric models (Table 3.2). In a first one, we proxy researchers' willingness to perform patentable research by the number of patents they have invented and we explore the impact of different explanatory variables on this number of invented patents. We construct this dependent variable by taking all the EPO patents invented by each researcher between 1993 and 2005. As usually done in this case, we estimate this model by relying on a negative binomial specification⁴.

In our second model, we run a logit regression to explore the variables that influence the declared choice of academic inventors to orient their research towards more or less patentable domains. To do so, we rely on an original dichotomised dependent variable (built on one specific question of the survey addressed to academic inventors). This variable scores 1 if the inventor acknowledges

⁴ A zero inflated model would not be relevant here since we do only consider academic inventors, i.e. scientists who have already invented at least one patent.

orienting his research towards patentable areas and 0 otherwise (Table 3.2)⁵. This second regression enables us to enrich the first step of analysis with empirical results calculated on declarative data. Indeed, such a methodological choice allows us to overcome an important drawback of most studies on the topic (Van Looy *et al.*, 2006; Azagra Caro *et al.*, 2006; Carayol, 2007; Stephan *et al.*, 2007), namely the validity of granted patents as an indicator of research orientation. Former studies that explore the influence of explanatory variables on the number of invented patents at the level of the university, the lab or the scientist, do not really assess the impact of university patent on the agenda of research because patent cannot always be taken as such as an indicator of the orientation of the research. It is indeed not because a scientist has been granted a patent that he deliberately orients its research toward patentable areas. The patent can be an unexpected outcome of his research as well. Similarly, it is not because a scientist has not been granted a patent that he does not orient its research towards patentable areas.

Table 3.2: Econometric specification

Model	Estimation method	Dependant variable	Description of the dependant variable	Minimum	Maximum	Average
Model 1	Negative binomial	PATENT	Integer=number of EPO patents invented by the researcher between 1993 and 2005.	1	49	3,04
Model 2	Logit	RES_AGENDA	dummy=1 if researcher acknowledges that he tries to orient its research in fields where he knows it will be possible to apply for patents	0	1	0,20

In sum, our data have the advantage of considering the willingness of academic inventors to orient their research due to patent considerations. Thanks to our survey we are able to compare two models: One that relies on revealed preferences and tries to explain the number of invented patent (model 1) and one that relies on declared preferences and tries to explain the determinants of scientists' willingness to apply for patents (model 2). Those two models are likely to give interesting complementary insights and to distinguish when a patent is the consequence of a deliberate choice of the scientist versus an involuntary by-product of his activity.

It is important to stress here one limit of our study: We work on academic inventors, which means that we only have information on scientists who have already been mentioned as patent inventors. We lack a control sample in which we would have information on scientists with no experience in patenting activities. This means that what we explain is the probability that a scientist orients its research towards patentable field (model 2) or the number of invented patents (model 1), knowing that the scientist has already been granted a patent.

⁵ The exact question was the following: "Does the possibility to be granted patents influence the nature of your research? (only one possible answer)". Then respondents had the choice between three answers: "Yes, I try to orient my research in fields where I know it will be possible to apply for patents", "No" or "I don't know". 19,4% of the respondents answered "yes", 77,4% "no" and 3,3% "I don't know". Notice that in the question we voluntarily did not use the words "applied research" and "basic research" in order to dismiss any misunderstanding from respondents.

3.4 Description of the independent variables

To test the different hypotheses presented in section 2, we mainly rely on information collected through the survey described above. This survey provides us with information about academic inventors' motivations to apply for patent, their experience with respect to patenting activities, their institutional environment, their opinion with respect to university patent, etc. Furthermore, via queries in ISI web of science, we were able to attribute to each researcher his number of authored publications, which we use as a proxy of the individual research performance. Overall, we have therefore twelve explanatory variables, which are displayed in Table 3.3.

Variables built on external data sources

- Hypothesis 1, on the effect of scientific discipline is tested by the use of sectoral dummies. Those dummies rely on the CNU (French "Conseil National des Universités") classification of each scientist (Table 3.1). They are therefore an indicator of scientific disciplines and not of industrial sectors.
- Hypothesis 2, on the role of the institutional environment is tested via two independent variables: First, we built an indicator of the quality of the university each academic inventor belongs to, using the latest Shanghai ranking (UNI_PERF). Second, we introduce the patent policy of the lab the researcher belongs to (LAB_PAT_POL). This latter information is collected through the survey in which we asked respondents to report whether or not their laboratory is involved in a policy of systematic patenting of their research.
- We use the age and the gender of the researcher to test hypothesis 3 (AGE and GENDER variables). We do not introduce the grade of the researcher due to its high correlation with the age variable.
- To test hypothesis 4 we built the PUBLI variables which accounts for the scientific productivity of academic inventors. Concretely, using "ISI web of science" we collected and summed all the publications attributed to each of the surveyed scientists. This variable is a classical indicator of scientific performance. It is not weighted by citations here.

Variables stemming from the survey

- To test hypothesis 5 we rely on the answers to a question in which we asked respondents whether or not their motivation to apply for a patent was to increase immediate earnings via licensing royalties (EARN_MOTIV). Although it is obvious that this variable cannot account for the complex set of scientists' motivations, it provides an indicator of the importance that academic inventors grant to immediate earnings as opposed to other motivations, such as reputation or scientific curiosity.
- To test hypothesis 6 we asked inventors whether they believe that university patent may undermine the norms of open science, i.e. may decrease trust and exchanges among scientists and decrease the rate of diffusion of research results. The answer to this

question reflects the scientist's subjective perception of university patent (PAT_PERCEPT)⁶.

- Finally, hypotheses 7 and 8 are tested with the help of three variables built from answers to the survey. We asked whether or not the respondent:
 - o Has already experienced a successful case of technology transfer and whether or not this success was directly attributable to the patent application (PAT_TT) (H7)
 - o Has already suffered from a delay in the publication process due to the patent application (PUB_DELAY) (H8a).
 - o Has already been involved in a patent litigation (PAT_LITI) (H8b)
 - o Has already been obliged to reorient its research due to the risk of patent infringements (BLOCK_PAT) (H8c)

4. Results

Results of the two econometric models are given in Table 4.1.

A first interesting finding is that the age of scientists (the AGE variable) does not affect their willingness to perform patentable research (model 2), thus invalidating hypothesis 3. This finding contradicts the hypothesis that older scientists may be more willing to apply for patent in order to constitute a complement of revenue for their pension (Carayol, 2007). However, in model 1 age is significantly and positively correlated to the number of patents invented by scientists. This second finding is hardly surprising, since our model does not measure scientists' yearly productivity but the total number of invented patents over the career of the scientist. This result is therefore likely to reflect a time effect. Older scientists have had a longer career than younger ones and therefore have had more time to accumulate experience, knowledge and, as a consequence, patents. Yet, even though this result must be taken with care, our findings, suggest that although older scientists may be granted more patents they do not act deliberately in order to do so. Patents seem to be an unintended outcome of their research activity.

Similarly, scientific performance (proxied by the number of scientific publications, the PUBLI variable) does not significantly affect academic inventors' willingness to perform patentable research but positively and significantly explains the number of patents invented. This result is consistent with most of other empirical studies that found a positive relationship between publishing and patenting at the scientist level⁷. This suggests the existence of an "individual productivity effect" (Breschi *et al.*, 2004): Best scientists are good both for patenting and publishing, which explains why the most productive scientists are also the ones who patent the most. Yet, those productive scientists do not specifically tend to orient their research towards patentable areas. If they patent more frequently it is because patents are a by-product of good science.

⁶ Respondents are mostly favourable to university patenting. They have a positive, and sometimes enthusiastic, image of university patenting (Pénin, 2010).

⁷ There are many strategic complementarities between patent and publications. Some researchers patent in order to publish without risking losing control on their ideas; others use publications as a way to stop firms from patenting (defensive publications) or publish around an invention (and a patent) as a way of marketing their idea to potential users, etc. See Schild (2004) for a collection of statements made by Swedish patenting scientists on the topic.

Table 3.3: Description of the explanatory variables

Name	Type	Minimum	Maximum	Average
AGE	Integer={1,2,3,4,5}, according to the age of the respondent in 2008. 1=between 30 and 40, 2=between 40 and 50, 3=between 50 and 60, 4=between 60 and 70 and 5=older than 70	1	5	2,66
GENDER	Dummy, 1= male	0	1	0,90
UNI PERF	Integer={0,1,2,3,4,5}, according to the Shangai 2006 ranking of the university to which the researcher belongs. 0=not among top 500, 1=between 500 and 400, 2=between 400 and 300, 3=between 300 and 200, 4=between 200 and 100 and 5 = among the top 100.	0	5	1,6
LAB PAT POL	Dummy, 1=researcher's lab has a policy of systematic patent application	0	1	0,36
PUBLI	Integer= number of past publications SCI before 2005	0	177	19,8
PAT PERCEPT	Integer={0,1,2,3,4,5}, according to whether or not the researcher believes that university patenting undermines the culture of open science. 0=strongly disagree; 5=strongly agree.	0	5	1,03
PAT LITI	Dummy, 1= researcher has already been involved in a patent litigation	0	1	0,14
PUB DELAY	Integer={0,1,2,3,4}, according to whether or not researcher has already experienced a delay in the publication of its research directly attributable to a past patent application. 0=no delay; 1=delay lower than 6 months, 2=delay between 6 months and 1 year, 3=delay between 1 and 2 years, 4=delay higher than 2 years.	0	4	1,87
PAT TT	Dummy, 1=researcher has already experienced technology transfer (commercialization or industrialization of an invention) directly due to academic patenting	0	1	0,33
BLOCK PAT	Dummy, 1=researcher has already been obliged to reorient its research in the past to get round a patent held by another researcher	0	1	0,25
EARN MOTIV	Integer={0,1,2,3,4,5}, according to whether or not the researcher considers that to increase its immediate earning through royalties is an important motivation to apply for a patent. 0= not important at all; 5=very important	0	5	0,86
SCIENTIFIC DISCIP.	Dummy for technological field: {Electronics, chemical sciences, biological sciences, medical sciences, pharmaceuticals and drugs, engineering sciences, others}, reference=biological sciences	See Table 3.1		

Sectoral dummies are not significant in model 2, thus invalidating hypothesis 1 (In model 1 the dummy for chemistry is the only significant one). This finding is particularly remarkable since important sectoral differences are usually observed with respect to patenting strategies (Cohendet

et al., 2009). Our work indicates on the contrary that there is no sectoral difference (researchers behave in a similar way across disciplines) both in scientists' willingness to invent patent and in the number of invented patents. Chemistry is the only discipline exhibiting some specificities regarding the total number of invented patents. One possible interpretation is that applying for patent and being granted a patent might be easier in this field than in the others.

Table 4.1: Econometric results

	Model 1		Model 2	
	Dependant variable: Patent		Dependant variable: Res_Agenda	
	<i>Coefficient</i>	<i>Std error</i>	<i>Coefficient</i>	<i>Std error</i>
AGE	0,298 (***)	0,0565	0,121	0,186
GENDER	0,167	0,198	-0,241	0,639
UNIPERF	0,003	0,028	0,068	0,093
LAB_PAT_POL	0,182 (*)	0,107	1,320 (***)	0,368
PUBLI	0,010 (***)	0,001	0,006	0,008
PAT_PERCEPT	-0,076 (*)	0,040	0,305 (**)	0,123
PAT_LITI	0,169	0,138	-0,148	0,481
PUB_DELAY	0,007	0,041	0,146	0,142
PAT_TT	0,190 (*)	0,108	0,604 (*)	0,366
BLOCK_PAT	0,387 (***)	0,111	0,948 (**)	0,376
EARN_MOTIV	0,070 (**)	0,034	0,153	0,110
Chemical_science	0,386 (**)	0,162	0,539	0,570
Electronics	0,252	0,188	0,621	0,639
Medical_science	-0,205	0,213	-0,808	0,882
Pharma_and_drug	-0,042	0,210	0,522	0,664
Engineering	0,070	0,213	0,524	0,712
Others	0,355	0,230	0,530	0,798
Const	-0,659 (***)	0,264	-3,964 (***)	0,903

Note: (***) significant at the level of 1%, (**) significant at the level of 5%, (*) significant at the level of 10%.

Fourth, researchers' institutional environment is likely to affect their patenting behavior: The lab patenting policy (LAB_PAT_POL) does positively and significantly influence both the researcher willingness to engage in patentable areas (model 2) and the number of invented patents (model 1). Put differently, the more a lab is engaged in an active patenting policy, the more its research members tend to orient their research towards patentable fields (hence validating hypothesis 2) and, as a consequence, the more its research members tend to invent patent.

Going on with the influence of the researchers' institutional environment, our empirical results show that the university performance (UNI_PERF) is not significant, neither in model 1 nor in model 2. This may be due either to the proxy we use (The Shanghai ranking, whose relevance is often criticized) or to the peculiarity of the French research and higher education system, in which universities are mainly dedicated to teaching, the research being mostly undertaken at the

level of the lab. When it comes to research, universities may hence be a non appropriate unit of analysis.

Surprisingly direct earning motivations (the EARN_MOTIV variable) are not significant in model 2 but are positively and significantly correlated with the number of invented patents in model 1. This result suggests that although scientists motivated by money do not specifically orient their research towards patentable areas, they succeed to invent more patents than their colleagues having other motivations.

Lastly, with respect to past patenting experience of researchers, we find three original results.

First, researchers who have already experienced a patent blockage in the past are more likely to look for patents and to invent patents. The BLOCK_PAT variable is indeed positive and significant in both models⁸. This result, counterintuitive at first glance (and contradicting hypothesis H8c), is likely to reflect the defensive value of patents. Researchers who have already been victims of a patent blockage, who have been compelled to stop or reorient some of their research due to the risk of patent infringements may be more aware of such a risk and therefore may be more interested to get a protection against it. In such a context, gathering a patent portfolio can be seen as a strategy dedicated to protect oneself against patent attacks: A researcher who holds its own patents can try to cross-license them and therefore may be more likely to preserve a freedom of research than a researcher who would not have any patent. An interesting question raised here is therefore whether this behavior of defensive patenting, which has mostly been observed at the level of the firm (because it requires important funds in order to collect significant patent portfolios), can be relevant at the level of academic scientists.

Second, the PAT_TT variable is positive and significant in both models 1 and 2: researchers' past experience of technology transfer does affect their current patenting behavior. More precisely, researchers who have already experienced a successful episode of technology transfer from academia to industry in the past, and who believe that applying for a patent was decisive for the success of this technology transfer, are more likely to look for patent today. Those researchers have indeed already experienced the advantages of patent to foster science-industry linkages, which makes them more willing to apply again. Hypothesis 7 is therefore validated.

Third, the publication delay variable (PUB_DELAY) is significant neither in model 1 nor in model 2, which means that there is no link between past publication delays imposed by the patenting process and the willingness to look for new patent application (thus contradicting hypothesis H8a). An explanation may be that academic inventors do not care about publication delay either because they do not believe in the norms of open science or, more likely, because

⁸ Linked to this point, the PAT_LITI variable is not significant in both models 1 and 2, which indicates that academic inventors who have already experienced a patent litigation are not more or less willing to apply for patents. This is likely to be due to the fact that a patent litigation can lead to very different outcomes. A patent litigation may be either a positive or a very negative experience for the scientist. And we do not know here whether or not the litigation has been settled at the advantage or at the disadvantage of the respondent. Another potential reason why university research does not seem influenced by scientists' past experiences in terms of patent litigations might be the regular infringement of patents by university researchers highlighted by Yancey and Stewart (2007).

they perceive that this delay is not so important as compared with the advantages of patents, such as better links with industry, successful technology transfer, etc.

This last explanation tends to be confirmed by the effect of the patent perception variable (PAT_PERCEPT). Conversely to what was expected in hypothesis 6, it appears that the more academic inventors believe that patent undermines the norms of open science, the more they are likely to orient their research towards patentable areas. We interpret this finding as a sign that researchers who specifically orient their research towards patentable areas are not naive when they come to assess the consequences of patent in science. Those scientists are perfectly clear and aware of the drawbacks and shortcomings of patents but also of their importance to foster technology transfer and links with industries. It might also testify the discrepancy between the official discourse of academic inventors (it is dangerous for science to engage into patenting activity) and their effective behavior (engaging more and more energy in this lucrative activity whatever the social consequences).

5. Conclusion

This paper is a first attempt to understand why some academic members may tend to orient their research towards patentable areas. As such, this work departs from the existing literature because we not only try to explain the number of invented patents but also, and most of all, scientists' decision to orient their research towards patentable domains. This makes an important difference, since considering only the number of invented patents does not really take into account scientists' willingness to perform patentable research. Some researchers patent whereas they do not really look for it, while others try to patent but are not successful. By using an original dataset that includes extensive information about 269 French academic inventors, we have thus analyzed the determinant of scientists' willingness to perform patentable versus non patentable research.

Our econometric analysis exhibits the following results: Older academic inventors are granted more patents than younger ones but do not more frequently orient their research towards patentable domains. Patents seem therefore to be the outcome of experience and not of the willingness of older academic inventors to earn additional revenues. We also found that the number of scientific publications is not significant to explain the choice of academic inventors to orient their research towards patentable domains. Yet, scientists who have more publications are also those who patent the most. Sectoral dummies did not prove significant either. Chemistry put apart, the discipline does not influence either the inclination to do patentable research or the number of patents invented. Our empirical analysis also allows us to show that academic inventors who belong to labs that massively patent their research have a higher probability to orient their research towards patentable areas and to invent patents. Yet, we do not observe any university effect. Scientists who belong to the best French universities do not behave differently than others. Lastly, experience of publication delay does not appear to hinder academic inventors' willingness to patent, whereas a successful past experience in technology transfer motivate scientists to engage into patentable research.

Those results are interesting in order to understand scientists' motivations for patenting. Indeed, by finding that the determinants to engage into patentable areas on the one hand, and to effectively invent patent on the other hand, significantly differ, we point out the fact that in France, patenting at universities is not always the outcome of a deliberate choice. More precisely,

scientists who patent are not systemically more inclined to select more patentable research areas. Patents often seem to be a by-product of research activity rather than a specific target they want to address. This, in turn, suggests that either patenting does not systematically distort the research agenda of researchers or that, if it does, it is on the long run. Patenting being indeed a long lasting process, scientists who are really motivated by patenting activities may have not been granted the IPR they are looking for yet.

Furthermore those results may be informative for policy makers. Indeed, understanding the criteria that influence scientists' choice of their research agenda is crucial in order to be able to design adequate incentive schemes for scientific research. In particular, understanding why scientists are looking to apply for patents is important if policy makers want to increase the number of university patents, as it seems to be the case in most developed countries (the question of the desirability of this policy is beyond the scope of this discussion). For instance, our finding that past and successful experience of patenting matters and plays a catalytic role on scientists' forthcoming patenting activity suggests that measures should be undertaken so as to ease the first patent application. Similarly, the significant role played by the lab policy testifies that patents should be more systematically integrated in the assessment grid used by public financiers when evaluating the labs they are going to support. Sponsoring actively patenting labs would in turn motivate the researchers of those labs to continue to get involved or even increase their patent activity.

This work was a first step towards a better comprehension of the determinants of the scientific research agenda. Yet, more work is still needed. For instance, it will be necessary to construct a control sample including non inventor scientists, i.e. scientists who have not applied for a patent yet but might be motivated to do it. By restricting our study to academic inventors we consider only a small fraction of the scientific population and, above all, it is likely that those academic inventors behave differently than other scientists. A second possible extension is to develop international comparisons. Academic patenting is indeed likely to be very sensitive to national contexts. Finally, it may be interesting to get information on the fate of the patents university members have developed (whether or not they have been exploited by a spin-off, sold to a large firm, abandoned? Did they give rise to a license agreement? etc.) so as to test whether the result (and ownership) of intellectual property emanating from university research influences the motivations to engage into patentable activities.

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