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IIR Working Paper WP#03-24

November 2003

Institute of Innovation Research
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Tokyo, Japan
http://www.iir.hit-u.ac.jp

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ABSTRACT
This paper aims at contributing to the literature on the determinants of patent value in two respects. It first puts forward new potential determinants of patent value which are mainly related to the identification of the institutional sources of knowledge and the geographical scope of patenting strategy. Second, it aims at validating the traditional and new determinants of patent value with academic patents. The empirical analysis focuses on 208 patent families applied by six main Belgian Universities. The patent value is approximated by the number of forward patent citations. The estimates confirm the role of most traditional determinants of patent value (e.g., backward citation and family size). Further, the new indicators underline the importance of identifying the institutional sources of knowledge. They provide a more in-depth view on the way non patent citations, backward patent citations, co-assignees, and the geographical scope for protection determine patent value. Policy implications emerge from these results, such as the benefit of local and international collaboration between public research organisations and the need to convince academic researchers with a high scientific profile in terms of publications to crystallize their tacit knowledge into high value academic patents.

JEL: XXX, XXX, XXX, XXX

Keywords: Patent value, patent indicators, knowledge sources.

Acknowledgment: This paper was partly written when Bruno van Pottelsberghe was Visiting Professor at the Institute of Innovation Research (IIR) of Hitotsubashi University, from July to December 2003. Financial support was provided by the SSTC, Belgium. We would like to thank Professors Sadao Nagaoka, Akira Goto, Hiroyuki Odagiri and the participants to the following seminars/conference for their useful comments: Tokyo University, 24 October 2003; MEXT, NISTEP, 27 October 2003; SPRU Conference, Sussex University, 19 November 2003.

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1. Introduction

Patents have been used to measure innovation performances for many years. They have been used as indicator of R&D output, as vector of knowledge spillovers, as a tool to assess the direction or strategy of research and as macroeconomic indicators of technological performances.[1] However the simple count of patents provides a highly biased view of the innovation reality, because their value distribution is highly skewed, as illustrated by Griliches (1990) and Scherer and Harhoff (2000) for instance. On average it is said that only one to three patents out of one hundred yield significant financial returns. This skewed distribution of patent value is at the origin of a small but burgeoning stream of economic research.

The main objective of this field of research is to identify the determinants of patent value. In this respect, forward patent citations (the number of citations a patent receives from more recent patents) has been identified as a major determinant of patent value. The other most important determinants are the family size (geographical scope for protection) and backward patent citations (the number of citations to previous patents). Several other potential determinants have been put forward recently.

The objective of this paper is to contribute to this literature on patent value. The contribution is twofold. It first aims at suggesting new determinants of patent value. These new indicators consist in improving the existing indicators (non patent citations, backward patent citations, co-assignees and family size) by formally identifying the related institutional sources of knowledge. Second, it aims at testing the validity of the traditional and new determinants of patent value with academic patents. Most of the existing literature focuses on business related patent applications. In the present analysis the focus is put on 208 patent families applied at the EPO (European Patent Office) by six Belgian universities.

This particular focus on academic patents finds its justification in the radical change observed in the patenting activity of Belgian universities since the early nineties. The number of patents has exploded since the late nineties, as witnessed by the filing of 142 patent families by the six universities, more than five times the number of patent families applied for during the late eighties period. One can further wonder whether these new academic patents have the same value determinants than the patents applied by the business sector.

The paper is structured as follows. Section 2 summarizes the existing literature on patent value. In the light of this literature section 3 suggests four new sets of potential indicators of patent value. The database and some basic indicators are presented in section 4. Section 5 concerns the empirical implementation and defines the various models that are used to identify the determinants of academic patent value. The empirical results are presented and interpreted in section 6. The last section concludes and provides some policy implications induced by our results. The results show that the new indicators related to the institutional sources of knowledge allow to improve our understanding of what determines the value of patents.

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[1] See e.g., Grilikes (1990) and Grilikes *et al.* (1986).

2. The literature on patent value

The skewed distribution is the main reason underlying the recent development of a literature specialised in the evaluation of patent value. Most of the empirical analyses in this field are summarized in table 1, and table 2.

It clearly appears that several empirical strategies have been used to approximate the value of patent. The existing studies listed in table 2 are not always comparable. They rely on different dataset (e.g. all patent applications in a regional office *vs.* a particular sector like biotech *vs.* a sample of firms in a given country), over various time span and with different data sources.

In addition, the functional forms of the empirical models vary from one study to the other. Some authors rely on the monetary value of each patent (Harhoff *et al., 1999,* 2002), on forward patent citations (Lerner, 1994), on a composite indicator (Lanjouw and Schankerman, 1999), on the probability to get a patent granted (Guellec and van Pottelsberghe, 2000), on patent opposition and renewal data (Pakes and Simpson, 1989 and, Lanjouw and Schankerman, 1997), and on whether a high-tech start-up has been created or not on the basis of the codified invention (Shane, 2001). As a matter of fact there are as many potential methodologies to approximate the value of patent as the number of existing investigations.

Similarly, the type and the number of explanatory variables that have been used as determinants of patent value are heterogeneous across studies. The most frequently used determinants are forward patent citations (when is not used as dependent variable), backward patent citation and the geographical scope for protection (number of countries in the patent family). Other variables rely on the concepts of opposition procedures, renewal data[2], application scope (claims) and non patent citations.

*** Insert table 1 around here ***

Despite this strong heterogeneity across studies, some similarities emerge. The most important one is probably the fact that forward patent citations (FPC) are closely associated with the value of a patent. All studies using forward patent citations reach this conclusion. In a similar vein, indicators of the geographical scope of protection of a patent (or family size) are closely related with patent value (see the bottom line of table 2).

Lanjouw and Schankerman (1999) develop a composite quality index significantly related to the decisions to renew and to defend a patent. They point out that forward citations and family size were important determinants to renewal decision but claims and backward citations were not. In the field of Computed Tomography scanners, Trajtenberg (1990) showed a close association between indicators based on forward patent citations (the number of citations from more recent patents) and independent measures of the social value of innovation in that field. Harhoff *et al.* (1999) also established for a set of German patented inventions that patents with greater economic value are more likely to be cited in subsequent patents.

A third indicator that has often been used and has received some substantial empirical validation is based on backward patent citations (BPC, the number of former patent cited by

[2] Schankerman & Pakes (1986) developed a model of patent renewal, considering that patent renewal decisions illustrate the value of a patent protection. Within four technology groups, Lanjouw *et al.* (1996) also used patent renewal to estimate a patent value index.

the inventors). Only two studies out of six studies using this indicator found that it has no significant impact on patent value.

*** Insert table 2 around here ***

Besides these three main indicators the other potential determinants that have been incorporated in patent valuation models have either led to conflicting results or received very little empirical validation. The biggest bone of contention concerns the scope of the invention (approximated by the number of claims and/or the number of technological classes associated with the invention).

On the one hand, Lerner (1994) examines how patent scope affects the valuation of new biotechnology firms. He finds that an increasing scope (measured by the number of four-digit IPC –International Patent Classification- classes into which patents are classified) of patent protection is associated with higher valuations. Focusing the 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. However, the valuable impact of the patent's scope is disputed by many authors, including Harhoff *et al.* (2002), Harhoff and Reitzig (2002) Guellec and van Pottelsberghe (2000, 2002) and Lanjouw and Schankerman (1997). The scope is sometimes inversely correlated with patent value, at least when measured with the number of technology class listed.

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.

The indicator based on non patent citations (NPC), or citations to the scientific literature has not been used extensively so far. Meyer (2000) underlines how important scientific tacit knowledge is important for inventive activity in certain fields: *scientific findings are important background knowledge playing an important indirect rather than a direct role*. However he argues that non-patent citations hardly represent a direct link between cited paper and citing patent. Experimental results vary. Analysing a set of German patent applied in 1977 and fully renewed until 1995, Harhoff *et al.* (2002) establish a significant positive impact of scientific citations on the monetary value of the patents. In another study, Harhoff and Reitzig (2002), investigating biotechnology and pharmaceutical patents, do not observe a significant influence of the number of non-patent citations on the probability that a patent will be opposed (considered as a value indicator).

In a nutshell, it clearly appears from the literature survey that the number of forward patent citations is one of the most important determinants of patent value. It is closely followed by the family size and backward citations. The scope of an invention has an ambiguous impact whereas non patent citations received little empirical support. One objective of this paper is to put forward more detailed indicators that would improve our understanding of patent value. The second objective is to test whether these indicators are valid in the case of academic patents.

3. New indicators of patent value

The central hypothesis that we put forward is that a more precise definition of the components of the existing value determinants might improve our understanding of what determines patent value. Most indicators reflect to some extent a broad source of knowledge : non patent citations are deemed to approximate the science base of an invention; backward patent citations reflect the codified origin of the technological knowledge used for an invention; the co-assignees indicators potentially measure the extent to which different sources of tacit knowledge have been merged in a single research objective; and patent family size witnesses the financial resources used to extend the intellectual property abroad.

Figure 1 illustrates how these four indicators might be improved through a more precise *'institutional'* typology. We put forward that if these indicators broadly reflect the sources of knowledge that have been used to invent a patent, they might be improved through a formal identification of their institutional origins. Similarly, the number of countries chosen for the international protection phase can be disaggregated into some strategic geographical choices.

*** Insert figure 1 around here ***

The scientific sources of knowledge, or non patent citations, have been little investigated in the literature, and no conclusive result has emerged. However, an important distinction can be made between self citations and non-self citations to the scientific literature (see the Eastern quadrant of figure 1). Self citations to the scientific literature can be assumed to represent an invention that is based on the researcher's (or the team's) own scientific and tacit knowledge. Non-self citations would have a lower potential impact on the value of an invention for two main reasons. First, it is a citation that is available to all inventors and is therefore open to competition from the rest of the world (scientific publications are in the public domain). Self citations also refer to the public domain but implicitly mean a large potential tacit knowledge associated with a substantial – and recognised- experience in the field of research. It can be assumed that an inventor that uses its own tacit knowledge (part of which has been published) is more likely to translate it into a successful invention. Second, it is well known that a substantial proportion of citations is imposed by patent examiners. These citations, although indubitably related to the field of research, would not have any, or at most very little, direct influence on the quality, and hence value, of an invention. Self citations would always appear in the patents (few scientists or researchers would forget to cite their own work), without any intervention from a third party.

Backward patent citations (the Western Quadrant of figure 1), or the technological source of knowledge, has been extensively validated as an indicator of patent value. The inventions that cites backward inventions are either architectural (i.e., merger of different technologies) or incremental (improvement of an existing invention). In the former case one can expect a higher value of the invention. In the latter case it depends on the incremental step. A small increment would probably be associated with a lower return than a large increment. The only information that allows to differentiate the cited inventions relates to their institutional origins. A cited patent can be applied by a public research institution (the invention is sourced from the scientific community), by a private firm (the invention is sourced from an invention that is being potentially exploited by the firm), or by the research team itself (self backward citations).

The relationship between these three institutional sources of technological knowledge and the quality or value of an invention (whether it is incremental or architectural) is far from being clear-cut. It can be expected, however, that the patents that cite other patents invented by public research organisations (PRI) are more related to the scientific field and face less potential competition on the final product market than the cited patents that have been applied by a firm (firm use patent for exploitation or licensing purposes). Self backward citations would relate more (implicitly) to incremental inventions and would therefore reflect mainly incremental inventions that would in turn be associated with a lower potential value.

The number of co-assignees (Southern quadrant of figure 1) has been little investigated as determinant of patent value in the literature. Nevertheless, it reflects either an active research collaboration, and/or a contractual research and/or an independent research project but whose intellectual property has been applied for by one of the co-assignees in order to commercialize the invention or license it. Co-assignees can be firms or public research institutions. The former type of co-assignee would witness either an active collaboration in research or a contractual research. The potential effect of these co-assignees is unclear. If it is purely a contractual research for the development of an invention one might expect a lower potential value (otherwise the research project would be implemented by the firm so as to avoid any potential knowledge leakages). On the other hand, if it is performed under a collaborative framework, where two knowledge bases and research skills are merged, one might expect a higher impact on the value of the invention. If the co-assignee is a public research institution a higher potential value can be expected as the knowledge-base of the invention would be related to more research efforts from the scientific sector.

The fourth indicator of patent value is the geographical scope of protection, or family size (Northern quadrant in figure 1). This indicator suggests that a patent that has been applied for in several countries is associated with a much higher value than a patent applied only in one country or region. However, countries differ markedly in terms of both size and technological intensity. It might therefore be expected that a patent extended to the US (for non US applicants) is more valuable than a patent applied only to the Australian market for instance. From a European viewpoint, this assumption can be tested by simply looking at the patents that have been applied in the United States and/or Japan, by far the largest 'homogenous' markets in the world.

4. The Database on academic patents in Belgium

Since 1985, Belgian universities have increasingly invested in the protection of their intellectual property. To assess this evolution, patent data have been collected in July 2002 through the DELPHION online database. In a first stage, the patents applied by the 19 Belgian universities or university faculty centres[3] were gathered. In a second stage the focus has been put on the six most productive universities in term of patent applications.[4] This study does not display the patents that have been invented at university but applied by another assignee [5].

[3] The universities from the French-speaking community are: Ulg, UCL, ULB, UMH, FUSAGx, FUNDP, FPMs, FUSL, FUCaM, FUL. The universities from the Flemish community: KUL, LUC, KUB, UA, RUCA, UFSIA, UIA, UG, VUB. Acronyms are defined in Annex 1.

[4] For the period 1985-1999, the KUL, UG, VUB, UCL, ULB and Ulg were holding 94% of the identified Belgian universities' patents.

[5] Saragossi and van Pottelsberghe (2003) show that the risk of having a wrong picture of patentable research looking exclusively at the patent filed by the universities is extremely high. It must be noticed that universities may use different names to file their patents. For instance KUL has used many names like KULeuven, R&D

The patents were grouped in families. A patent family is the set of patents characterised by the same priority number. To take into account only the potentially most valuable patents, it was decided to analyse the patent families whose at least one member was applied at EPO (European Patent Office). This selection criteria was preferred to the analogue one of having a member applied at the USPTO (United States Patent and Trademark Office). This choice has been made considering that EPO applications for the Belgian universities give a more complete view of universities' patenting strategy.

The six most active patenting Belgian universities (KUL, UG, VUB, UCL, ULB, Ulg) have applied for 208 patent families (with a priority date ranging from 1985 to 1999) at the EPO. Among these, 78 EPO patents have also been applied for at the USPTO. Only seven other patents have been applied at USPTO without being applied at the EPO. The period of investigation ranges concern the priority dates going from 1985 to 1999. This selection is due to the patenting process and the constraints of the data collection. The choice of the upper bound (1999) can be explained by two facts. On the one hand, there is a delay between the reporting date of the application in a database and the application date at a patent office. On the other hand, the PCT (Patent Co-operation Treaty) procedure is increasingly used. This procedure allows the decision to extend internationally the rights of the patents to be delayed (delay of 30 months after the priority date). Therefore, as far as this paper is focused on EPO patents, the extension of the date field after 1999 creates the risk of missing patents that are not primarily applied at EPO but whose protection could be extended to EPO by the end of the PCT procedure. Before 1985, the patenting activities of the Belgian universities were limited, 9 patents were applied at the EPO (5 by UCL, 1 by Ulg and 3 by KUL).

In what follows, unless specified, the use of the term "patent" will refer to patent family whose priority date is between 1985 and 1999 and of which one member at least has been applied at EPO. Table 3 presents the number of patent applications of the six Belgian universities over three 5 year-sub periods; the late eighties, the early nineties and the late nineties; and for the whole period ranging from 1985 to 1999.

*** Insert table 3 around here ***

There has been a spectacular growth of patent applications by Belgian universities. Actually, an increase of 44% has occurred between the late eighties period (1985-1989) and the early nineties period (1990-1994). This increase was followed by a huge growth of 264% that occurred between the early nineties and the late nineties (1995-1999). This evolution of the number of patent applications is more emphasized for the Flemish universities for which the first increase rate was 53% and the second was 322%, whereas the growth rates for the French speaking universities were respectively 33% and 181%. More recent data are not available for all universities for methodological reasons. However, it must be noticed that this tremendous increase has continued since 1999. The Brussels' University (ULB), for instance, has applied for more than 30 patents since the year 2000, a larger number than all patents applied for during the 15 previous years.

*** Insert table 4 around here ***

Leuven and REGA. These corrections have been implemented for the construction of our database. However, independent inventors and the patents invented in a university but applied by a firm were not taken into account.

Table 4 displays the number of forward patent citations received by the patents applied for between 1985 and 1999. It shows that KUL at the present time is the university with the highest number of patents and the highest patent quality in average. Conversely, the 5-FPC index shows that patents at KUL are on average cited less rapidly than the patents of other universities. [6]

On average, for the patents applied during the period 1985-1999, French-speaking universities received less citations overall than their Flemish counterparts but more within the five years following the priority date. However these facts hide other realities: the Flemish average is tremendously increased by the good results obtained by the KUL's patents applied between 1985 and 1994 (especially during the late eighties). The other Flemish university patents have been mainly applied during the late nineties, diminishing the probability to be already cited. Nevertheless, VUB's patents seem to be very promising with an average number of 5-year forward patent citations close to that for the patents applied during the late nineties. Except for the VUB's patents, the other recent Flemish patents (UG and KUL) are the ones with the smallest short-term (5 years) value determinants.

*** Insert figure 2 around here ***

Figure 2 shows that the well-known skewness of patent value distribution also holds for academic patents. Considering that value can be approximated by forward patent citations, this figure shows that among the 208 patent families applied by Belgian universities at EPO between 1985 and 1999, 140 patents weren't referenced by any subsequent patent whereas only two received more than 30 patent citations. The next section presents the econometric model that aims at explaining this skewed value distribution of patents.

5. Empirical implementation

To evaluate the value determinants of Belgian universities' patents, different Poisson models are used. Since we don't have the monetary value of the patents and according to conclusions drawn from the literature, the choice to approximate patent value by the number of forward citations was made. The choice of Poisson models - count models- relies on the fact that the value proxy was the number of forward patent citations: the used dependent variable was expressed as integers.

Equation (1) presents the general form of Poisson model.

$$y = \mathrm{B}X \qquad (1)$$

Where y is the independent variable, B, is the raw vector of the unknown parameters and X, is the column vector of the independent variables. The conditional density of y given x (an independent variable) is the Poisson distribution:

$$f(y|x,\beta) = \frac{e^{-m(x,\beta)} m(x,\beta)^y}{y!}$$

[6] More exhaustive descriptive statistics are available in annex 2.

where β is the parameter associated with the explanatory variable *x and m(x, β)* is the conditional mean of the dependent variable *y*. The conditional density of FPC given any independent variable is supposed to follow a Poisson distribution.

The dependent variable of our models is the number of all forward patent citations received from patents of any intellectual property office (FPC). This number wasn't limited to the amount of forward citations received within the five years following the priority date because the delay between the priority date of the university patent and the filling date of the first patent citing the university was on average of about 6 years.

The basic econometric model is described in equation (2). It is mainly based on the existing studies described in table 2. It includes three types of variables. The first one are the controle variables (CV). They mainly take into account the characteristics of the patent (the age of the patent, the number of inventor and whether it is in the biotech sector or not). The second type of variables are the value determinants (VD). They are composed of non patent citations, backward citations, the number of co-assignees and the family size. The third type of variables are the six main universities fixed effects (UNIV). As the universities have different endowments and processes to manage knowledge transfer. The estimates will confirm whether, taking into account the control variables and the value determinants, university effects vary across universities.

$$FPC_i = \sum_{m=1}^{3} \alpha_m CV_i^m + \sum_{j=1}^{4} \beta_j VD_i^j + \sum_{k=1}^{k=6} \gamma_k UNIV_i^k \qquad \textbf{(2)}$$

where FPC_i is the number of forward patent citations of each patent [i = 1,…, 208]. The vector of unknown parameter is $[\alpha_1,\ldots,\alpha_3,\beta_1\ldots,\beta_4,\gamma_1,\ldots,\gamma_6]$. CV^m holds for m = 1 to 3: YEARS (the age of the patent since 1985), INV (the number of inventors involved in the patent) and BIO (whether the patent is in the biotech sector). VD^j holds for j=1 to 4 : FAM (the family size), BPC (backward patent citations), NPC (non patent citations), and COAS (the number of co-assignees. $UNIV^k$ holds for k=1 to 6 (the six universities included in the present analysis: UCL, ULB, ULG, KUL, UG, VUB). The estimation strategy is first to estimate equation (2), as the basic model. In a second stage each value determinant is disaggregated into its various components, as described in section 3 and figure 1.

Control variables (CV)

Universities' patents are not cited immediately after filling. It is assumed that the older a patent, the more forward patent citations it will receive. This time effect is taken into account by the variable *YEARS*. It is computed as the difference in years between the priority date of the patent and the year 1985 (lower bound of our sample). It is therefore expected to have a negative impact on our proxy of patent value. *INV* is the number of inventors involved in the invention codifies in a patent.

The third control variable is *BIO*. The 208 patent families has been divided in two big technological fields: the biotechnological ones and the others[7]. Table A4.1 in the appendix

[7] To make the distinction between these two parts, we use the 4-digit IPC classifications. We have considered that a patent is part of the biotechnological field if its principal technological field is related to health, to environment, to organic chemistry or to biology. Annex 3 reports the related field for each 4-digit IPC classes that we have found in university's patents.

suggests that patents in the biotech sector have a higher probability to get at least one citation than the patent in the non biotech sector. Only 13 to 14 per cent of the patents that were applied in the late nineties have already at least one citation, whereas 85 percent of the biotech patents applied in the early nineties have received a citation. This last figure drops to 40 per cent for the non bio tech sector. Furthermore, an average of 2.57 patents has referenced a biotech university patent whereas only 0.8 patent has cited a non-biotech university patent.

Value determinants (VD)

The extent to which a patent is partly or fully based on scientific knowledge can be approximated with the number of non patent citations (NPC). Although the literature on patent value has not extensively used this variable, we incorporate it in the model. In addition, this variable has been disaggregated into two variables, as suggested in section 3: the number of citations to the inventors' scientific papers (self citations) and the number of citations to other scientific papers (non self citations). However, the available data in the database creates a bias: the self-literature citations are underestimated and the non-self literature references overestimated. Actually, partial information is available, because for each literature citation, only the name of the first author is referenced in the database. These two variables may be more relevantly seen as the number of literature citations for which one of the inventors is the principal author[8] and as the number of references to papers for which none of the inventors is the first author.

The second value determinant often used in the literature is the number of backward patent citations (BPC). According to our hypotheses, this variable can be disaggregated with respect to the institutional origin of cited patents. They have been clustered under three categories: the number of corporate applicants (firms or corporate R&D centres), the number of public institutional applicants (universities, hospitals, public research centres, state departments) and the number of self citations (citations to own previous inventions). The basic idea with this second approach is to test to what extent the quality and value of academic patents depends on the institutional origin of the invention. Most applicants of the backward patent citations are firms (53%)[9]. A non-negligible proportion of these backward patent citations are citations to a university's own previous patents (6%).

To assess the impact of a collaboration between different knowledge generating institutions, the number of co-assignees applying with the university has been computed (COAS). Only juridical entities have been looked at. COAS is the total number of co-assignees. In a second stage these co-applicants have been disaggregated into three categories: the corporate co-assignees (industries, corporate R&D centres), the international public co-assignees (non-Belgian public entities like universities, hospitals, public research centres, state departments) and the national public co-assignees (Belgian public entities like other Belgian universities, hospitals, public research centres, state departments etc…).

As suggested in the literature survey, family size (FAM) is one of the most relevant indicators of patent value. The variable takes into account the number of patents that are member of the family. The second approach is to disaggregate this information and to focus the analysis on

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[8] 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.

[9] It must be kept in mind that some of these 'corporate' patents might well have been invented in an academic research department.

two variables describing whether the EPO universities' patents are also applied at the JPO and/or at the USPTO. These variables take the value one if applicable.

The analysis of the size of a patent family pinpoints the same difference: biotech patents are more likely to be applied abroad than the non-biotech ones. 78% of biotech patents applied between 1985 and 1994 at the EPO were also applied at the JPO, 67% of these patents were also applied at the USPTO. Globally, 56% of the EPO bio patents applied between 1985 and 1994 were simultaneously applied at the JPO and the USPTO. These percentages fall respectively to 54%, 36% and 36% for the non-biotech patents. These statistics advocate that a patent applied in a biotech field is more likely to be cited than a patent in another technical field. To test this hypothesis, a dummy variable BIO is computed. This variable takes the value one when the patent technical field is biotechnology.

All these variables are used consecutively in six variants of the basic model described in equation (2). Model 2 disaggregates the information contained in the number of non-patent citations. Model 3 disaggregates the information contained in the number of backward patent citations. Models 4 and 5 disaggregate the information contained in the number of co-assignees. The information contained in the number of patent family members is disaggregated in Model 6. The last one, Model 8, presents the results with all value determinants disaggregated into their institutional origins.

6. Empirical results

Table 5 (a and b) presents the econometric results of seven variants of the basic Poisson model defined in equation (2). All these models have the number of forward patent citations as dependent variable. Model 1, relies on a set of thirteen 'basic' variables to explain the number of forward citations received by each academic patent in Belgium between 1985 and 1999. It includes the three control variables, four broad value determinants, and the universities' fixed effects. The subsequent models aim at improving this first model through a more detailed approximation of the three sources of knowledge (NPC, BPC and COAS) and of the patenting strategy regarding the geographical scope for protection.

The first column of table 5 shows that the age of a patent is positively correlated with its value. The difference between the priority date and 1985 has a significant negative influence on the number of received citations. The newer a patent, the more limited the probability to be already cited. The second control variable, the number of inventors (INV), has no impact on patent value, contrary to the conclusions of Guellec and van Pottelsberghe (2000, 2002). This difference might be due to the fact that they use all patents applications at EPO – i.e., mainly corporate patents.[10] The last control variable, BIO, has a positive and significant impact. This illustrates the rapid growth of research in the biotech sector, which yield more forward citations than the other sectors.

*** Insert table 5 (a and b) around here ***

[10] This study approximates the patent value by the number of received forward citations. In Guellec and van Pottelsberghe 's study, this value is evaluated by looking whether the patent is granted or not. The insignificant impact in the present study might also be explained by the fact that most academic patents are invented by a team of researchers. Therefore, there is little heterogeneity in this variable.

Amongst the value determinants, one can see that backward patent citations, the family size and the number of co-assignees have all a positive and highly significant impact on the value of patents. Non patent citations have no significant impact. This non significant result regarding the references to the scientific literature differs from the results of Harhoff *et al.* (2002). It might be due to the fact that all university patents have a strong tendency to cite the scientific literature. If this is the case, the NPC variable would not allow to differentiate the academic patents included in the database. University inventions are supposed to translate into more science-related patents than in the data set of Harhoff *et al.* (2002), which is mainly composed of patents applied by German business firms. This hypothesis is somewhat validated by the results of Harhoff and Reitzig (2002), who focus on biotech and pharmaceutical patents and do not observe any significant impact of non patent citations on their value indicator. It might also be that only university patents with a very large number of scientific references are more valuable. To validate this hypothesis, future verifications have to be performed, maybe through a quadratic model.

Model 2 suggests that the issue at stake is not really the total number of non patent citations but rather the origin of these citations. Self citations (the number of citations to scientific papers whose first author is one of the inventors) have a positive and significant influence on patent value, whereas non-self citations to the scientific literature are associated with a negative and significant parameter. These results suggest that the universities' most valuable patents are those for which the inventors (inventors who have successfully published in the field) master the related science base and decide to investigate further towards the crystallization of their tacit knowledge into technological inventions.

A second important determinant of patent value is backward patent citations. Model 1 shows that it indeed positively correlates with patent value. Model 3 investigates further the mechanism through which backward citations affect value by looking at the institutional origin of the cited patents. As suggested in the new methodological framework depicted in figure 1, disaggregated information on backward citations induces a better fit of the number of forward citations. The results clearly show that patents citing former university patents invented by at least one similar researcher (citations to self) are significantly less cited. One explanation might be that self backward citations witness mainly an incremental invention rather than a breakthrough invention. When the cited patents are invented by public institutions they seem to be significant and positive determinant of patent value. A similar relation occurs when the cited patents have been invented by firms, but to a lower extent. The lower impact of backward citations to patents invented by firms might be due to a weaker scientific content in the invention.

Model 1 also illustrates the positive impact of co-assignees on the number of forward patent citations. Similarly to non patent citations and backward citation we have investigated whether the institutional origin of the co-assignees affects this result. Model 4 shows that it is the case. Academic patents co-applied with either national or international public institutions are more likely to be cited.[11] In particular, the number of national public institutional co-assignees has the most significant and positive impact on the number of forward citations. Usually in those kinds of research projects, public research institutions involve their own

[11] Guellec and van Pottelsberghe (2000, 2002) show that the success rate of EPO patent applications that are filed by more than one domestic applicant is lower than for the applications filed by one co-applicant, but if the co-applicants are from different countries, the probability is higher. The present results partly fit with theirs. The main difference is most probably due to the fact that Guellec and van pottelsberghe used all patent application at EPO, which originate from the business sector.

researchers. Proximity might explain why national co-operations seem to be more fruitful than international ones. It allows for closer and stronger links between researchers and would therefore induce a more active cooperation. Patents that have been applied jointly with a firm do not seem to be associated with a significantly higher (or lower) number of forward citations than the average academic patent. Co-assignation with an enterprise sometimes does not reveal scientific co-operation but only the commitments of a research contract sharing the ownership of intellectual rights between the university (the research partner) and the industry (the financial partner).

We noticed that several academic patents (originating from Flemish universities) have been applied jointly with IMEC. [12] This public institution has been created by the Flemish Region as a consortium between the various academic departments specialised in information technology. It mainly aims at fostering university-industry knowledge transfer, by providing technical support and expertise in the field. The advantage of such an institution is that it is specialized in one field (information technology) and provides skilled support to several academic institutions. The estimates presented in model 5 suggest that the patents that have been applied jointly with IMEC are associated with a larger number of forward citations than the patents that have been applied jointly with another Belgian public institution (generally an academic institution). However this difference is not statistically significant.

The fourth indicator of patent value relates to the family size. In line with the findings of most existing findings Model 1 shows that the size of patent family is an important determinant of patent value. However, as argued in section three, some 'members' of a family might provide a more precise approximation of patent value. This idea is validated by Model 6. It shows that that an application at the JPO and/or at the USPTO has a positive and significant impact on the probability of a patent to be referenced by a subsequent one; especially the application at the USPTO, which is one of the most relevant predictors of the patent value, at least for Belgian academic inventions. This result is consistent with those obtained by Guellec and van Pottelsberghe (2000). They found that amongst all the patent applications at EPO, those that had a sound geographical strategy (the designation of a few European countries for protection) had a significantly higher probability to be granted.

Model 7 presents the estimates of the basic model with simultaneously disaggregated value determinants of the number of forward patent citations. The estimates are very close those of Models 2 to 6, and therefore reinforce the robustness of the results presented in the previous models. We also performed several regressions of Model 1 and Model 7 with only five universities (we consecutively dropped one university from the sample). The estimated parameters were stable (the results are available on request).

Since self backward citations have a negative and significant impact on the number of forward citations a patent receives one could logically wonder whether the dependent variable should be neat of 'self' forward citations. Indeed, many inventors might prefer to see their inventions to be cited more by other inventors than by themselves. Models 8 to 13 in table 5 aim at testing whether the institutional origin of FPC affects the empirical results. We use as dependent variable either the total number of forward citations, or the non-self forward citations or the forward citations exclusively made by firms. The estimates with the traditional

[12] IMEC (Interuniversity MicroElectronics Center) is an independent research centre in the field of microelectronics, nanotechnology, based in Flanders. Between 1985-1999, IMEC has co-applied 6 patents with VUB (on a total of 9 non-biotech patents), 7 patents with UG (on a total of 13 non-biotech patents) and 2 with KUL (on a total of 12 non-biotech patents)

variables are very stable. All the parameters keep their size and significance, except for the family size variable, which is no more significant with non-self FPC and corporate FPC. The results are also stable with the disaggregated model that includes the new variables (Models 11 to 13). The only difference occurs with self non-patent citations (no more significant) and the application in the Japanese Patent Office or the USPTO.

One might also wonder whether the recent growth in patent applications by Belgian universities witnesses a surge in innovative activity, or whether it merely reflects a higher propensity to patent innovations of lower quality or value. In the USA, Henderson *et al.* (1998) show that patenting by universities has risen dramatically in the last 25 years and that this increase is clearly associated with an overall increase in university attention to commercial applications of technology. However, they also notice that "*despite the approximate doubling in the total number of patents after 1980 [Bayh-Dole Act], there is no increase in the number of very important patents" and suggest that "their results could reflect either a change in the internal research culture of the US universities that makes scientists and engineers get involved in more applied research with less significant patents or the effects of entry into patenting after 1980 by institutions with little experience and expertise in patenting*".

These last conclusions are however criticized by Mowery *et al.* (2001a, 2001b, 2002) and Sampat *et al.* (2003). They argue that there is a truncation bias in Henderson's data and observe that universities with substantial pre-1980 patenting experience display no decline in importance and generality of their patents after 1980. They conclude that "*any changes in the characteristics of the U.S. university patents after 1980 are due in large part to entry, rather than to changes in university culture*." [Mowery *et al.,* 2001b – Page 1] They also stress that university patenting experience and learning aspects are key elements for applying important patents.

The university characteristics presented in the seven models of table 5 seem to confirm this latter argument. For instance, the university that has had the largest increase in patenting activity is the KUL. Its fixed effect in most regressions is an intermediate position which is not significantly different from those of the other five universities. We cannot conclude, therefore, that the recent surge in patenting activity by Belgian universities witnesses a higher propensity to patent inventions of lower value. It would rather suggest that it reflects a higher propensity to patent inventions of high potential value.[13]

[13] Model 7 is the only one where the university effects seem to be significantly different for some universities. However it is difficult to know whther the difference is due to potential multicollinearity biases (due to the high number of explanatory variables) or whether it is due to heterogeneous effectiveness of knowledge transfer management, as suggested by Mowery *et al.* (2001b) for American universities.

7. Concluding remarks

The intended contribution of this paper to the existing literature on patent value was twofold. It first aimed at improving the traditional determinants of patent value. The second objective was to test the validity of these new indicators as determinants of patent value for academic patents.

Regarding the methodological framework, the novelty consists in a desaggregation of the existing traditional determinants into the institutional origins of scientific and technological knowledge. The scientific knowledge base, which is approximated by the number of non patent citations can be disentangled into self and non-self citations to the scientific literature. The technological knowledge, usually approximated by the number of backward patent citations, can be disentangled into the institutional origin of the cited patents. Potential collaboration between different institutions can be disentangled into the type of collaborative institutions. Finally, we put forward that an alternative to the family size of a patent can be approximated by simply taking into account some of the largest 'homogenous' market targeted for protection, like the United States and Japan (from a European viewpoint).

The traditional structural form of the determinants of patent value and the new determinants put forward have been tested on the academic patents applied by six major Belgian universities. The patent value indicator that is used is the number of forward patent citations. The empirical results confirm the traditional results of previous analyses on corporate patents and validate them for Belgian university patents. Controlling for its age and its technological field, the most important value determinants of a patent are its family size and the number of backward patent citations. As far as academic patents are concerned, the presence of a co-assignee also seems to improve the patent value. This is probably due to an effective collaboration or an improved selection process. Another specificity of academic patents is that the total number of non patent citations does not seem to be an indicator of patent value. This last result might be due to the fact that most academic patents have a strong propensity to cite the scientific literature.

However, when these traditional indicators of patent value are disentangled according to their institutional origin, some interesting results appear. Regarding the citations to the scientific literature, the results suggest that the issue at stake is not really the total number of non patent citations but rather the origin of these citations. Self citations (the number of citations to scientific papers whose first author is one of the inventors) are a positive and significant indicator of patent value, as opposed to non-self citations. In other words, some of the universities' most valuable patents are those for which the inventors attempt to investigate further towards the crystallization of their tacit knowledge into technological inventions.

Similarly, the disaggregated information on backward patent citations induces a better fit of the number of forward citations. The results clearly show that self backward patent citations are associated with a lower patent value, as opposed to the backward citations to patents that have been invented by a public research institution or, to a lower extent, by a firm. The negative impact of self backward patent citations is probably due to the fact that these patents witness mainly an incremental invention.

Academic patents co-applied with either national or international public institutions are more likely to be cited. The number of national public co-assignees has the most significant and positive impact on the number of forward citations. This might be the results of an active collaboration between public institutions that have a strong scientific knowledge base. Academic patents that have been applied jointly with a firm do not seem to be associated with a significantly higher (or lower) number of forward citations than the average academic patent. The identification of some 'members' of a patent family also provides a more precise approximation of patent value. When a patent is applied at the JPO and/or at the USPTO, it is associated with a higher value than the other patents.

All these results stay quite stable when the dependent variable, total forward citations, is replaced by non-self forward citations or by corporate forward citations.

Several policy implications emerge from the improved indicators of patent value put forward in the present paper. The first one is related to the highly significant and positive impact of self citations to the scientific literature. This result clearly shows that when a patent is invented by a researcher who uses its own scientific and tacit knowledge, it crystallizes into a potentially higher economic value. That is, the current policies aiming at fostering knowledge transfer from the university to the industry should try to stimulate the academic researchers with a high scientific profile in terms of publications. Second, academic patents emerging from collaboration with a local or a foreign public research organisation are associated with a significantly higher value than other academic patents. This result validates the current Belgian Federal S&T policy (as well as the 6th Framework Programme implemented by the EC Directorate General for Research at the EU-wide level) that consists in fostering institutional collaboration. Third, a sound patenting strategy that consists in targeting the United States and Japan, seem to be a powerful predictor of patent value.

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9. Annex 1

FPMs	: Faculté Polytechnique de Mons
UMH	: Université Mons-Hainaut
FUL	: Fondation Universitaire Luxembourgeoise
FUSL	: Facultés Universitaires St Louis
FUNDP	: Facultés Universitaires Notre Dame de la Paix
FUSAGx	: Faculté Universitaire des Sciences Agronomiques de Gembloux
Ulg	: Université de Liège
ULB	: Université Libre de Bruxelles
UCL	: Université Catholique de Louvain
LUC	: Limburgs Universitair Centrum
UA	: Universiteit Antwerpen (groups the 4 Antwerpen university institutions UA, UIA, UFSIA, RUCA)
VUB	: Vrije Universiteit Brussel
UG	: Universiteit Gent
KUL	: Katholiek Universiteit Leuven
KUB	: Katholiek Universiteit Brussel

10. Annex 2: Descriptive statistics on indicators of patent value by university

11. Annex 3

Table A3.1 : IPC Codes classified in biotechnological or non-biotech scientific fields

IPC principal Code	*BIO-NBIO*	*IPC principal Code*	*BIO-NBIO*	*IPC Code principal*	*BIO-NBIO*
A01H	B*	C01F	N	F21V	N
A01K	B	C04B	N	G01B	N
A01M	B	C07B	B	G01F	B
A23K	B	C07C	B	G01J	N
A23L	B	C07D	B	G01L	N
A61B	B	C07F	B	G01N	B/N**
A61F	B	C07H	B	G02B	N
A61K	B	C07K	B	G06F	N
A61L	B	C08F	B	G06T	N
A61M	B	C08G	B	G10K	N
A61N	B	C08L	B	G21K	N
B01D	B	C10L	N	H01L	N
B01F	N	C11B	B	H01Q	N
B01J	N	C12N	B	H01S	N
B09C	B	C12P	B	H03F	N
B26F	N	C12Q	B	H03K	N
B29C	N	C22B	N	H04B	N
B29D	N	C23C	N	H04J	N
B31D	N	C25D	N	H04L	N
B32B	N	D03D	N	H05H	N
B62D	N				

* B : biotechnology field; N: non biotechnology field

** The IPC class G01N is a class linked to instrumentation apparatus related to the investigation or the analysis of materials by determining their chemical or physical properties. We have considered here that the patent within this classification could be a biotech patent or not. To determine in which field it should occur. We have looked at the others listed IPC codes. If they were biotechnology classes (as defined in the table). the patent was considered to be applied in the biotech field. Otherwise. the patent was considered to be a non biotech patent.

12. Annex 4: Descriptive statistics of determinants of patent value by technological fields

Table A4.1 : Descriptive statistics : Percentage of patents cited at least once by technological field and application priority period

Percentage of patents having received at least one forward citation	*Biotechnological field*	*Others technological fields*
1985-1989*	66.7%	50%
1990-1994*	85.3%	40%
1995-1999*	13%	14.3%

* Priority Date of the university patents
Biotech field : 1985-1989 : 21 patents 1990-1994: 34 patents 1995-1999: 100 patents
Non-Bio field: 1985-1989 : 6 patents 1990-1994: 5 patents 1995-1999: 42 patents
Source: own calculations based on Delphion database information

Table A4.2 : Descriptive statistics : Percentage of patents applied at the JPO and at the USPTO by technological field and application priority period

Percentage of the EP applications applied also elsewhere	*Biotechnological fields*			*Non-biotechnological fields*		
	Applied at JPO	Applied at USPTO	Applied at JPO & USPTO	Applied at JPO	Applied at USPTO	Applied at JPO & USPTO
1985-1989*	71.4%	52.4%	42.9%	66.7%	33.3%	33.3%
1990-1994*	82.4%	76.5%	64.7%	40.0%	40.0%	40.0%
1995-1999*	28.0%	24.0%	17.0%	33.3%	31.0%	16.7%

* Priority Date
Biotech field : 1985-1989 : 21 patents 1990-1994: 34 patents 1995-1999: 100 patents
Non-Bio field: 1985-1989 : 6 patents 1990-1994: 5 patents 1995-1999: 42 patents
Source own calculations based on Delphion database information

Table A4.3 : Descriptive statistics : Number of citations per university patent by technological field

Fields	*# Backward citations per application*	*# Forward citations per application*	*# Forward citations per application within 5 years after the priority date*	*Percentage of EP application with at least 1 forward citation*	*# Non patent citations per application*
Biotechnology	2.66	2.57	0.20	36.1%	4.02
Others	2.85	0.80	0.28	20.8%	1.25
Total	2.71	2.12	0.22	32.2%	3.31

208 family patents whose priority dates are comprised between 1985-1999
Biotech field: 155 patents Other technical fields: 53 patents
Source: own calculations based on Delphion database information

13. Annex 5: Descriptive statistics on backward patent citations

Table A5.1 : Descriptive statistics: Type of assignees of the backward patent citations of the Belgian university patents applied between 1985-1999

Priority year of the university patents	*Average number of BPC[0] per university's patent*	*Average number of assignees per BPC*	*% of private assignees in BPC*	*% of international academic assignees in BPC*	*% of international public institutional assignees in BPC*	*% of national academic assignees in BPC*	*% of self BPC*	*% of national public institutional assignees in BPC*	*% of individual[1] assignees in BPC*
1985-1989	4.33	1.09	45.3%	5.5%	28.1%	0.0%	7.8%	0.8%	12.5%
1990-1994	4.71	1.15	54.5%	5.7%	20.4%	0.0%	9.0%	0.9%	9.5%
1995-1999	1.84	1.12	55.8%	9.5%	12.6%	0.3%	3.7%	0.3%	17.7%
1985-1999	2.71	1.12	53.2%	7.4%	18.3%	0.2%	6.3%	0.6%	13.9%

0 BPC : Backward patent citations
1 Individuals are considered as an unique assignee
Source: own calculations based on Delphion database information

Table 1 : Literature on patent value

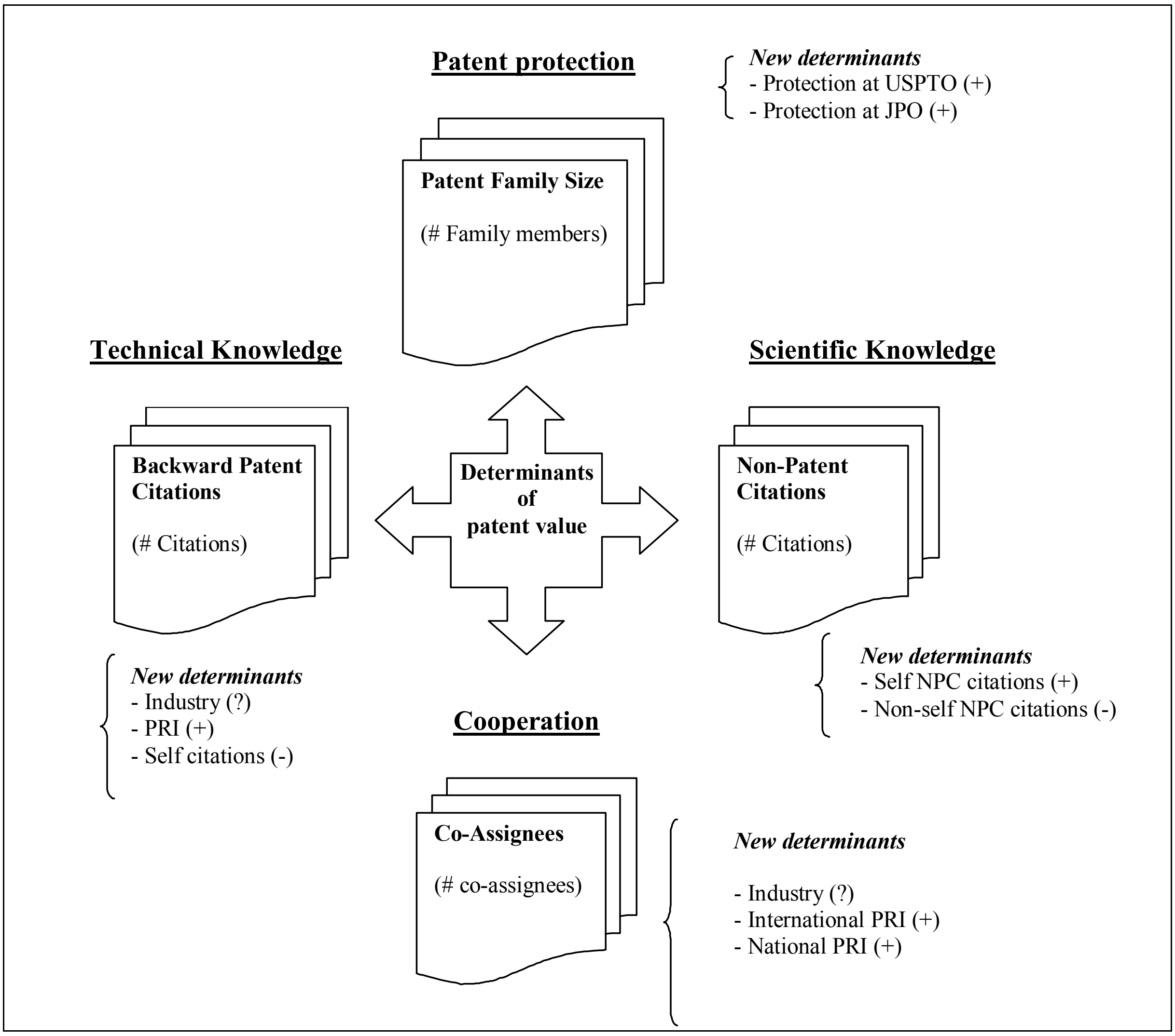
Authors	*Field*	*Sample*	*Model*	*Dep. Variable*
SCHANKERMAN and PAKES (1986)	Post 1950 period, UK, German and French patents	778	- Stochastic model	- Patent renewal
TRAJTENBERG (1990)	Computed Tomography (1972-1984)	456		- Patent citations may be indicative of the value of innovation - Close association between citation-based patent indices and independent measures of the social value of innovation
LERNER (1994)	Biotechnology (1973-92), USPTO patents	1678	- PROBIT	- # Citations
LANJOUW J. *et al.* (1996)	Precedent data and results of the authors			- # Years a patent is renewed and size protection are indicators of patent value
LANJOUW and SCHANKERMAN (1997)	USPTO 1975-1991	5452	- PROBIT	Probability of infringement and challenge suits
LANJOUW (1998)	Computers, textiles, combustion engines and pharmaceuticals West German patents (1955-88)	20000	-Dynamic stochastic discrete choice model	- Renewal decision
HARHOFF *et al.* (1999)	German and US patents (1977 expiring 1995)	994	- OLS regression - Negative binomial	- Forward citations
LANJOUW and SCHANKERMAN (1999)	Pharmaceutical; chemicals; electronic; mechanical US patents (1960-91)	8000	-Latent variable Model for a composite measure of quality - PROBIT for probability of renewal and litigation	- Composite index - Renewal - Litigation
GUELLEC, van POTTELSBERGHE (2000)	EPO 1985-1992	23487	- PROBIT	- Grant of a patent
SHANE (2001)	MIT patents 1980-1996	8420	- Cox regression	- Creation of new firm
HARHOFF and REITZIG (2002)	Biotechnology and pharmaceutics EPO (1979-1996)	13389	- PROBIT	- Opposition
HARHOFF *et al.* (2002)	German patents (1977 expiring 1995)	772	- Ordered PROBIT	- Monetary patent value

Table 2 : Determinants of patent value

	Patent Value		*Patenting Procedure*					*Patent characteristics*									*Others*
Authors	*PV*	*QI*	*OP*	*AP*	*GP*	*RP*	*FC*	*FPC*	*BPC*	*NPC*	*Claims*	*Scope*	*Size*	*IPC. Class*	*Time*	*Owner char.*	*Others*
SCHANKERMAN and PAKES (1986)						D°											
LERNER (1994)								D				+			+		
LANJOUW and SCHANKEMAN (1997)			D					+	+		+	-				+	*
LANJOUW (1998)						D°											
HARHOFF *et al.* (1999)	+							D						*			
LANJOUW and SCHANKERMAN (1999)		D						+	+		+		+	*			
LANJOUW and SCHANKEMAN (1999)					D			+	+		/		+	*			
LANJOUW and SCHANKERMAN (1999)			D					+	/		/		+	*			
GUELLEC , van POTTELSBERGHE (2000, 2002)					D							-	+		+	+	+
SHANE (2001)							D	+				+		*	+		*
HARHOFF and REITZIG (2002)			D					+	/	/		-	+	*		*	*
HARHOFF *et al.* (2002)	D		+	+				+	+	+		/	+				
CONCLUSIONS	+		+	+				+	+	(+)	(+)	(+/-)	+	*	+	*	*

PV: Monetary patent Value; QI : quality index; OP: opposition/ litigation procedure; AP annulment procedure; RP Renewal data; GP: Granting of patent application; FC : Firm creation. FPC: Forward Patent citations; BPC : Backward Patent citations; NPC: Non Patent citations. The signs inside the table are D: Dependent variable; +: Positive and significant impact of the explanatory variable on the dependant one; - :Negative and significant impact of the explanatory variable on the dependant one; / :No significant impact of the explanatory variable on the dependant one. * :The variable description hides a set of manifold variables. Among those, some may have a positive or a negative impact and others may have no significant impact on the dependent variable. ° :Model of patent renewal decision is constructed around the following variables: legal fees, renewal fees, annual return and expected future value

Figure 1. Institutional sources of knowledge and patenting strategy.[1]



1. The sign between parentheses indicates the expected relative impact of each characteristic associated with the main indicator (relative to the average impact of the main indicator). PRI = public research institution.

Table 3: Descriptive statistics of number of EPO patents of Belgian universities[1]

Number of EPO patents	*UCL*	*ULB*	*Ulg*	*KUL*	*UG*	*VUB*	*Fr. Univ.* *	*Fl. Univ.* **	*TOTAL*
1985-1989	9	3	0	14	1	0	12	15	27
1990-1994	7	7	2	18	3	2	16	23	39
1995-1999	14	18	13	55	25	17	45	97	142
1985-1999	30	28	15	87	29	19	73	135	208

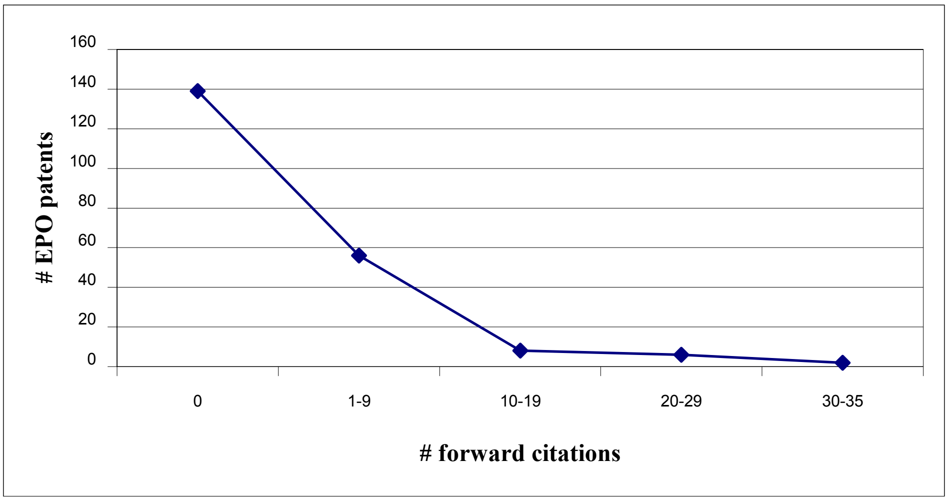
1. Sources: Delphion website and own calculations. * French-speaking universities (sum of EPO patent applications of UCL, ULB, Ulg); ** Flemish universities (sum of EPO patent applications of KUL, UG, VUB); all statistics are by priority date.

Table 4 : Forward patent citations of Belgian universities (priority date: 1985-1999)

Priority date : 1985-1999	*UCL*	*ULB*	*ULg*	*KUL*	*UG*	*VUB*	*Fr. Univ.**	*Fl. Univ.***	*Belgian Univ*
Number of patents	30	28	15	87	29	19	73	135	208
Average number of FPC per application[1]	2.37	1.32	1.33	3.25	0.34	1.05	1.75	2.32	2.12
Average number of 5-FPC per application[2]	0.33	0.25	0.27	0.09	0.10	0.74	0.29	0.19	0.22

1. * French-speaking universities (sum of EPO patent applications of UCL, ULB, Ulg); ** Flemish universities (sum of EPO patent applications of KUL, UG, VUB). 2 FPC: Forward patent citations. 3. 5-FPC: Forward patent citations received within the 5 years after priority date. Sources: Delphion website and own calculations

Figure 2 : Distribution of forward patent citations to Belgian academic EPO patents



Source: Number of forward citations, as of July 2002, own calculation, and Delphion database.

Table 5: Econometric results

POISSON MODEL	Dependent variable: number of forward patent citations							
Explanatory variables	Model 1	Std. Err.	Model 2	*Std. Err.*	Model 3	Std. Err.	Model 4	Std. Err.
Control variables								
# Years since 1985	- 0.281***	0.018	- 0.286***	0.018	-0.273***	0.018	- 0.301***	0.019
# Inventors	- 0.0052	0.038	- 0.0073	0.038	-0.031	0.038	- 0.010	0.040
Biotechnological field	0.667***	0.184	0.682***	0.184	0.543***	0.185	0.648***	0.188
Non-patent citations								
# Non-patent citations (Total)	- 0.0058	0.006			-0.023***	0.008	- 0.013***	0.007
# Self non-patent citations			0.031*	0.016				
#Non-self non-patent citations			- 0.014***	0.007				
Backward patent citations								
# Backward patent citations (Total)	0.102***	0.011	0.105***	0.011			0.094***	0.011
# Corporate applicants of cited patents					0.096***	0.017		
# Public applicants of cited patents					0.205***	0.032		
# Self patent backward citations					-0.214***	0.050		
Co-assignees								
# Co-assignees (Total)	0.191***	0.058	0.197***	0.058	0.164***	0.061		
# Corporate co-assignees							0.183	0.179
# International public co-assignees							0.722***	0.129
# National public co-assignees							1.238***	0.249
IMEC as co-assignee (equal 1 if relevant)								
Other national public co-assignees								
Family size								
Family size (# different applications)	0.020***	0.007	0.021***	0.007	0.029***	0.007	0.0094	0.007
Application at JPO (equal 1 if relevant)								
Application at USPTO (equal 1 if relevant)								
University characteristics								
UCL (equal 1 if UCL is the applicant)	1.223***	0.220	1.233***	0.220	1.166***	0.229	1.210***	0.233
ULB (equal 1 if ULB is the applicant)	1.393***	0.266	1.456***	0.267	1.584***	0.265	1.664***	0.274
ULG (equal 1 if ULG is the applicant)	1.437***	0.355	1.445***	0.356	1.659***	0.359	1.754***	0.370
KUL (equal 1 if KUL is the applicant)	1.279***	0.248	1.267***	0.249	1.574***	0.241	1.426***	0.257
UG (equal 1 if UG is the applicant)	1.125***	0.399	1.156***	0.400	1.191***	0.397	0.996**	0.400
VUB (equal 1 if VUB is the applicant)	1.970***	0.357	1.999***	0.360	1.944***	0.359	2.008***	0.354

Levels of significance: * : < 10% **: <5% ***: < 1% Number of observations: 208 patent families applied between 1985-1999 at EPO
Model 1: Wald chi2(13) = 2654 Log likelihood = -325 Model 2: Wald chi2(14) = 2643 Log likelihood = -322
Model 3: Wald chi2(15) = 2686 Log likelihood = -327 Model 4: Wald chi2(15) = 2751 Log likelihood = -307

POISSON MODEL	Dependent variable: number of forward patent citations					
Explanatory variables	Model 5	Std. Err.	Model 6	Std. Err.	Model 7	Std. Err.
Control variables						
# Years since 1985	-0.298***	0.019	- 0.291***	0.016	-0.291***	0.017
# Inventors	-0.014	0.040	- 0.0004	0.037	-0.045	0.040
Biotechnological field	0.756***	0.215	0.693***	0.188	0.668***	0.222
Non-patent citations						
# Non-patent citations (Total)	-0.013**	0.007	- 0.0046	0.006		
# Self non-patent citations					0.031*	0.018
#Non-self non-patent citations					-0.041***	0.010
Backward patent citations						
# Backward patent citations (Total)	0.095***	0.011	0.074***	0.012		
# Corporate applicants of cited patents					0.050***	0.019
# Public applicants of cited patents					0.203***	0.037
# Self patent backward citations					-0.183***	0.050
Co-assignees						
# Co-assignees (Total)			0.180***	0.059		
# Corporate co-assignees	0.205	0.179			0.301*	0.181
# International public co-assignees	0.699***	0.130			0.474***	0.145
# National public co-assignees						
IMEC as co-assignee (equal 1 if relevant)	1.628***	0.422			1.469***	0.433
Other national public co-assignees	1.038***	0.316			0.864***	0.315
Family size						
Family size (# different applications)	0.010	0.007				
Application at JPO (equal 1 if relevant)			0.255*	0.141	0.305**	0.149
Application at USPTO (equal 1 if relevant)			0.995***	0.169	0.981***	0.171
University characteristics						
UCL (equal 1 if UCL is the applicant)	1.151***	0.243	0.612**	0.247	0.495*	0.268
ULB (equal 1 if ULB is the applicant)	1.579***	0.288	0.794**	0.311	1.273***	0.329
ULG (equal 1 if ULG is the applicant)	1.650***	0.384	0.812**	0.388	1.247***	0.411
KUL (equal 1 if KUL is the applicant)	1.318***	0. 277	0.818***	0.278	1.043***	0.303
UG (equal 1 if UG is the applicant)	0.839**	0.427	0.750*	0.418	0.493	0.449
VUB (equal 1 if VUB is the applicant)	1.764***	0.420	1.446***	0.371	1.107**	0.445

Levels of significance: * : < 10% **: <5% ***: < 1% Number of observations: 208 patent families applied between 1985-1999 at EPO
Model 5: Wald chi2(16) = 2759 Log likelihood = -307 Model 6: Wald chi2(14) = 2559 Log likelihood = -317
Model 7: Wald chi2(20) = 2742 Log likelihood = -29

POISSON MODEL Explanatory variables	Dependent variable: number of forward patent citations (by type)					
	Model 8	Std. Err.	Model 9	*Std. Err.*	Model 10	Std. Err.
	FPC		**Non-Self FPC**		**Corp FPC**	
Control variables						
# Years since 1985	- 0.281***	0.018	-0.277***	0.018	-0.267***	0.021
# Inventors	- 0.0052	0.038	0.0054	0.038	0.015	0.045
Biotechnological field	0.667***	0.184	0.658***	0.186	0.512**	0.221
Non-patent citations						
# Non-patent citations (Total)	- 0.0058	0.006	-0.0059	0.0062	-0.001	0.007
# Self non-patent citations						
#Non-self non-patent citations						
Backward patent citations						
# Backward patent citations (Total)	0.102***	0.011	0.112***	0.011	0.108***	0.013
# Corporate applicants of cited patents						
# Public applicants of cited patents						
# Self patent backward citations						
Co-assignees						
# Co-assignees (Total)	0.191***	0.058	0.186***	0.060	0.155**	0.072
# Corporate co-assignees						
# International public co-assignees						
# National public co-assignees						
Family size						
Family size (# different applications)	0.020***	0.007	0.003	0.0075	0.004	0.0084
Application at JPO (equal 1 if relevant)						
Application at USPTO (equal 1 if relevant)						
University characteristics						
UCL (equal 1 if UCL is the applicant)	1.223***	0.220	1.296***	0.223	0.729***	0.274
ULB (equal 1 if ULB is the applicant)	1.393***	0.266	1.351***	0.271	1.079***	0.321
ULG (equal 1 if ULG is the applicant)	1.437***	0.355	1.402***	0.356	1.348***	0.405
KUL (equal 1 if KUL is the applicant)	1.279***	0.248	1.196***	0.253	1.021***	0.302
UG (equal 1 if UG is the applicant)	1.125***	0.399	1.034 **	0.414	0.931**	0.460
VUB (equal 1 if VUB is the applicant)	1.970***	0.357	1.230***	0.374	1.633***	0.430

Levels of significance: * : < 10% **: <5% ***: < 1% Number of observations: 208 patent families applied between 1985-1999 at EPO

Model 8: Wald chi2(13) = 2654 Log likelihood = -325 Model 9: Wald chi2(13) = 1701 Log likelihood = -319

Model 10: Wald chi2(13) = 1061 Log likelihood = -279

POISSON MODEL Explanatory variables	Dependent variable: number of forward patent citations (by type)					
	Model 11	Std. Err.	Model 12	*Std. Err.*	Model 13	Std. Err.
	FPC		**Non-Self FPC**		**Corpor. FPC**	
Control variables						
# Years since 1985	-0.293***	0.017	-0.276***	0.018	-0.286***	0.021
# Inventors	-0.041	0.040	-0.038	0.040	-0.048	0.048
Biotechnological field	0.549***	0.190	0.517***	0.191	0.533**	0.224
Non-patent citations						
# Non-patent citations (Total)						
# Self non-patent citations	0.031*	0.018	0.024	0.021	0.031	0.022
#Non-self non-patent citations	-0.040***	0.010	-0.040***	0.011	-0.032***	0.012
Backward patent citations						
# Backward patent citations (Total)						
# Corporate applicants of cited patents	0.047**	0.019	0.068***	0.020	0.100***	0.022
# Public applicants of cited patents	0.201***	0.037	0.221***	0.040	0.204***	0.047
# Self patent backward citations	-0.183***	0.050	-0.264***	0.056	-0.232***	0.063
Co-assignees						
# Co-assignees (Total)						
# Corporate co-assignees	0.282(*)	0.181	0.357**	0.182	0.533***	0.203
# International public co-assignees	0.491***	0.144	0.363**	0.155	0.134	0.187
# National public co-assignees	1.064***	0.249	0.962***	0.253	1.146***	0.280
Family size						
Family size (# different applications)						
Application at JPO (equal 1 if relevant)	0.269*	0.145	0.182	0.149	0.462**	0.185
Application at USPTO (equal 1 if relevant)	0.978***	0.171	0.825***	0.179	0.378*	0.204
University characteristics						
UCL (equal 1 if UCL is the applicant)	0.576**	0.254	0.657***	0.255	0.175	0.309
ULB (equal 1 if ULB is the applicant)	1.391***	0.305	1.338***	0.309	0.968***	0.367
ULG (equal 1 if ULG is the applicant)	1.385***	0.387	1.293***	0.389	1.116**	0.446
KUL (equal 1 if KUL is the applicant)	1.117***	0.273	1.142***	0.275	1.026***	0.324
UG (equal 1 if UG is the applicant)	0.662(*)	0.419	0.583	0.429	0.566	0.471
VUB (equal 1 if VUB is the applicant)	1.376***	0.366	1.230***	0.374	1.117***	0.430

Levels of significance: * : < 10% **: <5% ***: < 1% Number of observations: 208 patent families applied between 1985-1999 at EPO
Model 11: Wald chi2(19) = 2741 Log likelihood = -297 Model 12: Wald chi2(18) = 1775 Log likelihood = -301
Model 13: Wald chi2(19) = 1056 Log likelihood = -268