Centre Emile Bernheim
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From Science to License: an exploratory analysis of the value of academic patents

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JEL Classifications: L240, M130, O330, O340
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From Science to License:
an exploratory analysis of the value of academic patents

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ABSTRACT:

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The paper stresses also the importance of collaboration between public and corporate research teams in order to get patent licensed. It pleads for a better management and valorisation scheme of patents co-applied for by many academic assignees and draws attention on the need to focus on academic researchers with a high scientific profile in terms of publications in order to crystallize their tacit knowledge into valuable patents.

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1. Introduction

In 2006, universities around the world claimed more than EPO 2500 patent applications, representing more than 2% of the volume of the patents yearly applied at the EPO[1].

This increasing interest for protecting ideas at university has been the origin of a growing literature looking to the causes and consequences of this higher propensity of the universities to patent academic inventions. As a result of this new phenomenon, many questions have been raised by scholars. Among them, we might cite the impact of academic research on industry (see for example Jaffe 1989; Mansfield, 1991, 1995; Mansfield and Lee, 1996; Narin *et al.*, 1997; McMillan *et al.*, 2000), the management of technology transfer (E.g. : Siegel *et al.*, 2003a, 2003b, 2003c and 2004), the danger of putting at risk present and future innovation by endangering the two first missions of university (Eg: Sampat, 2004; Calderini and Franzoni, 2004; David, 2000; Nelson 2004; Thursby *et al.*, 2005)

Other authors finally have analysed if the new increase witnesses a higher propensity to patent inventions of lower quality or value. They have been wondering why academia should take part to the patenting game when it is known that only a few patents are really valuable and induce large licensing incomes. (Henderson *et al.*, 1998; Mowery *et al.,* 2002; Mowery and Ziedonis, 2002; Sampat *et al.,* 2003).

As a mater of fact, universities are more and more eager to protect their inventions, to license their patents (ex.: Thursby and Thursby, 2000, 2003a, 2003b and 2004; Bercovitz *et al.*, 2001; Thursby and Kemp, 2002 ; Jensen *et al.*, 2003; Sine *et al.*, 2003; Jensen and Thursby, 2001 and 2004) and to create spin-offs to exploit their patented sciences (Ex: Meyer, 2004 and 2006a; Shane, 2004a and 2004b; Lerner, 2005 ; O'Shea *et al.*, 2005). But the distribution of patent value is highly skewed (Scherer and Harhoff, 2000; Scherer *et al.,* 2000): only few academic inventions are really valuable. This statement pleads for a better understanding of value indicators.

This paper intends to contribute to the literature analysing the value of patent with a special attention to academic inventions. Based on the burgeoning stream of economic research that attempts to identify the determinants of patent value (Eg: Harhoff *et al.*, 1999; Lanjouw and Schankerman, 1999; Reitzig, 2004; Hall *et al.*, 2005), this paper analyses the value of the Belgian academic patent families applied at the European Patent Office between 1985 and 2003. Using license agreements to existing companies or to spin-offs, this paper investigates which patent characteristics determine the probability to get a technology licensed or spun-out.

The paper is structured as follows. Section 2 sums up the existing literature on patent value and sets the theoretical frame. Section 3 presents the databases and some descriptive statistics Section 4 describes the models to be implemented and leads to the results of section 5 and 6. The last section concludes and provides some policy implications.

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[1] At the USPTO, some 3000 patents were granted to universities representing also some 2% of the number of USPTO patents.

2. The literature on patent value

2.1. The value proxies

Scholars have put forward many different empirical strategies to approach the value of a patent.[2] To approximate the patent value, some authors have identified the monetary value of each patent (Harhoff *et al.,* 1999 and 2003) or the present value evaluated by experts on a value scale (Reitzig, 2003). Some others have relied on forward patent citations (e.g., Lerner, 1994; Sapsalis and van Pottelsberghe, 2007a), on a composite indicator (Lanjouw and Schankerman, 1999), on the probability to get a patent granted (Guellec and van Pottelsberghe, 2000 and 2002), on patent opposition and renewal data (Pakes and Simpson, 1989; Lanjouw *et al.* 1996; Lanjouw and Schankerman, 1997; Lanjouw, 1998; Harhoff and Rietzig, 2004; Maurseth, 2005), on requests for accelerated examination process by the applicant (Reitzig, 2004) and on whether a high-tech start-up has been created or not on the basis of the codified invention (Shane, 2001).

In this paper, we rely on three different measures to assess the quality of an academic patent: the fact that the patent has been licensed; the fact that the patent has been licensed to an existing company or the fact that the patent has been licensed to a spin-off.

The first measure looks if any company has been awarded a license (eg Dechenaux *et al.,* 2003). This measure is presented as the industrial impact of the patent. The fact that a license has been awarded to a company witnesses that the patent is recognised a potential commercial or industrial value by the licensee. However, one has to keep in mind that a licensee is not the guarantee of a commercial success. Indeed, Thursby and Thursby (2003a, 2004) found that 46% of all academic inventions licensed fail. University technologies are early stage inventions and half of university inventions licensed are no more than a proof of concept at the time of license (Thursby *et al.*, 2001). At that stage defining market opportunities is so uncertain that many university inventions have led to applications that were not even foreseen by the licensee or the licensor at the time of license (Shane, 2000). A survey of 62 US universities established that 45 % of the licensed academic inventions are no more than a proof of concept and only 12% are ready-to use technologies. The 72% of the first category face failure (Thursby et al., 2001; Thursby and Thursby, 2003a).

The two last value proxies derivate immediately from the previous variable as particular cases. The second value proxy reflects the fact that a license has been awarded to an existing company (eg Dechenaux *et al.,* 2003). The last value proxy stands for a license granted to a spin-off in order to develop the technology. This measure could be seen as the entrepreneurial impact of the academic patenting system as the patented technology supports the creation of a new venture. (Eg: Shane 2001, 2002a, 2002b)

2.2. The value determinants

In the literature, many determinants, indicators and explanatory variables have been introduced to explain the value of patent. Reitzig (2003) for instance relies on variables like the importance of the patent for current and future technical developments; the difficulty to invent around the patent and to prove its infringement; the learning value for competitors, the number of competitor and the fact that the patent is a base for further patent applications.

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[2] See Sapsalis and van Pottelsberghe (2007a) and Reitzig (2004) for a comprehensive survey of the literature on the determinants of patent value.

The strategy of this paper is to analyse the characteristics of the patented invention to see if any has an impact on the patent value[3]. To analyse an invention, patent documents are exceptionally rich source of information. They do not only list the characteristics of the invention like who is claiming the invention and what is claimed but they also define the scientific and technological context in which the patent evolves.

Based on the literature, we regroup the information that can be collected in a patent in five categories: the technology impact of the patent; the scientific and technological background on which the patent relies; the strength of the IP protection and the ownership scheme on which it was developed. Figure 1 illustrates in a glance the different classes and the indicators on which they rely. Most indicators reflect a broad source of knowledge. To some extent, indicators based on forward patent citations approximate how important the given patent is for subsequent patents. Proxies constructed with non patent citations estimate the scientific base of an invention. Measures built on backward patent citations reveal the technological background of an invention. Ownership indicators measure the extent to which different people and organisations have merged their knowledge into a single research project. And finally, IP protection characteristics witness the geographical and technical broadness of the protection.

2.2.1. Technological impact

The number of forward patent citations - the number of citations received by subsequent patents - can be seen as the technological impact or value of a patent (Eg: Jaffe *et al.*, 1998; Jaffe *et al.*, 2000; Hall *et al.*, 2001; Duguet and MacGarvie, 2005; Gay *et al.*, 2005). Citations can appear as the technological background/state of the art of a subsequent patent.
When not used as a dependent variable, the number of forward patent citations has been largely identified as an important value indicator. Lanjouw and Schankerman (1999) develop a composite quality index significantly related to the decisions to renewal and to oppositions and point out that the number of forward patent citations was an important determinant of renewal decisions. Looking to the Computed Tomography scanners, Trajtenberg (1990) finds a close correlation between indicators based on forward patent citations and independent measures of the social value of innovation in that field. Among others, Carpenter et al. (1981), Albert et al. (1991), Harhoff *et al.*(1999), Hall *et al.*(2000), Shane (2001), Betran (2005) support that forward patent citations are an indicator of technically, industrially, commercially and entrepreneurially important patents. Comparing academic and corporate patents, Trajtenberg *et al.* (1997) develop other forward-looking measures analysing the basicness of a patent like the generality (based on the proportion of received citations out of patent classes claimed in the cited patent), the appropriability (the number of self citations) and other distance measures.

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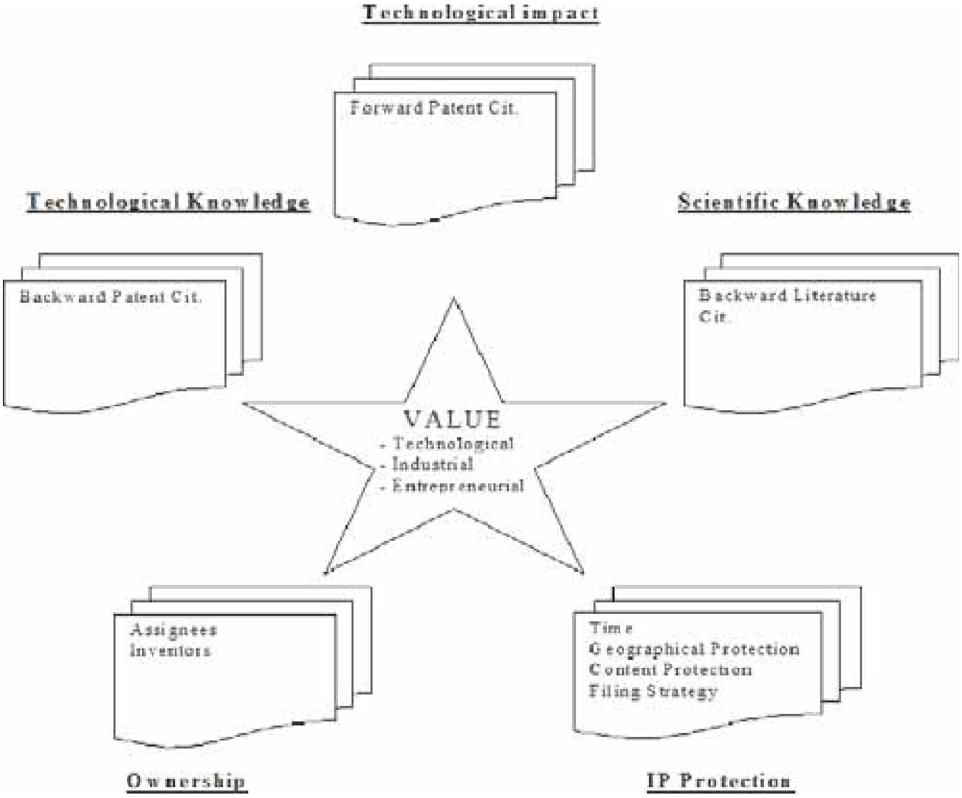
[3] This strategy is based on the fact that academic inventions are early stage technologies and the final market is often unknown. The companies that are bidding on a particular technology are particularly interested in the nature of the technology and then in the market characteristics (Thursby et al. 2001). However some companies are reluctant to license academic inventions because they are too embryonic (Thursby and Thursby, 2001).

Figure 1 : Typology of the patent information as value indicators



2.2.2. Scientific Knowledge

Narin *et al.* (1997) have detailed the increasing linkage between US technology and public science. Their results suggest that valuable information could be extracted from indicators based on non-patent citations (NPC) or citations to the scientific literature. But these indicators have not been used extensively so far. Trajtenberg *et al.* (1997) introduce an indicator measuring the basicness of an invention looking to the proportion of backward science citation on the total of backward citations (technical and scientific). Callaert *et al.* (2006) observe that developing indicators based on non-patent references is relevant to depict the proximity of technological and scientific developments.
However, even stressing that scientific tacit knowledge is important to inventive activity in certain fields; Meyer (2000) argues that non-patent citations hardly represent a direct link between cited paper and citing patent.

Experimental results about the impact of this science proxy vary from one study to another. Analysing a set of German patents applied for in 1977 and fully renewed until 1995, Harhoff *et al.*(2003) establish a significant positive impact of scientific citations on the patents' monetary value but this result could not be confirmed in Harhoff and Reitzig (2004) when analysing biotechnological and pharmaceutical patent renewals. In this context, Sapsalis *et al.* *(*2006, 2007a) have put forward the idea of separating the scientific literature in 2 classes: the first class regrouping the inventors' referenced publications as an indicator of the tacit knowledge and scientific credibility/quality of the inventors' team and the second class regrouping the remaining publications as an indicator of public science limiting the broadness of the patent. Experimenting this idea on 2 different datasets (Belgian academic patents and biotechnological industrial patents), they have identified a positive and significant impact of the self citations on the number of FPC a patent received. Oppositely, a negative and significant effect was found for the non-self citations.

2.2.3. Technological Knowledge

Backward patent citations - the number of former patents cited by the given patent - can be seen as the technological background of the given patent. This indicator has received some substantial empirical validation. Authors (E.g. Lanjouw and Schankerman, 1997 and 1999; Harhoff *et al.,* 2003; Harhoff and Reitzig, 2004) identify the positive effect of the backward patent citations when assessing the quality or the value proxies like the monetary value or quality indexes. However, they show that this indicator – if related to the probability of litigation – was not related to the probability of being renewed. Investigating opposition procedures, Reitzig (2004) computes in addition of the number of backward patent citations, the proportion of share of A- and X- classifications[4] among backward patent citations and finds a significant and positive impact of the number of backward patent citations.

Besides the simple count of the number of patents referenced by the given patents, new indicators based on backward patent citations have been developed.

Investigating the relation between technological opportunities and new firm creation, Shane (2001) finds that radicalness of a patent - a count of three-digit classes in which previous patents cited on the focal patent are found but that the patent itself is not in (Rosenkopf and Nerkar, 2001) - has a positive and significant on the formation of a new high tech start-up. Similarly Nerkar and Shane (2003) support that the radicalness of the academic patents influences the survival of the start-up exploiting them.

Comparing the basicness of corporate and academic patents, besides the count of the first and second generation of backward patent citations, Trajtenberg *et al.* (1997) develop some new backward-looking indicators like originality (based on the proportion of done citations out of patent classes claimed in the citing patent).

Focusing on Belgian academic patents and corporate biotechnological patents, Sapsalis and van Pottelsberghe (2006, 2007a) show the added value of models that disentangle the backward patent citations determinants by introducing the concept of institutional sources of knowledge and the origin of the citation.

2.2.4. Ownership

Indicators based on the number or the characteristics of the inventors and assignees have not been extensively used in the literature. Nevertheless, they can provide interesting information about potential alliance, collaboration (Guellec and van Pottelsberghe, 2001). Sapsalis *et al.* (2006, 2007) show that corporate and academic alliance and collaboration impacts positively the technical value of a patent. Guellec and van Pottelsberghe (2000; 2002) show that cross-

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[4] In an EPO patent, A- backward citations are considered relevant but not innocuous by the preliminary examiners. X-backward citations are considered potentially innocuous by the preliminary examiners.

border ownership of inventions, domestic and international research co-operation and the number of applicants are some of the characteristics that significantly affect the probability of a patent application to be granted.

2.2.5. Patent Protection

Patent are exclusive rights granted for an invention, which is a product or a process that provides a new and inventive way of doing something, or offers a new and inventive technical solution to a problem. But patents do not bid absolute protection, they only guarantee to be allowed to impede the exploitation of your ideas by a third party for a limited period of time and in the countries the patent has been enforced. So under the term “patent protection”, four aspects should be taken into account: the date of priority; the content protection, the geographical protection and the patent strategy.

Time should be taken into account when looking to the value of a patent and its effects differs from the used value indicator. For example, younger patents are expected to be less cited. Dechenaux *et al.* (2003) analyse MIT licensed technologies and find u-shape relations between patent age and the hazard of termination or of first sales of these licenses.

The size of the patent family, a proxy of the geographical protection has been identified as a valid value indicator by numerous surveys (Lanjouw and Schankerman, 1999; Guellec and van Pottelsberghe, 2000 and 2002; Harhoff and Reitzig, 2004; Sapsalis *et al.*, 2006 and Sapsalis and van Pottelsberghe, 2007a; Reitzig, 2004). Some variations have been also been put forward looking with success only to the largest patent offices (Europe - Japan – United States of America)

Tong and Frame (1994) put forward the number of claims as a measure of the size of an invention. Lanjouw and Schankerman (1997, 1999) show, however, that this indicator is related to the probability of litigation but not to the probability of being renewed. Recently, Reitzig (2004) pleads for a third generation of patent indicators and introduces indicators extracted from the patent text like the number of words describing the state of the art; the number of words describing the technical problem; the number of technical advantages and preferences; the number of independent, dependent, process and application claims and analyses their impact on the probability of being opposed.

Examining how patent scope affects the valuation of new biotechnology firms, Lerner (1994) finds that the scope of a patent (measured by the number of different four-digit IPC[5] classes) is associated with various measures of economic importance: firm valuation, likelihood of patent litigation, and citations. Focusing on MIT’s patent applications, Shane (2001) also demonstrates that the scope, the radicalness and the importance of MIT’s patents have a significant and positive impact on the probability to create new technology-based firms. Lastly Dechenaux *et al.* (2003) analysing the MIT licensed patents show that scope decreases the hazard of termination and increases the hazard of first sale. However, the impact of the patent scope is challenged by many authors, including Harhoff *et al.* (2003), Harhoff and Reitzig (2004), Guellec and van Pottelsberghe (2000, 2002) and Lanjouw and Schankerman (1997). Scope is sometimes inversely correlated with patent value, at least when measured with the number of listed technological classes. To take into account different practices and

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[5] International Patent Classification

specificities of the technologies, authors also introduce dummies for different technical classes. (See for ex: Hall *et al.*, 2001).

Little empirical evidence has been brought about the effects of the patent strategy. Nevertheless few authors (Guellec and van Pottelsberghe, 2000 and 2002; Reitzig, 2004; Sampat, 2005) have computed patent strategy related indicators. The procedures like IPC filing or accelerated search and examination request have shown some effects on the probability to be granted or on opposition procedures.

3. Databases on academic patents

Likewise in other countries, Belgian universities are more aware and concerned by the protection and the management of their intellectual property rights. To assess this evolution, patent data have been collected in December 2004 through the DELPHION® online database.

In a first stage, we identify all the inventions applied at the European Patent Office by the 19 Belgian universities or university faculty centres[6] and regroup them by patent families.

When patenting was quite anecdotic[7] in the early eighties, the nineties have witnessed a revolution in the number of EPO family patents applied by universities. The explanations of this phenomenon have to be found in different events: the Belgian policies fostering the patenting activities at university[8]; the commitment of Belgian universities towards the valorisation of their research results and the emergence of new research fields like biotechnology.

In this paper, the focus is put on the six most productive universities in terms of patent applications. Between 1978 and 2003, the KUL, UG, VUB, UCL, ULB and Ulg claimed 90% of the identified EPO Belgian academic patents. The other assignees have applied 90 % of their patents after 1995.

In a second stage, during the year 2005, a questionnaire was sent to the six universities asking for each patent if a license [9] had been awarded to an existing company or to one of their spin-off.

Among the 387 patent families applied between 1978 and 2003 (priority date), we collected exploitation information about the 334 patents applied between 1985 and 2003 (92% of the patents identified during this period). Some data could not have been retrieved because the

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[6] The database does not include patents that were invented within universities but applied for by third parties.

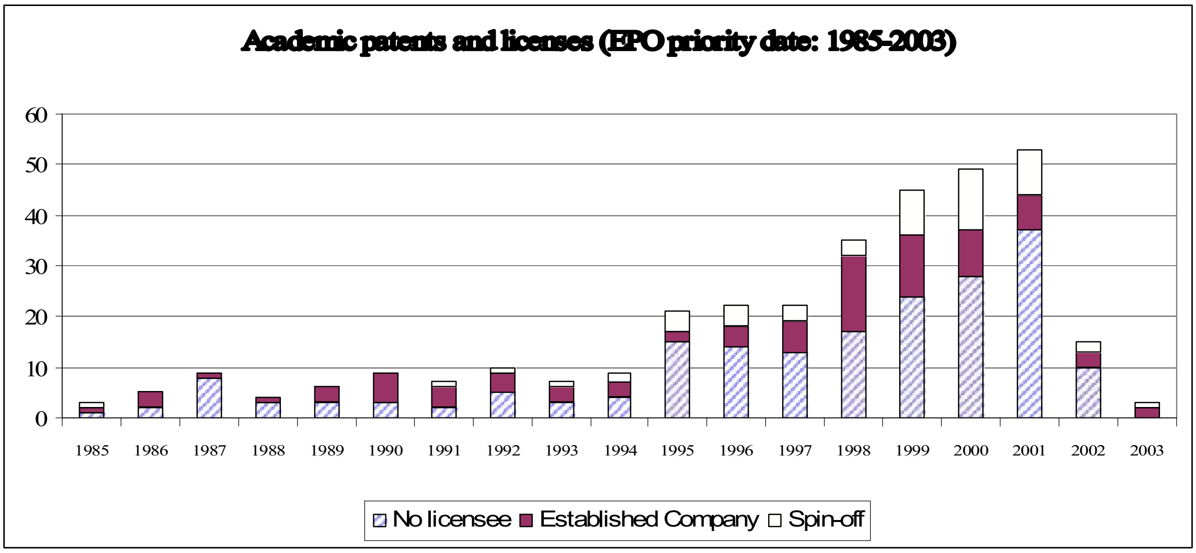
[7] Independent inventors and the patents invented at universities but applied for by firms are not taken into account.

[8] In 1995, the Flemish Parliament edited a decree ruling the modalities of research collaborations and stated that the university has to be equitably remunerated for the intellectual property rights resulting from the research collaboration. This retribution has to be defined when the research contract is signed. In 1998, the Flemish Region completing its decree of 16 June 1991 stated that the rights of the inventions done by academic researchers within the frame of their research missions are the sole property of the university. In 1998, the Walloon Region modified its legislation (decree of 5 July 1990) and granted the ownership of the intellectual property rights related to results of the research projects financed by the region.

[9] The license did not have to be still active.

records of the oldest patents were not available or because some patent rights were managed by co-assignees and the information was not available for each patent individually[10].

Figure 2: Evolution of academic patents and licenses



Between 1985 and 2003, 364 patents[11] were applied at the EPO. Among these patents, exploitation information was extracted from the technological transfer offices for 334 patents. Out of these 334, 42 % have been licensed representing a set of 142 licensed patents. Some 37% of the licensees were spin-offs when the rest of the licenses was granted to existing companies (78 % were large companies).

Figure 2 illustrates the evolution of the patents applied by Belgian universities and their exploitation[12]. Noticeably, it can be observed that the creation of spin-off is a quite recent phenomenon used to support the exploitation of academic invention. Before 1995, the creation of spin-off exploiting technology applied by the university was quite anecdotic.[13] Nevertheless, it has to be remembered that after 1995, the first mean to exploit academic technology remains existing companies.

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[10] A substantial number of patents of the Flemish universities were co-applied with Flemish research centres like IMEC (Interuniversity Micro- Electronic Research Centre), VIB (Flanders Institute for Biotechnology) and VITO (Flemish Institute for technological Research). Among these patents, the ones managed by these research centres do not appear in the final database.

[11] In the following pages, the term patent will be used for any patent family for which one member has been applied at the EPO.

[12] Figure 2 presents an important decrease of the number of patent applications for the year 2002 and 2003. This does not witness a decreasing interest for academic IPR but a data collection bias because of the delay between filing date and the publication date and the PCT procedure, it was not possible to identify in December 2004 every patent applied within the period at the EPO.

[13] The Flemish decree of 1995 defines also the modalities of participation of the Flemish universities in their spin-offs' capital authorising them de facto to finance the creation of their spin-offs. Gradually the Belgian universities have developed specific tools to support the creation of spin-offs. By 1997, the KUL was the first university in Belgium to create a specific pre-seed/seed fund (named Gemma Frisius) regrouping private investors, public investment funds and the universities. In the following years, the other universities have developed similar funds. Before 1997, the pre-seed funding was one of the roles of the technology transfer offices that were using university money to support the launch of a new company (within the limit of the financial means of the university for such kind of ventures). For example, the investment role of the Sopartec - the technology transfer office of the UCL - was recognised in 1992. In 1999, the investment mission of the Sopartec was strengthened and in 2003, VIVES a specific pre-seed/seed fund- was created with a mission to invest in the new technological companies using the research results of the university.

4. Empirical implementation

This paper aims to analyse how the patent characteristics could explain the patent value.
To achieve this purpose, the strategy implemented in Sapsalis and van Pottelsberghe[14] (2007a) will be followed.

4.1.1. The model

We rely on a binomial model for the binary variables constructed on the license information.

Probit models[15] are introduced. The dependent variable y_i can be only one or zero, and β_i the vector of parameters associated with the vector of explanatory variables x_i is estimated in:

$$\Pr(y_i = 1 \mid x = x_i) = \mathrm{N}(x_i\beta_i)$$

where *N* is the cumulative distribution function of the standard normal distribution and the vector of explanatory variables x_i is [TECH IMP, SCIEN KNOW, TECH KNOW, OWNER, IP, TIME]. The sub-vector TECH IMP is regrouping the variables constructed on FPC indicators. The sub-vector SCIEN KNOW is defined as the set of variables based on NPC indicators. The sub-vector TECH KNOW is relying upon variables built on BPC indicators. OWNER is defined as a sub-vector composed on variables based on the type and number of assignees, the number of inventors and the name of the academic assignees. IP is a sub-vector constructed on the number of claims, the patent scope, the size of the patent family. The sub-vector TIME regroups the time dummies based on the priority date of the patent.

4.2. The explanatory variables

4.2.1. Determinants of technological impact

The most technologically important academic patents are expected to be licensed by companies or exploited in spin-offs. Looking to statistics[16], it appears that in average a patent licensed to an existing company is cited 5 times, the double of the average citation rate of the entire patent portfolio. This figure goes down to 2.4 citations per patent for patent licensed to spin-off but spin-off creation is a recent phenomenon and so the patents exploited by spin-off are younger and - other thing equal - less cited.

Like in Sapsalis *et al.* (2006, 2007a), we disentangle the number of forward patent citations (FPC) by looking to the assignees of the patents citing the academic ones. The variable is disaggregated according to the institutional origin of citing patents. They have been clustered into three categories: the number of corporate applicants (firms or corporate R&D centres),

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[14] It has been presented that a more accurate analysis of the components of the existing value determinants improves the understanding of how patent value is determined.

[15] Logit specifications have also been computed and have led to similar results.

[16] Table A.1 in the appendix displays the average value of each explanatory variable in the different datasets. See Sapsalis and van Pottelsberghe (2003) for a more in-depth description of patent activities within the Belgian academic sector.

the number of public institutional applicants (universities, hospitals, public research centres, state departments) and the number of self citations (citations to previous own inventions). The basic idea is the characteristics of the citing institution could witness some maturity/broadness of the technology.

Self forward patent citations witness the capacity of university to develop a comprehensive technological platform around a first invention. This appropriation of technology and the on-going development witness by the fact that the research team is still involved in the field makes the invention more attractive for the companies that would be more willing to license a technology for which the inventors are committed to develop. This statement stands mainly for existing companies. Indeed for spin-offs, if the academic technology is identified as a business opportunity. The patent will be spun out and the future developments will be undertaken under the name of the spin-off[17] and will not appear as a self forward patent citation[18].

Citations done by corporate assignees might witness more closed-to-the-market inventions when citations done by academic assignees might reflect that the technology is more an emerging/ broad one.[19] Those two determinants are expected to have a positive impact on the probability to license the patent. Nevertheless, for spin-off even if attractive, too early-stage technologies could fail to secure investors' money[20] if a business opportunity is not clearly identified. Therefore some could suggest that citations from academic centres could impact negatively the probability to get the patent licensed by a spin-off.

<u>Hypotheses:</u>

- The more technologically important (witnessed by the number of FPC) the patent is, the more likely to be licensed.
- The greater the technological platform (witnessed by the number of self FPC) created around a patent, the more likely the patent to be licensed by existing company.
- The more early-stage (witnessed by the number of FPC done by academia) the patent is, the less likely to be licensed by a spin-off.

4.2.2. Determinants of scientific knowledge

How extensively a patent is based on science can be approximated with the number of non-patent citations (NPC) or references to the scientific literature. We disaggregate this figure into two variables: a dummy that reports whether the inventors' scientific papers (at least one) have been cited in the patent (self non-patent citations) and a variable for the number of

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[17] This statement is based on the fact that at least some inventors will leave the university and become the founders of the company. However, it was not possible to verify if some of the patents citing the licensed academic inventions were hold by the licensee of the technology because we were not given the name of the licensees. But we check that the academic spin-offs were not the main assignees of the corporate patents citing the academic patents (spin-offs count for some 2% of the assignees of corporate FPC).

[18] To assess if a FPC was a self citation, we look first to the name of the assignees of the citation, if one name is related to the studied university, we check if we find at least one inventor common for each patent.

[19] The theoretical basis of this hypothesis is to be found in the following statement. Because academic technologies have been proven to be early stage ones, it is more probable that a technology cited by an academic technology is more science-oriented, broad or related to an emerging field.

[20] The Venture Capitalists when looking to a spin-off do not finance research but business projects (see e.g. Vohora *et al.*, 2004; Wright *et al.* ,2004)

citations to scientific papers written by other scientists (non-self non-patent citations).[21] The first indicator reflects the appropriation by the inventors of science on which the technology relies. Because self citations express that the inventors' scientific works leading to the patent have been validated by peers and that their applications have been translated in patent, self NPC could affect positively the industrial/entrepreneurial value of the patent. Moreover, citations to inventors' scientific papers are implicitly associated with a large potential tacit knowledge and because tacit knowledge is particularly important for breakthrough discoveries and is the very basis of creativity (Zucker et al., 2002; Leonard and Sensiper, 1998), patents relying on self literature citations could be more valuable.

The second indicator relates to the non-self scientific publications. Because these are part of the public domain and that they can limit the broadness of the patent, non-self NPC could witness a patent of smaller value.

Hypotheses:

- The more based on inventors' scientific work the patent is, the more likely to be licensed.
- The more based on non-self scientific literature, the patent is, the less likely to be licensed.

4.2.3. Determinants of technological knowledge

Backward patent citations (BPC) approximate the technological background of the invention. This variable can be disaggregated according to the institutional origin of cited patents. They have been clustered into three categories: the number of corporate applicants, the number of public institutional applicants and the number of self citations. Looking to Belgian academic patents, Sapsalis and van Pottelsberghe (2007a) show that the cited patents filed by public assignees have a positive and significant impact on the number of forward patent citations when with the number of self citations the reverse effect was established.

Looking to the effect of BPC on being licensed is more complex. If it can be assumed that the broadness of cited technological background witnesses of the interest of other organisations to solve a technical problem, the influence of the origin of the citations could be disputed because for the licensee, what matter is not the previous development stage of technology but the ameliorations brought by the technology as measured by the FPC.

Hypotheses:

- The more based on technical background a patent is, the more likely to be licensed.

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[21] The available information in the database creates a potential bias: the self non-patent citations are underestimated and non-self non-patent citations are overestimated. Partial information is available: only the name of the first author is referenced in the database. These two variables may be more relevantly seen as the number of citations to the scientific literature for which one of the inventors is the principal author and as the number of references to papers for which none of the inventors is the first author. In health, life and engineering sciences, the first author of a scientific paper is usually the main researcher involved in the research described by the paper.

4.2.4. Determinants of ownership

We compute the dummy variables for each of the 6 academic assignees to verify if any of these have been able to produce patents of better quality, to develop a more efficient licensing strategy or have adopt a more entrepreneurial stance.

We introduce a variable *INV* measured as the number of inventors listed in the patent. Liebeskind and Oliver (1999) suggest that life-science scientists involved in patenting are more eager to limit the size of their research teams to minimize disputes over claims to discovery and inventions. If we assume that the patent-aware scientists are the ones who produce the most important patents, we should find a negative impact of the size of the inventors' team on the value of the patent (Sapsalis *et al.* 2006).

To assess the impact of collaboration with other knowledge generating institutions, the number of co-assignees applying with a university was computed (COAS). Only juridical entities were looked at. Then, these co-applicants were disaggregated into two categories: the corporate co-assignees (industries, corporate R&D centres) and the public co-assignees (public institutions such as universities, hospitals, public research centres and state departments).

Looking to patents co-applied with public partner, one could expect them to lead to technically more important patents because research teams from different institutions have regrouped their knowledge and skills in a unique project that they probably could not have realised alone (Sapsalis and van Pottelsberghe, 2007a). However to license such a patent could be more difficult without the interest of an industrial partner. Moreover, the management of such kind of patents might be more difficult to coordinate because one has to deal with the interest of many research teams across different universities. Legal, negotiation and marketing issues could rise up and impede the valorisation of such a patent

Looking to patents co-applied with industry, one can expect that these collaborations make the transfer of the patent easier because the project is closer to the interests of industry[22]. Though, one can suspect that maybe spin-offs are not the ones that exploit co-applied patents. However, spin-offs are sometimes created to pursuit the development of a patent issued from an industrial research project for which the industrial partner has showed no commercial interest (ex Vohora *et al.* 2004).

Hypotheses:

- Patents co-applied with public partner are less likely to be licensed or spun-out.
- Patents co-applied with corporate partner are more likely to be licensed (mainly to an existing company).

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[22] Even if we do not have the name of the licensee, we can suspect that a co-applied licensed patent has been licensed to the industrial co-assignee who has usually the first right of refusal.

4.2.5. Determinants of patent protection

To assess the patent protection subjacent to the patent, we compute three types of indicators: one based on the geographical protection; a second one on the scope and a third one on the claims.

To analyse how geographical protection could reveal the value of a patent, we rely on the family size (FAM) taking into account the number of patents that are a member of the family. The alternative approach we put also forward is to focus on two variables describing whether the patents have also been applied for at the JPO and/or at the USPTO. These dummy variables take the value of one if applicable, zero otherwise. We expect that these indicators are positively related to the value of the patents. On one hand they reflect the academic perception of the technical quality of their intellectual assets and that is why they protect it widely. On the other hand, in order to maximize the potential profit related to a patent, industry will make sure that the inventions they have licensed has been protected in the most attractive markets.

Shane (2001) supports and verifies that technological opportunities with broader intellectual property protection are more likely to be commercialised through firm creation. Following this argument we compute a variable SCOPE (measured as the number of different 4-digit IPC classes into which the EPO assigns the patent); a measure of the technical broadness of the patent. Nevertheless, the impact of scope is largely debated in the literature. One can assume reversely that existing companies are more eager to license more specialised patents, less broad but closer to their concerns. Finally, it can be expected that a broad patent is more likely to be cited because it covers different technical fields.

To take into account the disparity between different technical fields, a variable is *BIO* is introduced. The patents are regrouped under two broad technological fields: biotech and non-biotech.[23]

Claims are the essence of the patent, the codified inventive activity; they are the size of the inventions. Therefore, a patent with a lot of claims is more likely to have an important value.

Hypotheses:

- The more widely geographically protected a patent is, the more likely to be licensed
- The broader a patent is, the more likely to be licensed to a spin-off
- The more specialised a patent is, the more likely to be licensed by an existing firm
- The more claims, the more likely to get licensed

4.2.6. Priority dates

The time effect is taken into account through a set of time dummies that correspond to the priority year of each patent. Predict the effect of the filing date on the probability to get a

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[23] The 4-digit IPC classification has been used to identify biotech patents. We consider that a patent is part of the biotech field if its principal technological class is related to health, to environment, to organic chemistry or to biology. A model introducing also a variable ELECTwas also computed but is not introduced here. Results remain similar. The variable ELECT was standing for patents applied for in the nanotechnologies, electronics and instrumentation.

patent licensed is complicated. If we support the idea that every other thing equal younger patent is as important as the older one, we should only see a difference for the very last years because it might be expected that in 2005, the technology transfer offices were still probing the market or negotiating with a potential licensee the exploitation of their latest patents. On the other side, someone could expect that the most recent years have witnessed - other thing equal- more licenses because the universities have been more and more committed towards technology transfer, have been more business-oriented[24] and have better marketed their technology. Nevertheless, this idea could be challenged by the fact that in the past when it was not "fashionable" to apply for a patent, the technology was protected only when first promising contacts were taken with a potential licensee, in order to limit the risks and justify the patent.

5. Empirical results: industrial and entrepreneurial values of academic patents

Based the method developed in Sapsalis and van Pottelsberghe (2007a), we implement a disentangled set of value determinants.

In a first stage, we rely on the dataset for which we have retrieved the exploitation data and analyse the different patent value proxies. We analyse the industrial impact approximated by the fact that a license has been awarded to any type of company or more specifically to an existing one; and entrepreneurial impact evaluated by the fact that a license has been awarded to a spin-off.

In the next section, we put our attention only the patents that have been licensed and are looking if there are substantial differences between the patents licensed to spin-offs or to existing companies.

Tables 1 and 2 present the econometric results of the analysis of the industrial and entrepreneurial value. Table 1 shows the regressions based on the set of the simple indicators and table 2 introduces the detailed indicators in the regressions.

The dependent variables are dummies: the variable LIC is witnessing if the patent has been licensed; the dummy LIC_F is witnessing if the patent has been licensed by an existing company; and LIC_SO is equal to one if the patent has been licensed by a spin-off.

The simple set of indicators is constructed around thirty-three explanatory variables. It includes nineteen time dummies (1985 to 2003; 1993 used as time reference) [25]; three

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[24] TTOs have gained experience, market awareness and trained professionals have joined the technology transfer office.

[25] Table IV-15 and Table IV-16 present the econometric results of the different analyses. The size of the samples are respectively 331, 334 and 301 observations for the evaluation of the probability to get licensed, the probability to get licensed by an existing company or the probability to get licensed by a spin-off. These differences are to be explained by the fact that the time dummy "year 2003" explained perfectly success in awarding a license and thus 3 observations have been discarded from the regressions. The time dummies "year 1986", "year 1987", "year 1988", "year 1989", "year 1990" explained perfectly failure in awarding a license to a spin-off and so 33 observations have been discarded from the regressions. In the appendix, tables A.2 and A.3 present the econometric results of the different analyses for the same number of observations (298). Similar results emerge. A noteworthy difference is the fact the number of corporate FPC has a negative and significant impact on the probability of getting a patent licensed by an established company. Opposite, self and public FPCs are still positive but not anymore significant. Although, these differences, the interpretation of the results are remaining similar. Established companies are looking to license more emerging technologies.

indicators based on the technological impact; the scientific and technological background of the patent; four indicators evaluating the IP protection and eight standing for the ownership. The second set aims to improve the first model through a more detailed approximation of the institutional sources of knowledge (NPC, BPC and COAS), a more detailed analysis of the technological impact (FPC) and an more in-depth analysis of the patenting strategy regarding the geographic scope for protection.

Through the estimates of table 1, we can confirm one of our main hypotheses: companies are more eager to license the most technically important patents. The technological impact[26] is an indicator of the industrial and entrepreneurial value of a patent. Nevertheless, surprisingly the simple count of forward patent citations is positive but not significant when we are analysing only the licenses to existing firms. However, when disentangling the number of FPC, we find out that self forward patent citations have a positive and significant impact on the probability of having a patent licensed by an existing company. This result confirms our hypothesis: self FPCs witness that the research team is involved or willing to be involved in the development of the technology they have initially patented. As a matter of fact, the creation of a patent portfolio around a technology is particularly valuable. In that sense, Hall *et al.* (2000) find that self-citations are worth about twice as much as ordinary citations, especially to smaller firms. We could not verify the second part of the statement because we did not have to the name of the licensees. An extremely interesting result is that patents widely cited by companies are more likely to be licensed to spin-offs when patents widely cited by public research organisations are more likely to be licensed to existing companies. This striking result could suggest that existing companies are licensing patents closer to science than spin-offs or at least spin-offs are exploiting technologies with more immediate industrial applications than existing companies do. This would support that existing companies exploit academic early-stage inventions with a mid or long term perspective and might use academic patents in the view of foreseeing/ developing the next technological revolution [27] when spin-

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[26] Although we do not when the license deal has been signed between the company and the university, we suspect that most of the citations are arriving after the deal. Indeed, Sapsalis and van Pottelsberghe (2003) show that in average, Belgian academic patents wait some 6 year before being cited. And some TTO strategies recommend to give up a patent protection after 3 years (after the 1 year of priority and the 18 months of the PCT procedure) before entering the regional patent protection phase if no serious interest has been shown by an industrial partners. (However it is not always the case, some patents have been renewed for years and have recently found a licensee) In regard to this information, one can address some doubts of the use of this data to explain the variables “license”. Although, we acknowledge the necessity of developing FPC indicators including the notion of time lag in order to refine the study, we still support that for our database the use of the absolute number of FPC is acceptable. We support that in our case the number of FPC is a good measure of the technological impact of a patent and that the fact that the measure arrived after the license does not matter so much. Indeed, it can be argued that any technology has some latent and intrinsic technological value. The number of FPC is only the delayed and measured recognition of this impact by the outside world. The fact that a patent has not been yet been cited, does not mean that it has no value. Companies when patenting new inventions do not wait to have their patents cited to continue the development of their technologies if they identify them as valuable for the firm. In the same vein, companies are licensing technologies because their experts have recognised that these technologies represent some potential. So in our study, because we do not have access to the evaluation of an expert for each patent, we decide to rely upon FPC, a delayed measure of the technological impact of the patent. Finally, we performed additional regressions and verified that the licensing dummies do not explain neither the probability of being cited, nor the proportion of received citations. All these results confirm the following causality relation: it is because the patent is important that it is licensed and not because it is licensed that it gets cited.

[27] It can be also been put forward that this licensing behaviour might be based on the licensing-in strategy of established companies. Established companies are developing internally their own technologies. Because their R&D budgets are limited and because academic technologies are often not more than a proof of a concept and need additional efforts (which might be very costly because most of them are biotechnological inventions), established companies might be not willing to license technologies that are potentially similar to their own patent

offs have been able to identify short term applications for early-stage academic inventions. This result is in concordance with the findings of Shane (2000) who brings to light that many university inventions have led to applications that were not even foreseen by the licensee or the licensor at the time of license.

Table 1 : Econometric results: patent value and simple indicators

Explanatory variables	LIC		LIC_F		LIC_SO	
	Model 1	Std. Err.	Model 2	Std. Err.	Model 3	Std. Err.
	PROBIT		PROBIT		PROBIT	
Technological Impact						
# Forward patent citations (Total)	0,037*	0,022	0,016	0,021	0,057*	0,032
# Self Forward patent citations						
# Non Self Forward patent citations						
# Corporate applicants of citing patents						
# Public applicants of citing patents						
Scientific Knowledge						
# Non-patent citations (Total)	-0,006	0,010	-0,001	0,010	-0,011	0,011
Self non-patent citation (dummy)						
#Non-self non-patent citations						
Technological Knowledge						
# Backward patent citations (Total)	0,046**	0,018	0,053***	0,019	0,005	0,021
# Corporate applicants of cited patents						
# Public applicants of cited patents						
# Self patent backward citations						
Ownership						
Collaboration						
# Co-assignees (Total)	0,06	0,123	0,207°	0,134	-0,19	0,153
# Corporate co-assignees						
# Public co-assignees						
# Inventors (Total)	-0,034	0,047	-0,075	0,057	0,02	0,052
IP Protection						
Geographical Protection						
Family size (# different applications)	0,049***	0,015	0,03**	0,015	0,037**	0,018
Application at USPTO (dummy)						
Application at JPO (dummy)						
Content Protection						
Scope IPC 4	-0,089	0,076	-0,091	0,091	-0,021	0,084
# claims	0,020**	0,008	0,015*	0,008	0,008	0,009
Biotechnological field	0,165	0,188	0,195	0,214	0,086	0,225
Observations	331		334		301	
Log Likelihood	-182		-150		-124	

The 19 time dummies and 6 assignees dummies have been included but not displayed

Levels of significance (probability threshold): ° <15%; * < 10%; ** <5%; *** < 1%

This last statement is reinforced by the fact that patents licensed to existing companies are using more scientific publications than spin-offs. Nevertheless, non-patent citations (NPC) have no significant impact on either of the value proxies. This result differs somewhat from the results of Harhoff *et al.* (2003) who look to corporate patents and find a positive and significant impact. It might be because academic patents are protecting early-stage inventions and often no more than a proof of a concept; therefore the simple count of non-patent citations would not allow identifying the academic patents with the highest value indicator. But when disentangling the number of literature citations, table 2 shows that patents relying on inventors' publications are more likely to be widely cited or licensed by existing firms. This relation confirms the finding of Sapsalis et al. (2006, 2007a) showing that academic patents

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portfolio. On the other side, they will look for the next generation technologies which are not competing with their internal R&D projects.

and industrial biotechnological patents referencing inventors' scientific works are technically more important.
They support that citations to inventors' scientific papers witness the quality/experience of the inventors and are implicitly associated with a large potential tacit knowledge which is assumed to be translated into a successful invention.

Moreover, because academic patent are early-stage, existing companies that have licensed a university invention will try to decrease the technological uncertainty by licensing technologies from high level research teams and will maintain or get access to uncodified inventor know-how (Mowery and Ziedonis, 2001; Agrawal 2006) through research projects; consultancy etc… As a proxy of the experience and the tacit knowledge of the research team, self literature citations are a positive value determinant for patent licensed to an existing firm.

Table 2 : Econometric results: patent value and detailed indicators

Explanatory variables	LIC		LIC_F		LIC_SO	
	Model 4	Std. Err.	Model 5	Std. Err.	Model 6	Std. Err.
	PROBIT		PROBIT		PROBIT	
Technological Impact						
# Forward patent citations (Total)						
# Self Forward patent citations	0,249	0,218	0,296**	0,149	-0,111	0,123
# Non Self Forward patent citations						
# Corporate applicants of citing patents	0,025	0,032	-0,033	0,034	0,129***	0,049
# Public applicants of citing patents	0,097°	0,059	0,146°	0,097	0,049	0,062
Scientific Knowledge						
# Non-patent citations (Total)						
Self non-patent citation (dummy)	0,301	0,373	0,68*	0,382	-0,405	0,502
#Non-self non-patent citations	-0,01	0,015	-0,019	0,014	0,004	0,014
Technological Knowledge						
# Backward patent citations (Total)						
# Corporate applicants of cited patents	0,053*	0,029	0,041°	0,030	0,042°	0,031
# Public applicants of cited patents	0,015	0,064	0,055	0,063	-0,121°	0,089
# Self patent backward citations	0,049	0,144	0,081	0,135	0,015	0,190
Ownership						
Collaboration						
# Co-assignees (Total)						
# Corporate co-assignees	0,706***	0,212	0,643***	0,206	0,153	0,210
# Public co-assignees	-0,569***	0,202	-0,422*	0,241	-0,538**	0,260
# Inventors (Total)	-0,011	0,048	-0,06	0,060	0,037	0,054
IP Protection						
Geographical Protection						
Family size (# different applications)						
Application at USPTO (dummy)	0,127°	0,199	-0,005	0,222	0,189	0,230
Application at JPO (dummy)	0,37*	0,203	0,322°	0,218	0,102	0,246
Content Protection						
Scope IPC 4	-0,114	0,080	-0,151°	0,097	-0,012	0,086
# claims	0,024***	0,009	0,017*	0,009	0,013°	0,009
Biotechnological field	0,181	0,191	0,184	0,220	0,125	0,231
Observations	331		334		301	
Log Likelihood	-172		-139		-120	

The 19 time dummies and 6 assignees dummies have been included but not displayed.

Levels of significance (probability threshold): ° <15%; * < 10%; ** <5%; *** < 1%

Surprisingly, the relation between self literature citations and spin-off could not be established. It also can be noticed that a small amount of the patents licensed to spin-offs (7.5%) are referencing a least one scientific work authored by one of the inventors when this figure rises to 29% when analysing patents licensed to existing companies. Lowe (2002) supports that when inventors have an important tacit knowledge; new start-ups emerge to commercialize uncertain technologies to palliate the market failure. To explain the previous result, some could affirm that tacit knowledge is not to be found only in publications because scientific literature exposes only successes and rarely failures. Therefore some could suspect that beyond the publication of the patent, the publication of some scientific results have been delayed first to protect the invention but mostly to protect the secrets of a nurturing business.

The number of backward patent citations has a positive and highly significant impact on the value indicators except for the patent licensed to a spin-off. The classification of backward citations shows instructing results. Sapsalis et al. (2006, 2007a) show that the technically important patents are relying on technical background based on patents applied by public research institutions and suggest that academic patents are important source for technically important patents. Nevertheless, when looking to the licensed inventions, references to previous academic patents are respectively not significant for industrial value or slightly significant and negative for entrepreneurial value whereas references to previous corporate patents are respectively slightly significant and positive for industrial and entrepreneurial value. These results might suggest that the backward citations witness the concern of different licensing institutions. Patents applied by corporations are more likely to be related to immediate industrial applications than academic inventions. Thus, an academic patent that references an industrial patent could be closer to industrial concerns thus is more likely to be licensed. Although, industries could be interested also in emerging technologies, the results suggest that companies are more interested in technically important patents (measured by the number of FPC) than any patent whose state of the art is covered by academic patents (measured by the number of BPC related to academic assignee). No significant relation could be put forward concerning the self backward patent citations. This result is opposite to ones in Sapsalis *et al.* (2006, 2007a) who find a negative and significant relation and suggest that self BPC are a proxy for incremental innovation and thus are technically less important.

This result also is quite unexpected for patents licensed to companies because self BPC witness the fact that university is creating a technological platform around an invention. Although self BPC is not relevant when computed with the detailed set of determinants relying on FPC, it becomes positive and significant for the proxy license to existing firms[28] when computed only with the number of FPC. This suggests finally that the creation of a portfolio around an invention is valuable and increases the probability of being licensed by a company. This relation could not be established for spin-off. A spin-off will be created to develop and exploit a patent that is supposed promising. Thus, the spin-off will license the first generation invention (no self backward patent citation) and develop internally its own patent portfolio (no self forward patent citation from the point of view of the university).

To assess the ownership and relations between the different actors involved in the invention, we compute variables taking into account the number and the type of co-assignees, the number of inventors and the name of the assignees.

Looking first to the impact of collaboration, the number of co-assignees that have applied for the patent has no significant impact on the different proxies of value. However, when detailing the type of collaboration, we find different results.

Although, collaboration with industry seems to be less technically fruitful than academic collaboration when evaluating its effect on technical patent value (Sapsalis and van Pottelsberghe, 2007a), we find that collaboration with industry has a positive and significant impact on the probability to have a patent licensed to an existing company. Closer to the industrial concerns, these patents are more likely to find a licensee, most probably the one who is the co-applicant. In that context, the research collaboration has also created or

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[28] All the other relations are stable.

reinforced collaboration and trust between the two partners. Focusing on the license to spin-off, no significant relation could be established

Reversely, many academic assignees for a patent have a significant and negative impact on the probability of being licensed to any company. Even, if this result should be taken with caution[29], it can be argued that 1) different valorisation strategies or practices between the research organisations, 2) the fact that a company should convince several research teams to commit to the exploitation and development of the invention and 3) the fact that the industry does not have an unique academic negotiator may limit the chances of having a patent licensed.
No significant impact of the number of inventor was identified.

The analysis of the variables related to IP protection puts forward that the size of the family and the number of claims are two major indicators of value. This is expected if we compare our results to the existing literature. The patents that are protected widely are more likely to be licensed. Looking more specifically to the USPTO and the JPO, our results suggest that the USPTO dummy is an important determinant for technical value. This confirms our expectation regarding the patent value; universities will protect more widely their patents if their patents are important. Descriptive statistics show that licensed patents are more protected in average (66% applied at the USPTO) than non licensed patents (46% applied at the USPTO). We find only a slightly significant and positive effect on JPO and USPTO dummy on the fact that a patent will be licensed but these results have not been confirmed for the dependent variables taking into the characteristic of the licensee.

Other thing equal, licensees will tend to license patents with a lot of claims. We have not identified any significant impact for the scope and biotechnology value determinants.

6. Empirical results: one technology, two ways to license it

In a previous study, Shane (2001) analyses the relation between the technological opportunities and the creation of new firms. Looking to MIT patents between 1980 and 1996, he pinpoints that the patents to be spun out should be radical, important and with a broad scope. More recently, comparing the characteristics of technologies that lead to spin-offs and existing firm licenses, Shane (2004) supports that spin-offs tend to be launched to exploit radical, tacit, early-stage and general-purpose technologies. Those technologies are supposed also to present significant value for the customer and major technical advance. They will have a strong IP protection. Opposite, existing firms would exploit incremental, codified, late stage, specific purpose technologies with a moderate value for customer, minor technical advance and weak IP protection.

Nevertheless, one could feel not totally satisfied with the previous statements when looking to the exploitation of academic patents.

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[29] An explanation to this unpredicted result is that our database suffers from a bias, 24 patents all filed in with academic applicants are not taken into account because information about license was not available. For the 24 patents eliminated from the analysis, the other co-assignee was explicitly in charge of the valorisation of the patent.

One can agree with the fact that radical, important and broad patents are to be exploited by spin-off but can be puzzled by the idea that these characteristics should be less valuable for existing companies when these companies bid on academic technologies.
First, although academic intellectual assets are recognised to be widely early-stage, they get licensed by existing companies. In a survey on the technology transfer activities of 62 US universities (Thursby and al., 2001), 60% of the technology transfer offices indicated that small companies are more likely to take early stage technologies and large companies are more likely to take late stage technologies, but 40% says there is no difference. If late stage technologies are privileged by large firms, these technologies represent a small part of the amount of licenses (Thursby et al. 2001) by far smaller than the proportion of patent licensed by existing firms[30]. Indeed, academic technologies are so embryonic that additional efforts by the inventor are required by the licensees for a reasonable chance of success (Jensen *et al.*, 2001). To maximise the success rate and to capture the tacit knowledge underlying the patent it is required often the implication of the inventor in the future development of the invention: 71% of the licensed inventions are viewed as requiring inventor cooperation for commercial success (Thursby et al., 2001). This figure is higher than the 15% of the licenses given to start-ups according to the survey AUTM in 2002.

Second, in the licensing-in process, existing companies will always look first to appropriate technologies with strong IP protection and significant customer value.

Third, because defining market opportunities for academic patent is so uncertain and because many university inventions have led to applications that were not even foreseen by the licensee or the licensor at the time of license (Shane, 2000, and Thursby and Thursby, 2002), it can be argued that like spin-offs, existing firms should prefer general purpose and broad patents.

This section offers to analyse only the patents that have been licensed (to spin-offs or to other companies) and identify which are the significant determinants that will explain why a technology is better exploited by a spin-off than by an existing company. Table 3 presents the results of the regressions.

Looking at the determinants approximating the technical importance of the patent, model 7 suggests that the most technologically important patents will be licensed to spin-offs. However, looking to the origin of the citations, we observe that patents licensed by spin-offs are mainly cited by companies when references done by public research institutions have a negative impact on the probability of being licensed to a spin-off. This first result tries to confirm the results of the previous section putting forward the idea that existing companies are more eager to license patents cited by academia. This result could suggest that although most academic patents are early stage, spin-off relies on technologies that find an echo in the business. Spin-offs seem to go for disruptive technologies in the sense that they had the scope of create new markets (Wright *et al.* 2004) when existing companies seem to license more exploratory patents.
This tends to challenge the assumption that the most early stage technologies are the ones to be exploited by spin-offs. In a way, the last observations are in line with the idea that the creation of a spin-off presumes to attract investors who when taking part to a new venture do not want to fund research. (Vohora *et al.* 2004)

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[30] In 2002, the AUTM survey shows that 642 licenses were executed by start-ups, 2400 by established small companies and 1443 by established large firms.

Nevertheless the last statement should be taken with caution. Indeed analysing how non patent citations could reflect value, it appears that non-self scientific references have a positive impact on the probability of being licensed by a spin-off; this result suggests that spin-offs rely on more scientific patents. No significant impact was found concerning the self citations. In other words, it means that the inventors' scientific profile and the tacit knowledge used in the patent are not significantly different among patents licensed to existing companies or to spin-offs. When looking the inventors' characteristics, motivations and entrepreneurial spirit might be more relevant to explain the channel chosen to commercialise an academic technology than the scientific quality of the inventors' team.

Table 3 : Academic Licenses: Spin-off vs Existing companies

Explanatory variables	LIC_SO		LIC_SO	
	Model 7	Std. Err.	Model 8	Std. Err.
	PROBIT		PROBIT	
Technological Impact				
# Forward patent citations (Total)	0,216***	0,080		
# Self Forward patent citations			-0,758**	0,338
# Non Self Forward patent citations				
# Corporate applicants of citing patents			0,465***	0,129
# Public applicants of citing patents			-0,584°	0,400
Scientific Knowledge				
# Non-patent citations (Total)	-0,006	0,015		
Self non-patent citation (dummy)			-0,899	0,812
#Non-self non-patent citations			0,041*	0,024
Technological Knowledge				
# Backward patent citations (Total)	-0,034	0,029		
# Corporate applicants of cited patents			0,018	0,048
# Public applicants of cited patents			-0,229	0,186
# Self patent backward citations			0,048	0,309
Ownership				
Collaboration				
# Co-assignees (Total)	-0,516**	0,240		
# Corporate co-assignees			-0,240	0,303
# Public co-assignees			-0,517	0,461
# Inventors (Total)	0,079	0,089	0,010	0,102
IP Protection				
Geographical Protection				
Family size (# different applications)	0,004	0,028		
Application at USPTO (dummy)			0,335	0,373
Application at JPO (dummy)			-0,649*	0,362
Content Protection				
Scope IPC 4	0,165	0,149	0,257°	0,163
# claims	-0,023*	0,012	-0,014	0,014
Biotechnological field	-0,008	0,351	0,075	0,390
Observations	129		129	
Log Likelihood	-65		-54	

The 19 time dummies and 6 assignees dummies have been included but not displayed.
Levels of significance (probability threshold): ° <15%; * < 10%; ** <5%; *** < 1%

No indicator based on the technical state of the art can explain why a patent is more likely to be licensed by a spin-off or by an existing company.

Looking to the geographical protection, the JPO dummy has a significant and negative impact on the probability of being licensed to a spin-off. This result could be taken with caution because license to spin-off is a recent phenomenon in our database; the protections of some patents could have been extended since the collection of the data.

Finally patents licensed to spin-offs seem to be more broad (15% threshold significance) than patents licensed to existing enterprises and in that sense, this result supports Shane's idea that spin-off license more general-purpose patents than established ventures.

7. Concluding remarks

These days, many countries around the world are witnessing a revolution in the protection and valorisation of the inventions developed at university. Among the different stakes underlying this evolution, policy makers, society stakeholders and scholars have recently been interested in understanding the value and impact of academic patents. Focusing on the granted licenses, this paper aims to analyse the industrial and entrepreneurial value of 334 patent families applied for by six major Belgian universities and aims to identify the value determinants encrypted in the patent documents.

Analysing the Belgian situation, this paper reveals that the exploitation of academic patents by companies is not a recent phenomenon although by the past it was quite limited by the number of patents applied by academia. However spin-offs are. Since the mid-nineties, stimulated by regional innovation policies, spin-offs creation has become a new channel for the exploitation of academic technologies. It shows that existing companies and start-ups are two different valorisation patterns to commercialise academic inventions.

Results advocate also that there is a difference between the academic technologies licensed to existing companies and the ones licensed to spin-offs. Existing companies tend to license academic technologies that seem more early-stage. The creation of a technological platform around a specific academic technology by the research team as well as the high scientific profiles of inventors make patents very attractive for industry. These results might suggest that existing companies should be interested in licensing emerging academic technologies to investigate new research ideas when the academic inventors' team is committed to develop the technology and share tacit knowledge. Opposite, because probably of the relations between the spin-off and its investors, technologies granted to spin-offs seem closer to the market. These results relay an important policy question about the role of the spin-offs in the knowledge economy. Are spin-offs launched to develop academic technologies that are competing with the R&D projects and products of established companies?

Furthermore, the paper stresses the importance of collaboration between public and corporate research teams in order to transfer academic invention to industry. It pleads for a better management and valorisation scheme of patents co-applied by many academic assignees and draws attention on the need to focus on academic researchers with a high scientific profile in terms of publications in order to crystallize their tacit knowledge into high value academic patents.

These last results support many policies regarding the protection and exploitation of academic patenting. They plead for collaboration between the different research actors. We have observed that collaborations between universities tend to produce technologically important technologies highlighted by highly cited patents (Sapsalis and van Pottelsberghe, 2007a) but it has been shown that too many academic co-assignees reduce the probability of having a patent licensed. This advocates that the frame of research projects should also include specific clauses defining the valorisation scheme in the very beginning of the project like who is in charge the exploitation. This last argument is specifically important for funding public bodies financing big research projects where many academic actors are involved in. Recently some initiatives in Belgium have tried to regroup the technology transfer offices in networks. Among the different objectives of these associations a better involvement of the transfer offices on collaborative research projects was decided at the Belgian level.

Finally, our analysis pinpoints that self-citations to the scientific literature lead to patents that are more likely to be licensed to a corporate licensee. This outcome supports that the most valuable patents are invented by the researchers who rely on their own scientific publications. This result should encourage policy-makers to stimulate star scientists to codify their tacit knowledge into patents and take part to the process of technology transfer.

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9. Appendix

Table A. 1 : Descriptive statistics on indicators of patent value by university

	DB_ EXP	*DB_LIC*	*DB_ LICF*	*DB_ SO*
Number of EPO patent families	334	142	89	53
Technological impact				
% of patents cited at least once (%)	*43.7*	*47.9*	*49.4*	*45.3*
Average number of FPC per patent	2.58	4.04	5.03	2.4
Average number of self FPC per patent	0.38	0.80	1.21	0.11
Average number of FPC per cited patent	5.92	8.44	10.2	5.25
Average number of assignees of FPC	1.15	1.20	1.22	1.14
% of corporate assignees of FPC (%)	*60.3*	*55.0*	*52.0*	*66.7*
% of public assignees of FPC (%)	*24.0*	*26.5*	*26.4*	*27.1*
% of self FPC (%)	*12.8*	*16.4*	*19.6*	*4.1*
% of alone individual/unknown assignees (%)	*2.9*	*2.0*	*2.0*	*2.1*
Scientific Knowledge				
Average number of NPC per patent	3.94	6.33	8.3	3
% of Self NPC (%)	*12.3*	*11.9*	*12.9*	*6.9*
% of patent with self NPC (%)	*13.2*	*20.4*	*28.8*	*7.5*
Technological Knowledge				
Average number of BPC per patent	2.93	4.54	5.58	2.77
Average number of assignees of BPC	1.07	1.08	1.10	1.03
% of corporate assignees of BPC (%)	*58.6*	*56.0*	*51.4*	*72.4*
% of public assignees of BPC (%)	*23.3*	*24.9*	*26.9*	*17.8*
% of self BPC (%)	*7.9*	*9.7*	*11.2*	*4.6*
% of alone individual/unknown assignees (%)	*10.2*	*9.3*	*10.4*	*5.3*
IP Protection				
Age				
Average priority date	08/1997	05/1997	08/1996	09/1998
Content Protection				
Claims	19.3	21.8	22.0	22.5
Geographical protection				
Average number of family members	8.41	10.8	11.6	8.42
% of patents applied at EPO (%)	*100*	*100*	*100*	*100*
% of patents applied at JPO (%)	*74.2*	*82.8*	*93.2*	*64.7*
% of patents applied at USPTO (%)	*54.5*	*65.4*	*66.3*	*64.2*
Technological Field				

% of biotechnological patents (%)	*71.9*	*76.7*	*78.7*	*73.5*
Scope (IPC4)	1.98	1.95	1.93	1.98
Ownership				
Inventor				
Average number of inventors per patent	3.19	3.13	3.11	3.17
Assignee				
Assignee: KUL	*37.7*	*45.1*	*52.8*	*32.1*
Assignee: UCL	*17.4*	*15.5*	*15.7*	*15.1*
Assignee: ULB	*11.7*	*14.1*	*9.0*	*22.6*
Assignee: ULG	*10.8*	*7.0*	*6.7*	*7.5*
Assignee: UG	*15.3*	*12.0*	*13.4*	*9.4*
Assignee: VUB	*7.2*	*6.3*	*2.5*	*13.2*
Collaboration scheme				
Average number of co-assignees per patent	0.39	0.47	0.54	0.36
% patent applied alone (%)	*69.4*	*61.2*	*57.3*	*69.8*
% of corporate co-assignee (%)	*36.6*	*50*	*46.9*	*57.8*
% of public co-assignees (%)	*63.4*	*50*	*53.1*	*42.2*

FPC: Forward Patent Citations; BCP: Backward Patent Citations; NPC: Non Patent Citations

DB_EPO: database regrouping the 364 academic patents applied at the EPO between 1985 and 2003 by the six major Belgian universities.

DB_ EXP: database regrouping the 334 patents for which exploitation data have been collected

DB_ LIC: database regrouping 142 patents for which a license was given

DB_ LICF: database regrouping the 89 academic patents licensed to an existing company

DB_SO: database regrouping the 53 patents licensed to a spin-off

Table A. 2: Econometric results on the probability to get licensed

Explanatory variables	*LIC*		*LIC_F*		*LIC_SO*	
Technological Impact						
# Forward patent citations (Total)	0.019	0.027	-0.022	0.028	0.058*	0.032
# Self Forward patent citations						
# Non Self Forward patent citations						
# Corp. applic. of citing patents						
# Public applic. of citing patents						
Scientific Knowledge						
# Non-patent citations (Total)	0.0002	0.011	0.004	0.011	-0.01	0.011
Self non-patent citation (dummy)						
#Non-self non-patent citations						
Technological Knowledge						
# Backward patent citations (Total)	0.041**	0.019	0.048**	0.019	0.003	0.021
# Corp. applicants of cited patents						
# Public applicants of cited patents						
# Self patent backward citations						
Ownership						
Collaboration						
# Co-assignees (Total)	0.071	0.125	0.224°	0.138	-0.171	0.155
# Corporate co-assignees						
# Public co-assignees						
# Inventors (Total)	-0.03	0.048	-0.079	0.059	0.019	0.052
Academic Assignee						
UCL	-0.328	0.649	-0.354	0.628	-1.825**	0.717
ULB	0.24	0.663	-0.596	0.661	-0.898	0.726
ULG	-0.953	0.693	-1.185*	0.710	-1.874**	0.762
KUL	-0.099	0.622	-0.139	0.601	-1.68**	0.689
UG	-0.666	0.647	-0.726	0.635	-1.926***	0.737
VUB	-0.326	0.694	-1229672°	0.789	-1.31*	0.761
IP Protection						
Geographical Protection						
Family size	0.053***	0.016	0.031*	0.016	0.037**	0.018
Application at USPTO (dummy)						
Application at JPO (dummy)						
Content Protection						
Scope IPC 4	-0.105	0.080	-0.096	0.096	-0.039	0.087
# claims	0.021**	0.009	0.016*	0.008	0.007	0.009
Biotechnological field	0.122	0.192	0.136	0.221	0.103	0.227
Priority year						
1985	-1.591°	1.076	-0.888	1.079	-1.12	1.262
1991	-1.030	0.742	-0.526	0.683	-1.157	0.997
1992	-0.982	0.824	-0.091	0.787	-0.988	0.979
1994	-0.591	0.733	-0.732	0.707	0.167	0.780
1995	-1.563**	0.664	-1.785**	0.735	-0.254	0.712
1996	-0.985°	0.634	-0.937°	0.612	0.079	0.697
1997	-0.904	0.640	-0.901°	0.618	0.08	0.707
1998	-0.438	0.607	-0.128	0.570	-0.362	0.694
1999	-0.538	0.604	-0.588	0.569	0.289	0.657
2000	-0.434	0.607	-0.742	0.580	0.593	0.661
2001	-0.865	0.611	-1.052*	0.594	0.254	0.671
2002	-0.538	0.669	-0.382	0.664	0.091	0.761
Log Likelihood	-168		-134		-122	

298 Observations; 1993: Time Reference. Levels of significance (probability threshold): ° <15%; * < 10%; ** <5%; *** < 1%

Table A. 3: Econometric results on the probability to get licensed

Explanatory variables	*LIC*		*LIC_F*		*LIC_SO*	
Technological Impact						
# Forward patent citations (Total)						
# Self Forward patent citations	*0.344*	*0.329*	*0.438*	*0.342*	*-0.108*	*0.123*
# Non Self Forward patent citations						
# Corp. applic. of citing patents	*-0.012*	*0.040*	*-0.157****	*0.059*	*0.13****	*0.049*
# Public applic. of citing patents	*0.091°*	*0.059*	*0.121*	*0.148*	*0.051*	*0.063*
Scientific Knowledge						
# Non-patent citations (Total)						
Self non-patent citation (dummy)	*0.326*	*0.402*	*0.923***	*0.433*	*-0.367*	*0.501*
#Non-self non-patent citations	*-0.007*	*0.016*	*-0.018*	*0.016*	*0.004*	*0.014*
Technological Knowledge						
# Backward patent citations (Total)						
# Corp. applicants of cited patents	*0.046°*	*0.030*	*0.026*	*0.034*	*0.042°*	*0.031*
# Public applicants of cited patents	*0.011*	*0.068*	*0.061*	*0.070*	*-0.127°*	*0.090*
# Self patent backward citations	*0.174*	*0.172*	*0.257°*	*0.164*	*0.015*	*0.192*
Ownership						
Collaboration						
# Co-assignees (Total)						
# Corporate co-assignees	*0.633****	*0.216*	*0.613****	*0.219*	*0.201*	*0.215*
# Public co-assignees	*-0.534****	*0.203*	*-0.361°*	*0.241*	*-0.552***	*0.266*
# Inventors (Total)	*0.0003*	*0.049*	*-0.066*	*0.066*	*0.038*	*0.055*
Academic Assignee						
UCL	*-1.324°*	*0.832*	*0.112*	*0.845*	*-4.338****	*1.351*
ULB	*-0.742*	*0.825*	*-0.144*	*0.836*	*-3.393****	*1.296*
ULG	*-2.094***	*0.904*	*-0.98*	*0.946*	*-4.503****	*1.371*
KUL	*-1.037*	*0.845*	*0.347*	*0.855*	*-4.095****	*1.338*
UG	*-1.683***	*0.849*	*-0.322*	*0.860*	*-4.456****	*1.346*
VUB	*-1.105*	*0.871*	*-0.775*	*0.955*	*-3.602****	*1.362*
IP Protection						
Geographical Protection						
Family size						
Application at USPTO (dummy)	*0.052*	*0.205*	*-0.109*	*0.235*	*0.231*	*0.234*
Application at JPO (dummy)	*0.559***	*0.216*	*0.589***	*0.238*	*0.098*	*0.252*
Content Protection						
Scope IPC 4	*-0.15**	*0.084*	*-0.187**	*0.107*	*-0.034*	*0.089*
# claims	*0.027****	*0.009*	*0.021***	*0.009*	*0.013°*	*0.009*
Biotechnological field	*0.128*	*0.198*	*0.082*	*0.236*	*0.141*	*0.234*
Priority year						
1985	*-1.281*	*1.632*	*-6.339*	*1.104*	*2.259*	*2.013*
1991	*1.009*	*0.948*	*-0.296*	*0.940*	*0.253**	*1.376*
1992	*-0.081*	*0.839*	*-0.794*	*0.824*	*1.086*	*1.259*
1994	*0.349*	*0.866*	*-1.234*	*0.935*	*2.582***	*1.313*
1995	*-0.519*	*0.774*	*-2.645****	*0.996*	*2.144**	*1.227*
1996	*0.077*	*0.778*	*-1.035*	*0.797*	*0.219**	*1.240*
1997	*0.268*	*0.803*	*-1.081*	*0.810*	*2.476**	*1.315*
1998	*0.674*	*0.756*	*-0.258*	*0.739*	*2.103**	*1.251*
1999	*0.406*	*0.763*	*-0.929*	*0.753*	*2.562***	*1.254*
2000	*0.606*	*0.772*	*-0.965*	*0.768*	*2.867***	*1.277*
2001	*0.237*	*0.789*	*-1.285°*	*0.789*	*2.6***	*1.288*
2002	*0.614*	*0.830*	*-0.54*	*0.833*	*2.563**	*1.324*
Log Likelihood	*-156*		*-118*		*-116*	

298 Observations; 1993: Time Reference. Levels of significance (probability threshold): ° <15%; * < 10%; ** <5%; *** < 1%