Proactive versus reactive behaviors: Do the motivations to patent influence the number of patents invented by academic inventors?

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Abstract
In this paper we distinguish between two motivations that academic scientists may adopt when dealing with patenting activities: a proactive one, where scientists are patent enthusiastic, do believe in the entrepreneurial university and are actively looking for patents. Second, a reactive one, where scientists are more reluctant to patent and, if they however patent, it is only because they are constrained to do so by the context. We use an original dataset on 173 French academic inventors (in life science and electronics and engineering sciences) in order to investigate whether the scientist's motivations to patent affect the number of patents she invents.
Our econometric results indicate that the proactive type of motivations does not dominate the reactive one in order to explain the number of invented patents. In particular, a very positive perception of university patenting or a reported willingness to perform patentable research does not lead to more invented patents. Conversely, past patenting experiences seem to matter a lot: academic inventors, who have already experienced successful technology transfer due to patents, are more likely to invent patents. Some slight differences emerge across scientific disciplines.
Our results provide insights for building appropriate managerial tools to give support to scientists and technology transfer offices, which are looking to increase the number of academic patents.

Keywords: University, patent, strategy, technology transfer, academic inventors, motivation.
JEL Classification: O3

1. Introduction

Since the recognition of the university "third mission" of technology transfer, both theoretical and empirical studies on academic entrepreneurship and university patenting have flourished. Lots of paper sketched the profile of scientists who patent or analysed whether patenting activities might have a (positive or negative) impact on the traditional publishing mission of universities (Siegel *et al.*, 2007; Baldini, 2008). But only a limited (though growing) number of them investigate scientists' motivations to patent. However, if policy makers want to increase the number of university patents (what seems to be the case in most developed countries), one needs to understand how scientists perceive and use patents, and what are the motivations of the professors who are performing the research to patent it.

Among existing papers on the topic, Owen-Smith and Powell (2001), Baldini *et al.* (2007) and Figueiredo Moutinho *et al.* (2007) provide some original empirical investigations (on respectively US, Italian and Spanish data) of the factors explaining the faculty members' patenting activity. They show, among others, that scientists tend to balance the benefits of being involved in patenting activities (which mostly stems from reputation effects and less from financial arguments) with the costs of interaction with TTOs. Refining those findings, Baldini (2009) precises that different researchers exposed to different contexts are not uniformly driven by the same motives.

The present paper completes this literature and makes a contribution to the analysis of motivations of academic inventors by distinguishing between proactive and reactive motivations to patent. Indeed, so far, empirical studies mostly assume (rather than providing actual tests on this assumption) that academic inventors who patent are interested in patenting and that scientists who are not stimulated by patents choose not to use this instrument. Conspicuously absent from this literature is the idea that some academic inventors might invent patent without actively wanting to do so. This paper is an initial attempt to fill that void. We distinguish scientists according to two types of motivations: First, those who perceive and use patents as a proactive and offensive strategic tool to deliberately improve their forthcoming (economic and scientific) situation; Second, those who adopt patenting strategies in a reactive and defensive way, as an opportunistic answer to external constraints.

Indeed, scientists are not equally comfortable with the development of entrepreneurial universities. This is maybe linked to the fact that most scientists are not similarly educated about the stakes of patenting activities (Stephan, 2004). Consequently some of them are rather patent enthusiastic and others are more reluctant, but nevertheless constrained to adopt this new way of research valorization because of the generalization of patents in science, but also because they are stimulated to do so by new university policies (For instance, the Bayh-Dole Act passed in 1980 in the US and the "Loi Guillaume sur la recherche et l'innovation" passed in 1999 in France put a strong emphasis on patenting academic research). In such an environment some scientists might adopt patenting activity, backwards, to adapt and cope with this new working context.

Having drawn a distinction between offensive (or proactive) motivations to patent and defensive (or reactive) ones, our research question then consists in investigating, first whether proactive motivations dominate reactive ones in order to explain the number of invented patents (the offensive type of motivations being positively linked to the number of invented patents but not reactive ones), and second whether there exists significant differences of behaviors between life science disciplines and electronics and engineering sciences.

These are neglected but important research questions. Improving our knowledge on the origins of patenting behaviors among the academic community may be quite useful to design appropriate incentives to catalyse the three complementary missions of university simultaneously. Indeed, understanding whether scientists do (or don't) choose to disclose knowledge through patents could provide insights for building appropriate (differentiated?) managerial tools to give support to scientists involved in a patent application either by interest or by constraint: For instance, if patent enthusiastic scientists are the more patent active ones, stimulating patenting activity within the scientific community would go through an active communication campaign so as to convince patent reluctant researchers about the advantages of such a knowledge diffusion tool. If, on the contrary, remaining patent reluctant does not impede knowledge disclosure through patents, then the stress should be put on TTOs, which should act in a proactive way and regularly come and visit scientists in their labs in order to detect potentially patentable results and to start the patent application process on behalf of the scientists.

Our empirical study is based on a survey administered in spring 2008 to French academic professors who are also inventors of at least one European patent. Through this survey (detailed in Pénin, 2010) we collected in depth personal and professional information on 173 academic inventors, including their opinions and motivations for patenting. We indeed directly questioned scientists to assess their perception and use of patent so as to better understand their more or less active involvement in patenting activities.

We run an econometric analysis of the determinants of the number of patent invented by scientists, distinguishing between two main types of potential underlying motivations (offensive versus defensive) and two scientific disciplines (life sciences and engineering sciences). Our econometric results indicate that the proactive type of motivations does not dominate the reactive one in order to explain the number of invented patents. In particular, a very positive perception of university patenting or a reported willingness to do patentable research does not lead to more numerous patent inventions. Conversely, past patenting experiences seem to matter a lot. Academic inventors who have already experienced successful technology transfer due to patents, for instance, are more likely to invent patents. Lastly, differences between the behaviors in life science and in electronics and engineering exist.

The rest of the paper is organized as follows. Section 2 reviews the existing literature on the determinants of academic patenting activity at university 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. Why academic scientists chose to patent? Theory and hypotheses

The literature on the motivations of academic inventors unanimously suggests that patenting determinants are of various natures. Baldini (2009) distinguishes between intrinsic and extrinsic motivations, the first ones dealing with scientists' individual perception on this activity, whereas the second are provided by the organisation scientists belong to (through remuneration of a good performance for instance). Figueiredo Moutinho *et al.* (2007) conclude in the same vein that the patenting decision is explained by contextual explanatory factors (disciplinary, organisational, institutional, etc.) and individual explanatory factors (characteristics of the scientist, past behaviours, subjective perception). Refining the organisational influences Renault (2006, p. 229) explains that: "there are three possible institutional influences on university researchers that could explain their decisions to patent. Researchers make choices within the context of constraints imposed by the university. Some constraints are policy-based incentives; others are based on the researcher's discipline. Less understood, however, are the constraints imposed by the norm of the university. Further constraints are also imposed by the individual's capabilities and the *publish or perish* paradigm".

In the present contribution we go one step further, suggesting that sometimes scientists do not have any willingness to patent, but however do patent their result *ex-post*. For instance, in her study on the Swedish case, Schild (2004) explains that: "when asked why they patented, respondents gave two sets of replies [...] those who saw patenting as a necessary evil which went hand-in-hand with the increasing industrial orientation of their work, and those who identified strongly with industrial interests and wanted to patent". This statement is in line with our objective to test whether French scientists have different patenting motivations (offensive versus defensive) and whether patent offensive scientists do hold effectively more patents than their counterparts.

In the two following sections, we therefore detail scientists' motivations to patent by distinguishing two categories: First we consider the motivations which reflect an offensive or proactive patenting behaviour and then we focus on those which rather account for a reactive or defensive patenting behaviour from scientists who are in a sense reluctant to patent but compelled to do so.

2.1 Patenting as an economic and scientific opportunity: The proactive/offensive strategy

The scientists here foresee the advantages of developing an active patenting behaviour. They deliberately choose to engage in this activity with a willingness to gain profits out of this experience. Among the main motives to patent, we find here:

To increase personal earnings

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. 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.

According to the objective function defined above, scientists may hence be interested by patenting their research because it may result into a financial reward for them. There are number

of ways by which it is possible for a scientist to make money out of a patent[1]: Academic inventors may be directly remunerated by royalties or percentage of the sales generated by the patent, and/or indirectly rewarded by additional research funds, better position in the academy, etc.
Therefore, one can expect that academic scientists who grant more importance to immediate earning would be more willing to engage into patenting activities than those with a strong "taste for science" (Levin and Stephan, 1991).

> *H1: Scientists looking for immediate earnings patent more than those primarily motivated by puzzle solving*

This first hypothesis is all the more interesting to test that many empirical studies consider it as too simplistic. For instance, for Lach and Schankerman (2003) the exact impact of the growth of royalties devoted to inventors on those scientists' number of patent disclosures remains unclear. Similarly, Baldini (2009) finds that Italian academic inventors rank personal earning as their last motivation to patent (the second one being the opportunity to get support for the research).

Faith in "entrepreneurial science"

Another motive for scientists to apply for patents is the intimate conviction that academic patenting does not have any negative effect on science or may even have a positive impact. In the literature and in the public opinion, university patenting is seen as a threat to scientific progress due to its potential restrictions on sharing and using new knowledge (Baldini, 2008). "Academic capitalism" (Slaughter *et al.*, 1997) emphasizes intellectual property rights and the additional wealth reached through the commercialization of results, whereas open science builds upon the communism of intellectual property. Owen-Smith and Powell (2001) confirm that many faculty members worry about a possible loss of openness and knowledge dissemination. On the contrary, Etzlowitz (2000) assumes that entrepreneurial activities will bring new opportunities and autonomy to universities. Finally, as shown by Roach and Sauermann (2010) all scientists do not believe the same way, some of them being less worried by the potential negative consequences of patents, or being more comfortable in taking up simultaneously their academic identity with their "commercial persona" (Jain *et al.*, 2009). In such a context, we expect that:

> *H2: Scientists who do not see any contradiction between the rules of science and exclusion through patents, i.e. which adopt a positive attitude towards academic capitalism invent more patents than their less patent-enthusiastic counterparts*

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[1] For instance, in the case of France, it has been 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.

Among those researchers who do believe in the promises of more entrepreneurial scientific activities, some may not change their research habits. They may not hesitate to apply for patents when they have the opportunity to do so, but in the same time they may not modify their research agenda in order to be able to apply for more patents. Here, the patent application is in a sense a by-product, a welcome but unexpected outcome of the research performed by the scientist. It is a consequence of the "individual productivity effect" developed by Breschi *et al.* (2004) and according to which, best researchers, who produce more knowledge, are likely to be granted patents and publications at the same time.
However, some researchers may be so patent enthusiastic that they may choose to change their research agenda in order to increase their probability to apply for patents. In this case, the patent application is definitely the outcome of a proactive behavior of the scientist. Our third hypothesis investigates therefore whether or not the scientist's willingness to patent really leads to a more effective patenting activity:

> *H3: Scientists who deliberately choose to orient their research toward patentable areas do invent more patents.*

<u>To renew with past successful experience of technology transfer</u>
Linked to the former hypothesis, the literature also suggests that patent perception is substantially influenced by past experiences in patenting: Researchers who have never been involved in patenting tend to overestimate the costs and problems associated with patent application as compared with those who have already patented (Figueiredo Moutinho, 2007). But the other way round, past patenting activities may 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 and to valorise the competences they developed for their first patent application. For instance, in their paper on the determinants of a scientist's decision to start his/her own company (another entrepreneurial activity that scientists may choose), Krabel and Mueller (2009) confirm that the outcomes of their past activity strongly matters.
Similarly, if past patent applications have not been harmful, scientists may be more willing to patent again. For instance, the literature mostly documents the problem of publication delay induced by patenting university research (Liebeskind, 2001; Cohen *et al.*, 2002; Pénin, 2010; this problem being even more accurate in Europe, where the US "grace period" does not exist, Franzoni and Scellato, 2010), which might dissuade scientists to repeat their patenting experience. But for researchers who did not experience such delays, the motivations to patent should not be affected. Our fourth hypothesis becomes therefore:

> *H4: Faculty members who have experienced a successful episode of technology transfer due to a patent and/or who have not experienced publication delays due to past patents are more likely to invent patents.*

2.2 Patenting as a necessary evil enforced by the context: The reactive/defensive strategy

The logics that drive reluctant academic inventors to patent is very different from the motives displayed above: Here scientists do patent as a response to the context or to others' (patenting) behaviours. Their patenting activity is less enthusiastic and corresponds to a reaction towards a (eventually bad) past experience. Sometimes it can even be an *ex-post* decision which drives the decision to patent, the scientist being not interested in patenting when performing her research, but discovering at the end of the discovery process that her scientific result is patentable. Here, the main motives to patent are:

To mimic the others and to fit with the institutional context

The patenting culture at work within the lab or the university (i.e. the level of acceptance and support of such activities) might shape the faculty members' choice to patent. Indeed, Carayol (2007) shows that labs characteristics largely affect individual patenting production in universities, whereas Callaert *et al.* (2009) highlight that patenting activities in universities versus engineering/technical schools strongly differ. Bercovitz and Feldman (2003) talk about "observational learning" to account for this influence of the social context in terms of tolerance and support of patenting activities, on scientists' individual decision to disclose knowledge trough patents. Being aware of patenting experiences of colleagues may indeed influence one's own perception of patents, and the priority order that one assigns to the different possible missions and activities. This point is confirmed by a Swedish scientist's verbatim collected by Schild (2004), and according to which "the central importance of patenting was never made explicit to him when he started his job at university, but is something he had gradually grown to realize as he learned how ... fundamental to the economic well-being of his department it was". Finally, if most of the time scientists are free to choose their scientific contest, more or less explicit rules developed within their organization might influence their decision to patent. So we test the following hypothesis:

> *H5: Belonging to actively and systematically patenting labs leads a scientist to become more patent productive*

To acquire bargaining power and to secure freedom to operate

An important illustration of defensive and reactive patenting motivation is when a scientist decides to patent its research in order to protect himself from external threats. It is often argued that a bad past experience linked, for instance with difficulties in the interaction and communication with technology transfer offices, may deter scientists to be involved again in patenting activities (Owen-Smith and Powell, 2001). However, we also believe that scientists can be confronted to other painful situations, which on the contrary may stimulate them to patent by their own. For instance, researchers who may have been blocked in their own research by an existing patent in the past may be forced to realize the importance of patents as a defensive tool (Kingston, 2001), which in turn may induce them to patent more. Yancey and Stewart (2007) hence reports "regular infringement of patents by university researchers", what might lead to patent litigation problems. In such a conflicting context, patenting one's research might be seen as an appropriate defensive strategy to develop the researcher's bargaining power and to secure its freedom to operate. Thus we investigate whether:

> *H6: Researchers who have already been confronted to legal problem generated by an existing patent are more inclined to patent*

Moreover, we expect this hypothesis to be more particularly relevant in sectors where the technology is "complex" (ie based on multiple patents as it is the case in electronics for instance) than in sectors where the technology is "simple" (ie when one technology leads to one unique patent and a unique product, as it is the case in pharmaceuticals). It is indeed well-known in the literature that defensive patenting strategies are linked to complex technologies where freedom to operate may not be granted by the patent right (Kingston, 2001) [2].

To summarize, we have argued here that some of the determinants that affect scientists' decision to apply for patents refer to intrinsic motivations of the researchers (who may be more or less patent enthusiastic), whereas others rather suggest that those decisions are guided by the context surrounding scientific activity (and that in this case the decision to patent may be more a reactive than a proactive one). In the next section we present the methodology and original dataset we use to test whether or not the motivations to patent affect the number of invented patents.

3. Research methodology

3.1 The sample

Our analysis focuses on the behaviours of French academic inventors, i.e. tenured university (associate and full) 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 (according to the methodology developed in Lissoni *et al.*, 2007). The name-matching between tenured university professors and inventors leads us to identify 1228 confirmed French academic inventors, i.e. people that confirmed us in case of doubt (due to homonymy problems for instance) that they are both university professors and inventors of a European patent. We then sent a questionnaire to all of those confirmed French academic inventors during Spring 2008. The questionnaire was divided into three parts: In a first section we collected individual information such as age, gender, status, etc. Then we focused on scientists' motives to patent. In the third part we questioned academic inventors on their past experiences with patents. A preliminary version of the questionnaire has been sent to three faculty members of our institution[3], as a pilot test, to improve its content.

Data collection ended with a total number of 269 complete questionnaires and 11 incomplete ones, i.e. with a response rate higher than 20%. Our analysis is focused on a final sample of 173 respondents, corresponding to complete questionnaires in life sciences (95 answers) and engineering sciences (78 answers) exclusively.

We decided to focus on life sciences (medical sciences, biotechnologies and pharmaceuticals and drugs) versus electronics and engineering because the literature suggests that patenting behaviors in those sectors exhibit significant differences. As emphasized in section 2, inquiries on firms' patenting behaviors usually highlight that the primary motive to patent in life sciences is of offensive nature (to exclude other firms), whereas in electronics patents are used in a more defensive way (to prevent being excluded). Our work thus aims at investigating whether such differentiated behaviors remain valid in the case of academic patents, and at analyzing the consequences of offensive versus defensive motivations on patent production. Moreover, the area

[2] According to Kingston: "[in complex technologies] The motivation for their extensive use of patents is therefore quite different from that of firms in simple technologies. In the latter, the emphasis may be said to be primarily offensive (to prevent others from *using* the invention); in complex technologies it is primarily defensive (to avoid being *denied* the use of an invention)." (Kingston, 2001, p. 408)

[3] The questionnaire is available on request to the authors.

of biotechnology and pharmaceuticals tends to be an area of extremely high university patenting activity in many countries (see Geuna and Nesta, 2006 for European data) and Renault (2006) explains that life sciences, pharmaceuticals and biotechnologies, are substantially more entrepreneurial–oriented: “Life sciences have been more supportive of entrepreneurial behavior over the past 20 years compared to engineering” (p. 230). All those reasons motivate our idea to compare the rationales to patent in life sciences versus in engineering and electronics.

Table 3.1 gives the profiles of the 173 respondents and of the French population of academic inventors according to their age, gender, academic position and scientific disciplines.

Table 3.1: Profiles of French academic inventors in life sciences, engineering sciences and electronics

Characteristics		% in the sample	% in the surveyed population
Age	30-40	16	8
	40-50	34	31
	50-60	32	27
	60-70	17	28
	More than 70	1	6
Gender	Male	90	90
	Female	10	10
Academic position	MCF	43	36
	PU	57	64
Scientific discipline	Life sciences	56	61
	Electronics and engineering	44	39

The comparison between the whole population of confirmed French academic inventors and the respondents does not exhibit major significant differences (Pénin, 2010; Chi2 difference test results being not provided here but available on request). Most of our respondents are male (90%), University professors (57%) and over 40 years old (84% of the respondents is more that 40 years old).

At this stage; we want to stress the fact that personal information on academic inventors have only been collected once even if some scientists have invented several patents on the period. Indeed, when testing our questionnaire on academic inventors holding several patents, we notice they have difficulties in remembering the different situations they faced for each patent they have been involved in. Thus, we choose to simplify our questionnaire and to collect information once per inventor rather than every times an inventor has developed a patent. Yet, according to the study conducted by Renault (2006 p. 233) on US data, “most of the professors indicated that their attitude about academic capitalism had remained constant throughout their career”, meaning that our data, even if not longitudinal ones, do not generate to much bias, perceptions and behaviors remaining quite stable through time.

3.2 Description of the variables

To test the different hypotheses presented in section 2, we mainly rely on information collected through the survey described above. Overall, we use twelve explanatory variables, all displayed and described in Table 3.2, in order to explain the number of invented patents (the dependent variable).

Dependent variable

We proxy the outcome of researchers' patenting activity by the number of patents they have invented on the period of study (PATENT). We construct this dependent variable by taking all the EPO patents invented by each faculty member between 1993 and 2005. As shown in Table 3.2 the production of patents by academic inventors in our sample ranges from 1 to 22 with a standard deviation of 2.56, testifying a huge behavioral diversity, which we ambition to explain more deeply.

As usually done in this case, we estimate our econometric model of the determinants of patent number, by relying on count data models and more precisely on a negative binomial specification. A zero inflated model is not relevant here since we do only consider academic inventors, i.e. scientists who have already invented at least one patent.

Independent variables

- Proactive strategy

To test the importance of the earning motivation on patent production, we use 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 (MONEY). It provides an indicator (on a five point Likert-scale) of the importance that academic inventors grant to immediate earnings as opposed to other motivations, such as reputation or scientific curiosity. We can see, that on average, academic inventors of the sample do not consider the increase of immediate earning as an important motivation to patent (mean= 0.9). But again the dispersion of answers is rather important (standard deviation= 1.45)
Similarly, we measure the scientist's individual attitude toward "academic capitalism" by using the answers to the following question of the survey: "Do you believe that university patenting 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"? (Again respondents had to answer on a five point Likert scale). The answer to this question reflects the scientist's enthusiasm towards university patent and allows us to distinguish between patent enthusiastic and patent reluctant-but compelled-to-patent scientists. More precisely, our variable PAT_ENTHUS equals 0 if respondents strongly disagree with the proposed statement and equals 5 if they strongly agree. If, on average scientists rather disagree (mean= 1.6), some of them however clearly see patent as a threat for the Republic of science (even if they do patent!), as shown by the maximum value of the variable. Note that, if our hypothesis 2 holds, the sign of this variable should be negative.
Furthermore, to test hypothesis 3, i.e. whether or not researchers who patent the most are those who deliberately orient their research towards patentable areas, we rely on the answers given to the following question: "Does the possibility to be granted patents influence the nature of your

research? (only one possible answer)". 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". We thus built a dichotomised independent variable (WILLING) based on the answers provided. This variable scores 1 if the inventor acknowledges orienting her research towards patentable areas and 0 otherwise. Only, 18% of the respondents answered "yes" suggesting that patenting is a rather reactive strategy in the sense that the scientists do not deliberately modify their behavior so as to be able to patent their research but rather realize *ex-post* that their results are patentable and thus start writing a patent application.
Finally, two questions in the questionnaire account for the fact that the respondent may have experienced a successful case of technology transfer or, on the contrary a frustrating case of publication delay. The two exact questions were: "Have you already experienced a successful episode of technology transfer (commercialization or industrialization of an invention) directly due to academic patenting?" and "Have you experienced a case of publication delay directly attributable to a past patent application? (and if yes, what was the length of this delay)". Answers to those two questions enabled us to create two variables: One dummy which scores 1 if the scientist reports a successful experience of technology transfer (GOOD_EXP). A second variable which takes a value between 0 and 4 according to the length of the reported publication delay (PUB_DELAY). We can notice that only one third of the respondents in the sample have been confronted to a positive experience of technology transfer directly attributable to patent. The average publication delay they have to suffer from is between 6 month and a year.

- Reactive strategy

To test the mimetic assumption according to which an academic scientist is more actively involved in patenting activities if other members of her lab do patent, we question the inventors on the patent policy adopted within the lab they belong to (LAB-POL). If respondents declare that their laboratory is involved in a policy of systematic patenting of research, the variable scores 1, if not, the variable scores 0. Here, 35% of the collected responses are positive.
Similarly, we test hypothesis 6, which posits that scientists' patenting activity comes in reaction to previous disappointing experiences they had with respect to others' patents by using two variables built on two questions of our survey. The first question was: "Has the scientist already been involved in a patent litigation?" If yes, PAT_LITI variable scores 1. The second was: "has he/she already been obliged to reorient its research due to the risk of patent infringement?" If it is the case, BLOCK_PAT scores 1. Only a limited number of the inventors in our sample have been confronted to such negative consequences of patenting, as testified by the average value of both variables (0.12 and 0.26 respectively).

<u>Control variables</u>

We use several control variables in order to isolate as precisely as possible the influence of each above variables. First we control for age and gender. Note that according to the literature we expect that female scientists patent less than their male counterparts (Breschi *et al.* 2005; Thursby and Thursby, 2005; Bunker et al., 2005) and that the age of scientists should play positively on the number of invented patents (Levin and Stephan, 1991; Thursby *et al.*, 2007).

Table 3.2: Descriptive statistics of the variables (dependent and independent ones)

Name	Type	Minimum	Maximum	Average	Standard deviation
PATENT	Integer=number of EPO patents invented by the researcher between 1993 and 2005.	1	22	2.30	2.56
MONEY	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	0.90	1.45
PAT ENTHUS	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	1.6	1.41
WILLING	Dummy; 1= researcher acknowledges that he tries to orient its research in fields where he knows it will be possible to apply for patents	0	1	0.18	0.39
GOOD-EXP	Dummy, 1=researcher has already experienced technology transfer (commercialization or industrialization of an invention) directly due to academic patenting	0	1	0.33	0.47
PUB DELAY	Integer={0,1,2,3,4}, according to whether or not researcher has experienced a delay in the publication of its research directly attributable to a patent. 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	1,85	1.28
LAB POL	Dummy, 1=researcher's lab has a policy of systematic patent application	0	1	0.35	0.47
PAT LITI	Dummy, 1= researcher has already been involved in a patent litigation	0	1	0.12	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	0.26	0.44
AGE	Integer={1,2,3,4,5}, 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	2.25	0.99
GENDER	Dummy, 1= male	0	1	0.90	0.29
SCI-EXC	Integer= number of past publications SCI before 2005	0	155	17.13	22.28
SCIENTIFIC DISCIP.	Dummy for technological field: {life sciences or engineering sciences},	See Table 3.1			

We also include disciplines dummies, since scientific field might significantly influence the propensity to patent (Stephan *et al.*, 2007). Indeed, scientific and technological domains are characterized by diverse levels of patenting opportunities and by heterogeneous strategic values associated to patenting (Griliches, 1990), as the gap between academic research and industrial applications and the effectiveness of patents as means of protecting inventions strongly vary

(Schild, 2004). Concretely, we include an indicator of scientific disciplines of the researchers (and not of industrial sectors of the patents) based on the disciplinary classification of each scientist's official position (French CNU classification). Life sciences scores one if the scientific discipline of the faculty is one of the following ones: medical sciences, biotechnologies and pharmaceuticals and drugs. Engineering sciences scores one if the scientist's discipline is either electronics or engineering sciences.

Third, we control for the scientific performance of the researcher. The SCI-EXC variable accounts for the scientific excellence of academic inventors, which is proxied using ISI web of science. We collected all the publications of the Science Citation Index attributable to each of the surveyed scientists (until 2005). This publication variable is a classical indicator of scientific excellence. It ranges between 0 and 155, with an average of 17.13, suggesting that patenting scientists are not similar in terms of publishing activity. In line with previous studies, we clearly expect the sign of SCI-EXC to be positive. Most studies indeed find that researchers and labs who patent the most are also those who publish the most (Thursby and Thursby, 2002; Breschi *et al.*, 2005; Van Looy *et al.*, 2006; Carayol, 2007; Stephan *et al.*, 2007; Buenstorf, 2009)

4. Results and analysis

The results of the three negative binomial regressions (on the whole population of 173 academic inventors, in life sciences exclusively and in the subsample of electronics and engineering sciences) are displayed in Table 4.1, 4.2 and 4.3 respectively.

Table 4.1 The effects of proactive versus reactive motivations on the number of academic patents (n= 173)

Independent variables	Dependant variable: PATENT	
	Coefficient	Standard error
Offensive and proactive variables		
MONEY	0,05	0,039
PAT ENTHUS	-0,043	0,045
WILLING	0,19	0,15
GOOD-EXP	**0,259 (**)**	**0,124**
PUB_DELAY	-0,071	0,048
Defensive and reactive variables		
LAB POL	0,164	0,131
PAT LITI	**0,465 (***)**	**0,156**
BLOCK PAT	**0,322 (**)**	**0,131**
Control variables		
SCI-EXC	**0,005 (**)**	**0,002**
Dummy_Life sciences	-0,186	0,131
AGE	**0,303 (***)**	**0,065**
GENDER	0,233	0,256
Constant	-0,467	0,285

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

First of all, one can mention that many of the dependant variables are not significant, which is likely to come from the small size of our sample and the large dispersion of variables within the sample. Yet, all the signs are conformed to the expectations made in section 2.

The main result of those three models is that both proactive and reactive motivations matter in order to explain the number of invented patents. No strategy clearly dominates the other. To put it differently, offensive and proactive motivations are not more decisive than defensive and reactive ones to explain the number of invented patents. Scientists who do believe that university patenting does not undermine the norms of open science and/or who deliberately engage into patentable research area, are not more patent prolific (as testified by the lack of significance of their respective coefficients). A noticeable exception however is the sub-sample of life sciences, where the willingness to orient one's research towards patentable areas is positively linked to the number of invented patents (but only at a 10% level). Hence, contrary to what could have been expected, being a patent enthusiastic does not mean being the inventor of more patents. Hypothesis 2 and 3 are not validated by our data.

Similarly, scientists whose main motivation to patent lies in increasing their immediate earning do not invent more patents, thus invalidating hypothesis 1. Indeed, their respective coefficient, although positive never proves significant. This conclusion holds whatever the discipline considered. A possible explanation to this result is that scientists motivated primarily by money might focus on the development of a limited number of high potential patents (those of better quality which protect key technologies) rather than on multiplying the number of patent they invent. It is indeed well-known that the distribution of patent revenue is highly skewed with only a few numbers of patents yielding important revenue.

If the faith in the entrepreneurial science does not explain the number of invented patents, it is not the case for past patenting experience, which seems to matter a lot. For instance, researchers who have already experienced a successful technology transfer due to a patent tend to invent more patents (as shown by the positive and significant coefficient of GOOD-EXP variable). Similarly, researchers who have already been blocked in their past research by a patent held by a tierce individual or organization tend to patent more (see the BLOCK-PAT negative and significant coefficient). Hence hypothesis 4 (for its first part) and 6 do hold. The first result tends to support the importance of offensive motivations. Researchers perceive the worth of patents to disclose knowledge and hence tend to patent more. Conversely, the second result rather supports reactive and defensive motivations to patent. By having experienced a blockage in the past researchers realize the importance of patents to secure freedom to operate and then tend to invent more of them.

Furthermore, in both the general and life sciences cases, a past experience of patent litigation is positively correlated to the number of invented patents. Again, this result suggests that reactive motivations do matter to explain the number of invented patents. Scientists who have been involved in past litigations do measure the economic and technological power of patents and are thus more patent active. On the contrary, it is interesting to notice that past publication delays due to patent application do not systematically reduce academic patenting activities, as testified by the lack of significance of PUB-DELAY variable, thus invalidating the second part of hypothesis 4.

It is also worth to stress that the patenting policy of the lab is not significantly correlated with the number of invented patents (even though the sign is positive). This clearly invalidates hypothesis 5. Scientists who work in departments with an intense and systematic patenting policy are not more patent prolific. The stimulating collective dynamics we hypothesize is not verified.

With respect to control variables, scientific excellence and the age of the scientist do positively and significantly influence their number of patents. Those two results are in line with most empirical results in the literature which tend to show that more prolific researchers (the one who publish the most) are also the more prolific inventors (the one who patent the most). Note that the positive sign of age is somehow spurious because we do not have panel data. Consequently it is obvious to find that, *ceteris paribus*, older scientists have accumulated more patents than younger ones.

The second idea of this paper was to compare the situation in life science disciplines and electronics and engineering ones. We have indeed seen in sections 2 and 3 that it is frequent in the patent literature to put in opposition simple technologies (like in the pharmaceutical sectors) in which patents are used in an offensive way, with complex technologies (like electronics) in which patents are used primarily in a defensive way. Consequently, we expect to find defensive and reactive patenting behaviours as being more important in electronics and engineering than in life science.

Table 4.2 The effects of proactive versus reactive motivations on the number of patents in Life sciences (n= 95)

Independent variables	**Dependent variable : PATENT**	
	Coefficient	**Standard error**
Offensive and proactive variables		
MONEY	0,058	0,047
PAT ENTHUS	-0,056	0,062
WILLING	**0,366 (*)**	**0,211**
GOOD-EXP	0,005	0,167
PUB_DELAY	-0,039	0,064
Defensive and reactive variables		
LAB POL	0,243	0,168
PAT LITI	**0,693 (***)**	**0,203**
BLOCK PAT	**0,318 (*)**	**0,174**
Control variables		
SCI-EXC	0,004	0,002
AGE	**0,354 (***)**	**0,093**
GENDER	0,486	0,344
Constant	**-1,08 (***)**	**0,368**

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

What we found is that those two disciplines differ on several points. First, the willingness to patent matters to explain scientists' patent production level in life sciences, which is not the case in engineering sciences. Hence, we observe that in life sciences, more substantial responsibility falls upon the scientists themselves, as catalyzing patenting activities require patent willing professors. Second, the experience of a positive technology transfer does matter in electronics and engineering but not in life sciences. This seems to confirm Jensen et al. (2003) and Thursby and Thursby (2003) according to which TTO’s support (to guarantee a first exciting patenting experience) is mostly useful for scientists who are not very much motivated by entrepreneurial activities (in our case, in engineering sciences).

Regarding the patent litigation variable, it also positively and significantly correlated to the number of invented patents for life sciences but not for electronics and engineering., Yet, those differences do not enable to conclude whether or not proactive or reactive motivations dominate in one case and not in the other, but show that patent motives have differentiated impacts on academic patent production in those two disciplines. Stimulating patenting activities in those two disciplines would thus require different managerial tools.

Table 4.3 The effects of proactive versus reactive motivations on the number of patents in electronics and engineering sciences (n=78)

Independent variables	**Dependant variable : PATENT**	
	Coefficient	**Standard error**
Offensive and proactive variables		
MONEY	0,029	0,068
PAT ENTHUS	-0,035	0,067
WILLING	0,177	0,221
GOOD-EXP	**0,513 (***)**	**0,178**
PUB_DELAY	-0,112	0,0715
Defensive and reactive variables		
LAB POL	-0,107	0,225
PAT LITI	0,12	0,277
BLOCK PAT	**0,400 (**)**	**0,198**
Control variables		
SCI-EXC	0,005	0,008
AGE	**0,244 (***)**	**0,088**
GENDER	-0,087	0,389
Constant	0,075	0,46

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

5. Conclusion

- Theoretical contributions

This paper focused on academic inventors’ motivations to invent patent and on the consequences of different set of motivations on the scientist’s patenting performance. Our main originality lies in distinguishing between two types of motivations to patents: Proactive strategies where the scientists clearly perceive the benefits of patenting activities and thus are actively looking for patents; and reactive strategies where scientists are rather involved in patenting activities as a defensive reaction to their environment. We empirically explored whether or not those two sets of motivations influence the number of invented patents, i.e. whether offensive and proactive type of motivations do lead to more patent production. To do so, we relied on extensive survey data about 173 French academic inventors.

Our main result is that neither proactive nor reactive types of motivations seem to dominate in the explanation of the number of invented patents. In particular, scientists who believe in the entrepreneurial science and/or who are primarily motivated by immediate earnings are not more likely to invent patents. On the other hand, past experience seems to matter a lot to explain the number of invented patents (especially in the engineering sciences). Academic inventors who report a past successful technology transfer due to patents and/or who have already been obliged to reorient their research in order to get round a patent held by a tierce do invent more numerous patents. In life sciences, a past experience of patent litigation also triggers the decision to patent.
Regarding the willingness of scientists to orient their research towards patentable area, it is not correlated to the number of invented patents (except in life sciences). In other words, scientists who patent are not systemically more inclined to select more patentable research areas. This suggests that in many cases patents are often by-products of research activity rather than a specific objective that scientists want to address. Scientists apply for patent since their research area offers patenting opportunities not because they are actively looking for it.
Lastly, prolific patent inventors are also prolific researchers, and the patenting policy of their respective research lab does not significantly influence the number of invented patents.

Finally, there is no straightforward relationship between the nature of the motivation to patent and the effective number of patents invented by a given scientist, suggesting that several managerial tools might be developed to catalyze French scientists' patent production.

- Managerial implications

As being patent enthusiastic and patent willing does not systematically increase the number of invented patents, we assume that improving the communication around patent at university and advertising the advantages of such an activity for scientists (so as to reconcile them with patent) do not seem to be required. In line with this is the finding that prolific patent inventors are also prolific researchers. This suggests that favoring patent application and technology transfer does not imply to hire new profiles of competences. The traditional high publishing profiles are compatible with the newly required ones (high technology transfer potential), even when the former are not particularly interested in disclosing knowledge through patents.
Moreover, the non-significant role played by the lab policy suggests that to encourage patent applications the focus (of the incentives) should be put on the scientist himself rather than on her institution. Sponsoring actively patenting labs would not guarantee an increase of the patenting activity of scientists within those labs.
On the contrary, by showing that reactive patenting strategies are really effective ones and that past experience in patenting matters, we believe that TTO activities are the cornerstone of academic patenting activities in France. Indeed, what seems fundamental is the quality of past experience, meaning that most of the resources should be concentrated on helping scientists during their first application, and limiting their potentially bad experiences either with competitors or with TTO members. To do so TTO should think about recruiting scientists among their teams, so as to ease the creation of shared knowledge code books among faculty members and TTO patent project managers. Finally, we confirm the idea developed by Meyer et al (2005) according to which in European universities, which are too recently involved in entrepreneurial

activities, the effectiveness of introducing incentive schemes is limited when support structures are missing or do not possess the required skills.

- To go further

Additional work is still needed. Indeed, the present paper was mostly focused on motivations to patent and did not account for the costs associated to patenting activity, despite Owen-Smith and Powell (2001), among others, clearly demonstrated that negative perceptions of the costs can offset the scientists' willingness to patent and finally limit their effective patenting activity. Moreover, we only collected data and opinions of faculty who have a patenting experience as inventors. We lack a control sample in which we would have information on scientists with no experience in patenting activities. Panel data could also be quite useful to limit endogeneity problems. Indeed, with the current dataset the dependent variable we use might explain some of the independent variables (and notably those related to past patenting experiences), what makes our conclusions more fragile. Unfortunately such longitudinal data are rather difficult to collect.
It may also 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 in turn influences the motivations to engage into patentable activities.
Last, but not least, more theoretical and empirical research is still required to explore the consequences of patenting university research on social welfare. Indeed, we do not discuss here this normative point. Our managerial recommendations assume that policy makers and TTOs managers want to increase the number of patents invented by university. This assumption seems to be in line with the current context. Yet, it is still unclear whether or not this trend towards a systematic patenting of university research is desirable.

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